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Living with Wildfire: The Impact of Historic Fires on Property Values in Kelowna, BC

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Living with Wildfire: The Impact of Historic Fires on Property Values in Kelowna, BC

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Abstract

Wildfires in British Columbia result not only in large direct damages, but also significant indirect losses associated with lost amenity values and the risk to life and property. The indirect values can potentially be measured by changes in property values. In this study, we assume that the threat of wildfire affects property values by shifting homebuyers' willingness-to-pay. Using ten years of data from the City of Kelowna, we develop a hedonic pricing model that employs spatial autoregression to determine the marginal effects that wildfire occurrence, average fire size, and the location have on a residential property's aggregate sales value ($) and on its per unit price ($/m^2). Results indicate that historical wildfire occurrence has a statistically significant impact on property values, but that fire size has a more significant impact than frequency. It also appears that homebuyers discount the impact of fire on their purchase if large fires occurred nearby – as if fires do not strike twice in the same region. Finally, the evidence suggests that amenities available in the wildland urban interface add more value to residential properties than that is lost as a result of wildfire risk.

Key Words: Wildfire, Property Value; Hedonic Pricing Method; Spatial Autocorrelation

INTRODUCTION

Every summer, British Columbia suffers moderate to severe damage from wildfires, resulting in large direct loss of commercial timber stocks and long-lasting indirect economic costs, primarily lost amenity values and social costs related to anxiety, loss of neighborhood unity, et cetera (Butry et al. 2001). One approach for measuring the indirect costs is through their impacts on residential property values. Because wildfire results in lost amenity values and, in the wildland urban interface, poses a potential threat to property per se, house prices are believed to be sensitive to wildfire occurrence and nearness to fire-prone regions (Huggett 2003; Troy and Romm 2007). Among current studies, one basic assumption is that, if homebuyers are aware of the risks of wildfire in their own or neighbouring areas, the disamenities arising from past wildfires and the threat of future ones, among others, will show up in households' willingness-to-pay (WTP) for residential properties, which, in turn, can be measured by values in real estate markets.

In studies of wildfire and property values, one geographic term of significance is the 'wildland urban interface' (WUI), which is defined as the region where residential properties and other human structures meet or intermix with wilderness areas that contain flammable vegetation (Ministry of Forests & Range and Ministry of Public Safety & Solicitor General 2008). Wildfires in the WUI tend to be more devastating than those in rural areas because of their greater potential threat to properties and the surrounding environment from which urban residents often receive significant amenity values. Consequently, more firefighting resources are preferentially targeted at wildfires in the WUI.

In British Columbia, most wildfires occur in rural areas of the interior and far from residential properties, principally because 95% of the province's timberlands are publicly owned. Even though only a small proportion of wildfires occur in the WUI, losses can still be substantial; damage to buildings and reduced recreational, viewing and other amenity values negatively impact property values. During the 2003 fire season, the Okanagan Mountain Park Fire destroyed 238 homes around the City of Kelowna, and more than 33 000 people were evacuated. Later in the same year, 72 homes and nine businesses were destroyed in the communities of McLure, Barriere and Louis Creek by the McLure Firestorm, which was larger than the earlier fire. Wildfires occurring outside the WUI are also believed to alter homebuyers' WTP by decreasing amenity levels or environment conditions (Huggett et al. 2008).

Because several recent severe fire seasons in the western United States resulted in catastrophic losses, more attention is now paid to the impact of wildfire on property values (Donovan et al. 2007). In British Columbia, the 2003 and 2009 fire seasons led to record-breaking property damage and the largest evacuations in history. This is partly attributable to increasing housing density in the WUI because, despite the relatively higher wildfire risks, these areas also provide the amenities residents desire (Hammer et al. 2007). Further, it is possible that many homebuyers may not even be aware of the potential wildfire risks when they make purchase decisions, particularly if there has been no recent experience with wildfires in the region and/or record of property damages from wildfire (Champ et al. 2008). Even when people are aware of wildfire risks, homebuyers might underestimate the risks of rare but devastating wildfires, given that they are random events spread over time and spatially across a broad landscape.

Finally, although many factors affect wildfire risk, including forest management strategies and fuel load reduction efforts, climate change is also expected to result in more frequent wildfires. As a consequence, knowledge of the relationship between wildfire occurrence and property values is important as a guide to decision makers regarding wildfire mitigation efforts. The purpose of this paper, therefore, is to make a contribution to knowledge about this relation; in particular, we employ a spatial hedonic pricing model to examine the potential effect of ten years of wildfire occurrence on residential property values in the British Columbia interior.

We begin with a brief background discussion of the hedonic pricing method, followed by a detailed description of the study area and the data. We then provide the empirical model for this particular study and summarize the regression results. We end with concluding remarks.

BACKGROUND TO HEDONIC PRICING METHOD

Risk of wildfire occurrence has an indirect impact on property values that can be determined quantitatively using the hedonic pricing method (HPM). The hedonic pricing method is an indirect approach for measuring non-market values that relies solely on market evidence. The researcher regresses property values on their identifying characteristics, including identifiable (and measurable) environmental amenities, with the estimated coefficients assumed to represent the implicit prices of the characteristics (Freeman 2003). Examples include studies of air quality (Pearce and Markandya 1989), water availability (Loomis and Feldman 2003), damage to forest landscapes by pests (Price et al. 2010), and presence of urban trees (Mansfield et al. 2005; Donovan and Butry 2011).

Forest fires also impact residential values; the main factor that has been extensively considered to impact homebuyers' willingness to pay (WTP) is the vicinity's wildfire history, particularly their number (occurrence) and size. Stetler et al. (2010) investigated the effect of wildfire size on home values for 256 fires by employing an HPM framework. They found that size together with a property's proximity to hotspots had a significantly negative impact on residential values. Some other studies focused only on the potential effect of a single severe wildfire event on property values. For instance, Loomis (2004) found that there was a statistically significant decline in property values when a major wildfire had occurred within two miles of a prpoerty. Studies also looked at the value of information about wildfire risk. For example, Donovan et al. (2007) examined the effect of disclosure of wildfire risk ratings for 35,000 residential parcels within the WUI in Colorado Springs, Colorado, concluding that such information has a statistically discernible effect that offset some of the positive amenity values and neighbourhood characteristics of these properties.

In addition, Mueller et al. (2009) analyzed the effect of repeated fires in a relatively small area, finding that a second fire in the same general location will reduce house prices by a greater extent than the first fire. Huggett et al. (2008) introduced a ‘difference-in-differences’ technique in a conventional hedonic model to explain the effect of rapid disturbance, such as a hurricane or wildfire, on house prices by examining the change in prices across locations before and after the disturbance.

Clearly, because wildfire occurrence and property value display spatial aspects, spatial autocorrelation needs to be taken into account in hedonic pricing models. Among others, the most common technique to deal with spatial autocorrelation in statistical models is the spatial-weights matrix. Price et al. (2010) employed a distance-based weights matrix in their hedonic model to estimate the implicit marginal price of the mountain pine beetle infestation for property values in Colorado. Donovan and Butry (2011) tested spatial dependency using the semi-variogram and the Moran’s I index in their examination of the effect of urban trees on rental prices of single-family homes.

Conventional HPM usually takes the form of a two-stage procedure (Freeman 2003). In the first stage (Equation [1]), it is assumed that the utility a consumer receives from a good (residential property) can be measured by its individual characteristics – the marginal WTP or demand for the good is determined by the levels of the characteristics. Suppose that the marginal WTP for a property is represented by its market value V as a function of its n various features or characteristics $z_1, \ldots, z_n$:

[1] $$V = f(z_1, z_2, \ldots, z_n)$$

Equation [1] is the hedonic price equation, which could be linear, logistic, semi-log, quadratic or even a Box-Cox transformation function (Stetler 2008). The implicit marginal effect of any feature i can be derived as $\partial V/\partial z_i\, (i < n)$, which is a constant if [1] is linear. In the case of linearity, each additional unit of the characteristic, say, number of bathrooms, adds the same value to the house regardless of how many bathrooms are already present. To employ the implicit price from the first stage in the second stage, where the implicit price is regressed on variables that affect this price, it cannot be constant or unvarying. If an attribute's implicit price does not vary over some range of the attribute, one cannot estimate a marginal benefit function for the attribute. A further problem is that, in the second stage regression, one wishes to employ regressors that affect (shift) the inverse demand function for the attribute in addition to varying levels of the attribute. However, it is challenging to find adequate information regarding explanatory variables, such as the incomes of homebuyers, which affect the implicit price of an attribute; indeed, when it comes to amenities like viewscapes, it is difficult enough to find relevant data on varying observed levels of the amenity. The extra data required in addition to that of the first stage regression could complicate the analysis, over and above the potential bias found in the first stage results (Huggett et al. 2008).

In addition, one needs to consider two types of spatial autocorrelation: First, spatial lag dependence describes correlations between the value of one property and that of neighbouring properties. For a linear function, this type of correlation can be expressed as:

[2] $$V = \alpha + \rho\, W\, V + \beta Z + \varepsilon,$$

where α is an intercept term, W is a spatial-weights matrix describing the spatial correlations among neighbouring properties, Z is a vector of property characteristics (features, amenities), ρ and β refer to the vectors of associated coefficients to be estimated, and ε represents the error structure. This kind of model is appropriate for explicitly testing the existence of spatial dependency (Anselin 2007). If spatial autocorrelation exists, regular OLS regression will be biased and inconsistent, although the spatial-weights matrix W might well take into account the spatial autocorrelation among neighbouring properties. In this regard, the spatial autocorrelation parameter ρ should be included in estimating the marginal effects of interesting characteristics. W can be developed on the basis of various factors, such as the Euclidean distance between properties, number of adjacent neighbours, or varying numbers of nearest neighbours within a specified radius of each property (Ham et al. 2012).

The second type of spatial autocorrelation refers to the spatial error dependence, where the error term of the observation in question is correlated with that of neighbouring observations. This type of spatial dependence usually occurs due to model misspecification. In that case, OLS estimates are unbiased but inefficient (Anselin 2007). Following Ham et al. (2012), this type of spatial dependence in a linear model specification could be described as:

$$[3] \qquad V = \alpha + \beta Z + \varepsilon, \text{ where } \varepsilon = \lambda W \varepsilon + \upsilon, \quad \upsilon \sim \text{i.i.d.}$$

Ham et al. (2012) point out that these two types of spatial dependence are sometimes employed jointly. In that case, values of ρ and λ can be simultaneously estimated by maximum likelihood methods, and, if ρ is significant, adjustment for estimated marginal effects by a spatial multiplier is also necessary. A more general situation discussed by Mueller and Loomis (2012) is simultaneous spatial dependency in both the dependent variable V and the explanatory variables Z, in which case the so-called Spatial Durbin Model can be used (see LaSage and Pace 2009).

STUDY AREA AND DATA

Our study area is the City of Kelowna, which is located on the east side of Okanagan Lake in the southern interior of British Columbia (Figure 1). The study region has an area of 220 km^2 and average elevation of 334 m. We choose Kelowna because it lies in the central Okanagan Valley and the rain shadow of BC's Coastal Mountains. The region has the warmest and driest climate in BC and, compared to the surrounding mountains, the seasonal climate in the valley during summer time is even hotter and drier, which makes the valley vulnerable to wildfires. Further, since Kelowna is the largest city in the Okanagan Valley and one of BC's fastest growing communities (City of Kelowna 2011), significant development is occurring near or within the WUI – in dry forested areas within the Wildfire Development Permit Area (WDPA) in Figure 1. Land located in a WDPA is private but the risk that a property could be impacted by wildfire is moderate to high (City of Kelowna 2011). WDPAs are established in the immediate vicinity of public lands (provincial or federal crown forestlands, or national, provincial or local parks), and require that certain development standards for new construction are met (District of West Kelowna 2013).

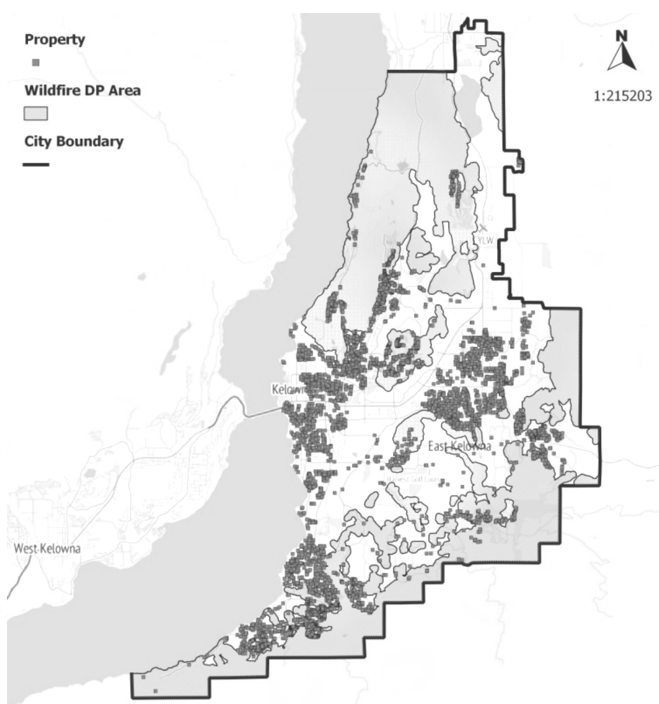

Figure 1: The City of Kelowna and Property Distribution[1]

[1] The base maps in all figures are from the Stamen Terrain-USA/OSM layer.

Almost every summer, wildfires threaten communities in and around Kelowna, but the severity of the threat varies substantially across years. During the 2003 fire season, eight wildfires were recorded within the City of Kelowna, seven of which occurred in the WDPA; in the same season, the catastrophic Okanagan Mountain Park Fire destroyed 25,600 hectares of forestland and 238 homes on the southern edges of Kelowna (Filmon 2004). Although there were only two wildfires in 1998, one of them burned about 20 hectares of forestland only 4 km from downtown Kelowna.

As of 2011, more than 117,000 people lived in the 10 sectors into which Kelowna is divided, with most concentrated in Central City (central west), Rutland (central east), and North and South Okanagan Mission in the southwest (Figure 2). According to Statistics Canada's census data for 2006, there are 44,915 occupied private dwellings in Kelowna (72% occupied by their owners), with an average value of $376,151 (Community Information Database 2006). More frequent catastrophic wildfire events during the past decade led the provincial government and local fire departments to put more effort into fire prevention and education. A Community Wildfire Protection Plan was created in 2011 and standards for fuel treatments and recommendations were developed as part of fire-free future community planning. An interactive manual for developers and homeowners, the 'FireSmart Wildland/Interface Planner', was also developed and made available online to help homeowners mitigate wildfire risk.[2] However, areas most vulnerable to wildfire remain in the northern sections of the city and along the southern boundary (see Figure 1).

[2] See http://www.kelowna.ca/CM/page384.aspx (viewed on 13 May 2013).

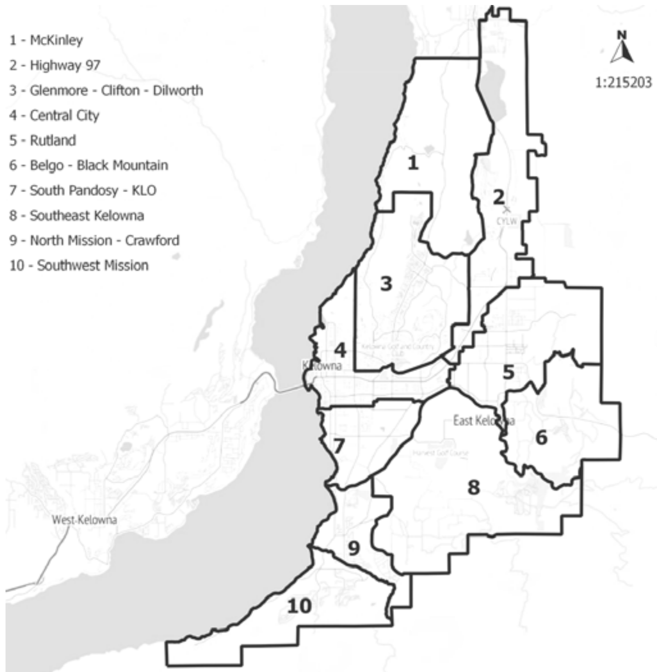

Figure 2: City Sector Map of Kelowna

Three datasets are employed in this study. First, real estate data for Kelowna consist of property information (e.g., location, actual use type, and other attributes associated with residential structures) and detailed sales information (price, date and transaction number) for properties sold between 2004 and 2009. Since we can only identify the location of properties using the owners' physical addresses, all rental properties have to be excluded from the sample because the owner did not reside at that location. For remaining observations, we translated the physical addresses to geographic coordinates and then further verified their locations using Google maps. We also excluded those properties whose actual use type was not single-family dwelling to focus attention on house attributes for which we had information. This left 6,496 properties (shown in Figure 1) for estimating our hedonic pricing model.

Our second dataset constitutes the historical wildfire dataset from DataBC, provided by the Wildfire Management Branch, Ministry of Forests, Lands and Natural Resource Operations.[3] This point-based GIS dataset contains detailed information of each wildfire event since 1950. For

[3]Supported by the BC provincial government, DataBC is a comprehensive open-access database for public government data, applications and services that is available from: http://www.data.gov.bc.ca/.

this particular study, given that the property data are available only from 2004 and we intend to analyze the effect of wildfires that occurred in the decade before properties were sold, we employ the size, date, location and total incidence of wildfires that took place during the period 1994 through 2009; the spatial distribution of these wildfires is provided in Figure 3. Unfortunately, the wildfire events that occurred on the west side of the Okanagan Lake (including West Kelowna) are not included in the analysis for lack of real estate data.

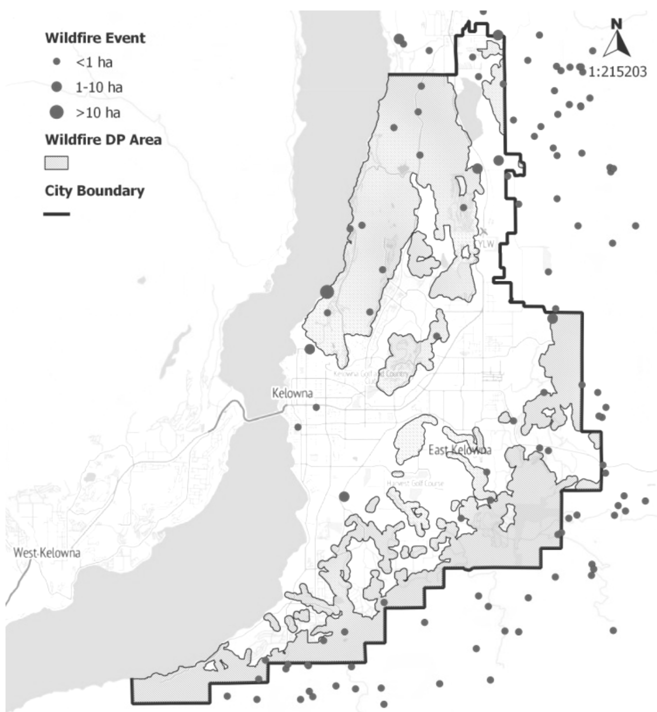

Figure 3: Wildfire Events within and around the City of Kelowna, 1994-2009

Our final dataset constitutes the GIS spatial layers for the City of Kelowna and the WDPA that used in Figures 1 and 3. These maps are formatted as shapefiles and can be downloaded from the City of Kelowna website. We use the city boundary to identify wildfire occurrence within Kelowna and treat the WDPA as a dummy variable in the regressions, our objective is to explain the marginal effect of wildfires on property values in those areas.

EMPIRICAL MODEL

We utilize a semi-log hedonic price equation to investigate the potential effect of historic wildfire occurrence on homebuyers' WTP for houses in Kelowna:

[4] $$\ln(P_j) = \beta_0 + \beta_1 W_{ij} \ln(P_j) + \beta_2 S_j + \beta_3 A_j + \beta_4 D_j + \beta_5 F_j + \varepsilon_j, \quad \forall\ i \neq j,$$

where P_j is the value of the last available sale of a property j, W_{ij} is a measure of distance between property i and j (a spatial-weights matrix); S_j and A_j are vectors of structural and environmental amenity characteristics, respectively, for property j; D_j is the year when the property was last sold; F_j is a vector of fire occurrences; and ε_j refers to the error structure. The data used in the model are summarized in Table 1.

Table 1: Variables and Summary Statistics

Attribute	Mean	Std. Dev.	Range [Min; Max]
Property Value			
Sales value ($'000s)	412.86	249.48	[3; 6,100]
Unit price ($ per m^3)	492.71	260.87	[3.37; 3,234.06]
Land to Value Ratio	0.5	0.12	[0.14; 1]
House Structure and Location			
Area (acres)	0.25	0.26	[0.04; 12.51]
Age[a]	21.78	19.86	[-3; 106]
Number of storeys	1.24	0.41	[1; 1.5; 2; 3]
Number of 4-piece bathrooms	1.62	0.77	[0; 7]
Number of 3-piece bathrooms	0.54	0.64	[0; 5]
Number of 2-piece bathrooms	0.48	0.55	[0; 4]
Number of bedrooms	3.51	1.01	[1; 13]
Number of multi-car garages	0.63	0.51	[0; 3]
Number of single-car garages	0.22	0.43	[0; 2]
Number of car ports	0.19	0.39	[0; 2]
Pool (1=Yes; 0 otherwise)	0.09	0.28	[0; 1]
Other buildings (1=Yes; 0 otherwise)	0.002	0.05	[0; 1]
Corner lot (1=Yes; 0 otherwise)	0.11	0.31	[0; 1]
Waterfront (1=Yes; 0 otherwise)	0.007	0.09	[0; 1]
Environmental Amenity			
Prime view (1=Yes; 0 otherwise)	0.08	0.28	[0; 1]
Good view (1=Yes; 0 otherwise)	0.08	0.28	[0; 1]
Fair view (1=Yes; 0 otherwise)	0.07	0.25	[0; 1]
Dummy variable for year of sale			
2004	0.16	0.36	[0; 1]
2005	0.2	0.4	[0; 1]
2006	0.2	0.4	[0; 1]
2007	0.24	0.43	[0; 1]
2008	0.16	0.36	[0; 1]
2009	0.04	0.21	[0; 1]
Wildfire Occurrence			
Number of fires within 500m	0.07	0.26	[0; 2]
Average size within 500m	0.05	0.79	[0; 20]
Number of Fires within 1 km	0.24	0.5	[0; 2]
Average size within 1 km	0.22	0.35	[0; 20]
Number of fires within 2 km	0.83	0.91	[0; 4]
Average size within 2 km	0.48	1.39	[0; 10]
Number of fires within 5 km	3.44	1.7	[0; 10]
Average size within 5 km	1.86	2.1	[0; 7.2]
Total number of fires	15.05	2.85	[12; 21]
Total average size	0.73	0.12	[0.6; 0.92]
WDPA (1=Yes; 0 otherwise)	0.21	0.41	[0; 1]

[a] Negative values included in *AGE* indicate incomplete developments that were under construction at the time of sale and would not be completed by 2010

WE employ two dependent variables for property value – (1) the actual sales value of the property ($) and (2) the property's unit price ($\$/m^2$), which is obtained by dividing the sales value by the physical area of the property. The latter variable permits us to identify a more explicit impact of various environmental amenities on property values because it adjusts for sprawling estates in the data set. We also employ another variable related to property value, namely the land to value ratio (LVR), which is equal to the assessed value of the bare land divided by the total assessment (bare land assessment plus improvements). We use the LVR as an explanatory variable in order to control for the contribution that improvements make to the property's value.

As indicated in Table 1, information on properties includes the area occupied by the property, age of the house, extra attributes (e.g., a swimming pool), and the numbers of storeys, bedrooms, bathrooms, garages (single and multi) and car ports. In addition, the data include location factors such as whether the property is located on a street corner or waterfront. Environmental amenities are represented by dummy variables for each of three different view categories. There are six sale year categories beginning in 2004.

The potential effect of historic wildfire occurrence is primarily modeled in terms of two factors – the number of fires that occurred in the 10 years before a property was sold and their associated average size. These two factors are then further classified according to the distance that the nearest wildfire was from a property. This is done using concentric circles with radii of 500 m, 1 km, 2 km and 5 km from a property, with nearby wildfires assumed to have a stronger impact on property values than more distant ones. For comparison, we also estimate a model that examines the effect of any wildfire occurrences in the study area.

Finally, a dummy variable is used to identify properties located in a Wildfire

Development Permit Area (WDPA) as the values of such properties are expected to be different from prperties elsewhere, ceteris paribus. The expected impact of locating in a WDPA is not known a priori. A potential purchaser of a home in a WDPA would be aware of the fire risk, and thus would reduce their WTP. However, houses in the WDPA might be more attractive than a similar house elsewhere because of the added environmental amenities associated with the wildland-urban interface that is often identical to the WDPA.

We employ a spatial matrix W to account for possible spatial autocorrelation in property values. The matrix is constructed on the basis of distances between properties in neighbouring areas. We use the inverse distance to the nearest six properties as weights on the neighbouring property values. The number of neighbours is determined on the basis of the spatial distribution of our observations. Since most observations in our dataset are from densely populated areas, where community blocks are bounded by streets, defining the spatial matrix using the nearest six neighbours ensures as much as possible that the selected neighbours are from the same or adjacent blocks, within which properties are expected to have stronger similarity than those from other blocks. We test the hypothetical spatial autocorrelation for both sales values and unit prices in the model. Note that we assume that there is no spatial autocorrelation among non-price features.

Following Price et al. (2010), we employ two-stage least squares (TSLS) in all the regressions, because including spatial lags of the dependent variables (i.e., the sales values and unit prices of nearby properties) would lead to endogeneity. To deal with that, we employ the spatial lagged values of certain explanatory variables in the house structure category for the six nearest neighbouring properties as instrumental variables in addition to the other regressors.[4]

RESULTS

The regression results for the dependent variables, sales value ($) and per unit value ($/m^2), are provided in Tables 2 and 3, respectively. In each table, we present coefficient estimates for five regression equations, one equation for each of the four concentric circles around a property in which fires might occur and an equation for all fires regardless of distance from the property (but within the study region).

The estimated coefficients on most of the housing characteristics are statistically significant and have the anticipated sign in both regression equations. However, for two characteristics (age of house and size of property), the estimated coefficients are statistically significant in both regressions but have opposite signs. An increase in a house's age and a property's size appear to increase the sales value ($) of a property, but reduce the property's unit price ($/m^2). One possible explanation is that older properties (some properties in our data are more than 100 years old) tend to be larger on average; thus, one expects the property to be worth more overall, but worth less on a square meter basis.

The estimated coefficients on other statistically significant structural variables (e.g., number of 4-piece bathrooms, number of bedrooms, whether there is a pool or it is waterfront) have the expected signs. There is no apparent impact on the value of a property from being on a corner, nor does there seem to be any benefit in having more car ports, single-car garages or other buildings on the property, although more multi-car garages appears to enhance overall value. More storeys appear to add to per unit value, while more bedrooms do not. Further, as

[4]For the sales value, we employ the spatial lagged values of area and LVR for the six nearest neighbours as two extra instrumental variables. For the unit price, another two instrumental variables, the spatial lagged values of age of a property and the number of bedroom, are also included. All those instrumental variables are determined separately through preliminary estimations.

expected, the LVR is negatively and statistically significant in its effect on both the dependent variables. The reason is that a higher LVR implies that there have been fewer improvements to the property.

The impact of the quality of views (the environmental proxy variable) is somewhat mixed. A 'prime' view has a significantly positive impact on the value of a house, while a much poorer ('fair') view pulls down the property value and an in-between ('good') view has no statistically significant impact on property values. However, when we consider the unit price of a property (Table 3), all three dummy variables tend to pull down the value of property. One possible explanation is that most properties with higher unit prices are located in the three most-densely zoned sectors identified earlier (e.g., downtown area), where views are relatively poor compared to outlying neighborhoods, such as the Glenmore-Clifton-Dilworth sector (see Figure 2).

The estimated coefficients on all of the year dummy variables are consistent across the two tables and are highly statistically significant. They indicate that, compared to average prices, those in 2004 and 2005 were lower and those in more recent years were higher. This indicates that property values were rising throughout the period regardless of wildfire effects.

Finally, consider the impact of wildfire on property values. The occurrence of wildfires in the ten years prior to the sale of a property generally has a negative impact on property values. However, except for the estimated coefficient on fires occurring within a 5 km radius, there is no statistically detectable effect on housing prices (Table 3). On the other hand, the estimated coefficients on size of wildfires are positive and statistically significant in the sales value equations, except in the case of the regression equation for the 5 km radius. Likewise, the impact of locating in the WDPA increases property values in a statistically significant way (Table 2), but actually reduces the per unit value of houses (Table 3).

Table 2: Estimation Results: Sales value ($) as Dependent Variable[a]

Variable	Coefficient (Std. Dev)				
	0.5km radius	1km radius	2km radius	5km radius	All Area
Intercept	10.3689***	10.3419***	10.4081***	10.4566***	10.4972***
	(1.3049)	(1.3117)	(1.4022)	(1.5071)	(1.2981)
Age	0.001**	0.001**	0.001**	0.0013***	0.001***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Area	0.1181**	0.1171**	0.1184**	0.1152**	0.1192**
	(0.0488)	(0.0487)	(0.0496)	(0.0478)	(0.0486)
# of bedrooms	0.0001	-0.0001	0.0004	-0.0003	0.0002
	(0.0055)	(0.0055)	(0.0054)	(0.0055)	(0.0055)
# of car ports	0.0046	0.0041	0.0049	0.0019	0.0047
	(0.012)	(0.012)	(0.012)	(0.0122)	(0.012)
Corner lot	-0.0031	-0.0032	-0.0023	-0.002	-0.0015
	(0.0115)	(0.0115)	(0.0116)	(0.0116)	(0.0115)
Fair view	-0.0531**	-0.054**	-0.0517**	-0.0484**	-0.0506**
	(0.0219)	(0.0218)	(0.0219)	(0.022)	(0.0219)
Good view	-0.0153	-0.0126	-0.0135	-0.0141	-0.0133
	(0.0221)	(0.022)	(0.022)	(0.0221)	(0.022)
Prime view	0.0532***	0.0538***	0.054***	0.0569***	0.0548***
	(0.0175)	(0.0175)	(0.0176)	(0.0176)	(0.0175)
LVR	-0.3591***	-0.3528***	-0.3376***	-0.3942***	-0.3536***
	(0.0723)	(0.0726)	(0.0732)	(0.0756)	(0.0711)
# of multi-car garages	0.1321***	0.1329***	0.1338***	0.1294***	0.1332***
	(0.0153)	(0.0153)	(0.0156)	(0.0158)	(0.0152)
Other buildings	0.0447	0.0458	0.0468	0.0375	0.0477
	(0.0857)	(0.0855)	(0.0856)	(0.0855)	(0.0838)
# of 2-piece bathrooms	0.04***	0.04***	0.0405***	0.038***	0.0399***
	(0.01)	(0.01)	(0.01)	(0.0101)	(0.0099)
# of 3-piece bathrooms	0.078***	0.0778***	0.0793***	0.0778***	0.0784***
	(0.0103)	(0.0104)	(0.0106)	(0.0109)	(0.0102)
# of 4-piece bathrooms	0.0229**	0.0236**	0.0235**	0.0223*	0.0228**
	(0.0116)	(0.0116)	(0.0116)	(0.0117)	(0.0115)
Pool	0.2049***	0.2051***	0.2068***	0.2044***	0.2061***
	(0.0198)	(0.0199)	(0.0201)	(0.0203)	(0.0198)
# of single-car garages	0.0119	0.0118	0.0126	0.0095	0.0115
	(0.0108)	(0.0108)	(0.0107)	(0.0108)	(0.0108)
# of storeys	0.0203	0.0205	0.0202	0.0198	0.0206
	(0.0144)	(0.0144)	(0.0143)	(0.0145)	(0.0144)
Waterfront	1.3706***	1.3667***	1.3667***	1.3819***	1.3727***
	(0.1091)	(0.1089)	(0.1114)	(0.1143)	(0.1083)
# of fires	-0.0126	-0.0139	0.0009	-0.0007	-0.0061
	(0.0206)	(0.0115)	(0.0039)	(0.0018)	(0.0061)
Fire size	0.0119***	0.0101***	0.0047	-0.0073***	0.0433**
	(0.0045)	(0.0034)	(0.0032)	(0.0022)	(0.0193)
WDPA	0.0304**	0.0245*	0.0285*	0.0378***	0.0323**
	(0.0135)	(0.0138)	(0.0149)	(0.0143)	(0.0135)
NEIG[b]	0.1813*	0.1833*	0.1768	0.1773	0.1725*
	(0.1026)	(0.1032)	(0.1106)	(0.1194)	(0.1017)
Y2004	-0.3716***	-0.3711***	-0.3722***	-0.3728***	-0.341***
	(0.0153)	(0.0153)	(0.0154)	(0.0157)	(0.0196)
Y2005	-0.212***	-0.2116***	-0.2125***	-0.2121***	-0.207***
	(0.0142)	(0.0142)	(0.0142)	(0.0142)	(0.0142)
Y2006	0.1887***	0.188***	0.1882***	0.1856***	0.2056***
	(0.0124)	(0.0124)	(0.0124)	(0.0124)	(0.0155)
Y2007	0.312***	0.3127***	0.3119***	0.306***	0.3556***
	(0.0129)	(0.0129)	(0.013)	(0.0132)	(0.0211)
Y2008	0.1802***	0.1819***	0.1804***	0.1676***	0.264***
	(0.016)	(0.0161)	(0.016)	(0.0165)	(0.0317)
R^2	0.4767	0.4772	0.4762	0.4768	0.4762

[a] We use *, ** and *** to denote statistical significance at 0.1, 0.5, and 0.01 levels, respectively, for all tables.

[b] *NEIG* refers to the coefficients of the weighted sales values of the six nearest neighbours.

Table 3: Estimation Results: Unit Price ($\$/m^2$) as Dependent Variable

Variable	Coefficient (Std. Dev)				
	0.5 km radius	1 km radius	2 km radius	5 km radius	All Area
Intercept	5.4251***	5.4203***	5.4286***	5.405***	5.2227***
	(1.0277)	(1.0352)	(1.0507)	(0.9975)	(1.0623)
Age	-0.0008*	-0.0008*	-0.0008*	-0.0013***	-0.0007
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0004)
Area[a]	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
# of bedrooms	-0.0328***	-0.0328***	-0.0328***	-0.0327***	-0.0326***
	(0.0075)	(0.0076)	(0.0075)	(0.0074)	(0.0076)
# of car ports	-0.1144***	-0.1148***	-0.1149***	-0.1152***	-0.1137***
	(0.0169)	(0.0169)	(0.0169)	(0.0165)	(0.0169)
Corner lot	0.0035	0.004	0.0041	0.003	0.0055
	(0.0133)	(0.0133)	(0.0132)	(0.0132)	(0.0133)
Fair view	-0.0631**	-0.0632**	-0.0627**	-0.0629**	-0.0611**
	(0.025)	(0.0248)	(0.025)	(0.0246)	(0.0247)
Good view	-0.0797***	-0.0772**	-0.077***	-0.0689**	-0.0773**
	(0.0305)	(0.0301)	(0.0296)	(0.0301)	(0.0303)
Prime view	-0.085***	-0.0836***	-0.0845***	-0.0754***	-0.0836***
	(0.0214)	(0.0214)	(0.0211)	(0.0206)	(0.0213)
LVR	-0.6116***	-0.6037***	-0.5935***	-0.6141***	-0.6115***
	(0.0858)	(0.0861)	(0.0856)	(0.0896)	(0.0839)
# of multi-car garages	-0.0064	-0.0055	-0.005	-0.0026	-0.0062
	(0.0306)	(0.0306)	(0.0303)	(0.0304)	(0.0303)
Other buildings	-0.1739*	-0.1734*	-0.1718*	-0.1529	-0.1745*
	(0.1001)	(0.0995)	(0.0996)	(0.0988)	(0.0994)
# of 2-piece bathrooms	-0.0144	-0.0143	-0.0141	-0.0118	-0.0148
	(0.0113)	(0.0113)	(0.0112)	(0.0111)	(0.0113)
# of 3-piece bathrooms	0.0252**	0.0254**	0.0258**	0.022*	0.0251**
	(0.0118)	(0.0119)	(0.0119)	(0.0119)	(0.0117)
# of 4-piece bathrooms	0.0081	0.0086	0.009	0.0096	0.0073
	(0.0144)	(0.0145)	(0.0141)	(0.0142)	(0.0143)
Pool	0.0703***	0.071***	0.0722***	0.0771***	0.071***
	(0.0246)	(0.0247)	(0.0242)	(0.0241)	(0.0244)
# of single-car garages	-0.0704***	-0.0703***	-0.0704***	-0.0719***	-0.0706***
	(0.014)	(0.014)	(0.014)	(0.0138)	(0.014)
# of storeys	0.073***	0.0724***	0.0734***	0.0722***	0.0726***
	(0.023)	(0.0228)	(0.0226)	(0.0227)	(0.0229)
Waterfront	1.1378***	1.135***	1.132***	1.1283***	1.1364***
	(0.141)	(0.1415)	(0.1442)	(0.1381)	(0.1404)
# of fires	-0.0057	-0.0061	-0.0011	-0.0063***	0.0028
	(0.0258)	(0.0148)	(0.005)	(0.0018)	(0.0073)
Fire size	0.0167***	0.0072*	0.0065	0.0027	0.0685***
	(0.0044)	(0.0039)	(0.004)	(0.0031)	(0.0229)
WDPA	-0.0763***	-0.0792***	-0.081***	-0.0806***	-0.074***
	(0.0171)	(0.0175)	(0.018)	(0.0174)	(0.017)
NEIG[b]	0.2022	0.2024	0.1998	0.2125	0.2038
	(0.1634)	(0.1648)	(0.1672)	(0.1603)	(0.1615)
Y2004	-0.3879***	-0.3879***	-0.3881***	-0.3821***	-0.3699***
	(0.0189)	(0.019)	(0.019)	(0.0188)	(0.0227)
Y2005	-0.2175***	-0.2178***	-0.2183***	-0.2196***	-0.21***
	(0.0163)	(0.0164)	(0.0163)	(0.0163)	(0.0164)
Y2006	0.1792***	0.1782***	0.1787***	0.1813***	0.185***
	(0.0147)	(0.0147)	(0.0148)	(0.0147)	(0.0181)
Y2007	0.3175***	0.3175***	0.318***	0.3232***	0.3478***
	(0.0149)	(0.015)	(0.0151)	(0.0151)	(0.0244)
Y2008	0.1955***	0.1961***	0.1968***	0.202***	0.2797***
	(0.0225)	(0.0224)	(0.0222)	(0.0236)	(0.0402)
R^2	0.5276	0.5273	0.5269	0.5271	0.5279

[a] As in the case of the dependent variable, *AREA* is measured in square meters instead of acres.
[b] *NEIG* refers to the coefficients of the weighted unit prices of the six nearest neighbours.

Following Price et al. (2010), we also calculated the associated marginal effects of wildfires on both dependent variables, taking into account the effect on values of spatial autocorrelation among neighbouring properties (Table 4). The results indicate that a one hectare increment in the average size of a wildfire occurring within the past 10 years and no more than 1 km from the property could actually increase the value of an average property by $5,106 and per unit value by $4.45 per m2. The increases are even higher had the fire been within 500 m of the property, while the marginal impact of wildfires farther away (but within a 5 km radius) is actually to decrease property value. Nonetheless, when all wildfires in Kelowna are considered, the marginal impact of a fire becomes positive again and adds $21,604 to a property's value, or $42.41 per m2. This is explained further below.

Table 4: Marginal Effects of Wildfire Occurrence on Sales Value and Unit Prices

	0.5 km radius		1 km radius		2 km radius		5 km radius		All Area	
Variable	Sales value	Unit Price	Sales value	Unit Price	Sales value	Unit Price	Sales value	Unit Price	Sales value	Unit Price
# of fires								-3.93		
Fire size	6,001	10.31	5,106	4.45			-3,663		21,604	42.41
WDPA	15,330	-47.15	12,385	-48.97	14,294	-49.87	18,970	-50.47	16,115	-45.85

More evidence regarding the impact of risk of wildfire comes from data on the WDPA. Homes located within the WDPA are worth roughly $16,000 more than comparable homes outside this zone. However, the results also suggest that there is a negative impact of some $47 per m2. These contrary findings are also discussed below.

DISCUSSION AND CONCLUSIONS

The regression results concerning wildfire occurrence have several interesting implications. First, the size of wildfires that occurred in the past decade does have significant influence on both sales values and unit price, while the fire incidence does not. This suggests that homebuyers do not consider frequent fire events as a threat when they buy a new home (Champ et al. 2009), or that such effects are outweighed by other amenity values. Further, homebuyers' risk preferences affect their WTP: when facing the same wildfire history, risk-averse buyers are likely to have a lower WTP for properties, ceteris paribus, than those who are less risk averse. Without examining the risk preferences of homebuyers, an overall risk neutral assumption ignores such differences in the estimates. However, this issue is similar to that of income – like income, the buyers risk preference might enter into the hedonic regression model in the second stage and would not normally be available to the analyst.

Second, while fire size has a significant impact on property values, the impact is generally positive, which appears to contradict the results from some previous studies. According to the marginal effects of past fire size at different distances, the homebuyer is likely to consider the risk of fire to be reduced in proportion to the size of nearby fires – there is now a smaller risk that their property will be affected by wildfire in the near future if greater areas were burned in the past decade, but when fires are farther away they likely perceive there to be a greater chance that a fire could occur closer to home. One possible explanation is that, if large areas have burned in the past decade, there is a perceived lower risk that there will be a future wildfire that will affect the property – homebuyers behave as if wildfire is unlikely to strike two or more times in the same general location. Likewise, when all wildfires in Kelowna are considered, the value of property increases.

Third, as indicated by Tables 2 and 3, there is significant spatial autocorrelation in sales values but not in unit prices. This implies that the aggregate price at which neighbouring properties had previously sold has an effect on what the homebuyer is willing to pay, but that this has little impact when standardized per unit property values are considered. In this regard, the unit price does not present a distance-based gradient at the neighbourhood level; rather, it is expected to be distinguished at a relatively large district scale (see Figure 2).

Finally, houses located within Kelowna's WDPA are relatively less valuable in standard or per unit price terms due to higher fire risks, but the value of properties in the WDPA tend to be higher. There are two potential reasons for this. First, as argued above, amenity values of locating in the WDPA (which are not captured by any of the control variables in the model) have a positive impact on property values that exceeds the downward pressure on values associated with the greater risk of fire in these areas. For example, most parks and golf clubs in Kelowna are located in the WDPA in northwest Kelowna, which also has more convenient access to downtown than the southwest. Second, the homes located in the WDPA are required to meet certain 'fire-proofing' standards that increase the costs of construction which, in turn, get capitalized in the property value and/or reduce the perceived risk of damage from wildfire.

The results of this study provide some indication as to how wildfires affect residential property values within the WUI in Kelowna. However, because we find little negative incentive for homebuyers to locate in the WUI, further research is required to determine why this might be the case. Perhaps one needs to investigate more closely the impact of a single catastrophic wildfire event affecting an urban municipality, as was the case with the Okanagan Mountain Park Fire. In this regard, it would be useful to expand the study area employed here to include properties in urban and semi-urban areas near Kelowna, and include additional environmental amenities in the regression analyses as control variables. It might also be useful to survey residents in the WUI, and outside it, to determine attitudes, perceptions of fire risk, et cetera, and include these variables in the hedonic pricing model. Important in this regard is knowledge about any perceived and realized public subsidies from which homeowners in the WUI might benefit. Clearly, public policy related to wildfire mitigation (fuel load management) and suppression (firefighting efforts), zoning laws, building codes, provision of public services (school buses, electricity, sewage, etc.), and property rights impact the willingness of homebuyers to live in the WUI and these too need to be investigated further.

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