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Do crime hot spots affect housing prices?

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ABSTRACT
Our knowledge about what happens to housing values when properties are close to places with high concentrations of crime, often called 'hot spots', is limited. Previous research suggests that crime depresses property prices overall, but crime hot spots affect house prices more than crime occurrence does and may affect prices of single-family houses more than prices of flats. Here we employ hedonic price modelling to estimate the impact of crime hot spots on housing sales, controlling for property, neighbourhood and city characteristics in the Stockholm metropolitan region, Sweden. Using a Geographic Information System (GIS), we combine property sales by coordinates into a single database with locations of crime hot spots. The overall effect on house prices of crime (measured as crime rates) is relatively small, but if its impact is measured by distance to a crime hot spot, the effect is non-negligible. By moving a house 1 km further away from a crime hot spot, its value increases by more than SEK 30,000 (about EUR 2,797). Vandalism is the type of crime that most affects prices for both multi- and single-family housing, but that effect decreases with distance from a crime hot spot.

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Crime clusters; hedonic modelling; spatial analysis; GIS; Sweden; property values

Introduction

Where crime rates go up, property prices go down (Ceccato & Wilhelmsson, 2011, 2012; Clark & Cosgrove, 1990; Dubin & Goodman, 1982; Munroe, 2007; Naroff, Hellman, & Skinner, 1980; Rizzo, 1979; Thaler, 1978; Tita, Petras, & Greenbaum, 2006; Wilhelmsson & Ceccato, 2015). Yet, little is known about what happens to housing values when properties are close to places with high concentrations of crime, often called 'hot spots'. Hot spots are 'small places in which the occurrence of crime is so frequent that it is highly predictable, at least over a one-year period' (Sherman, Gartin, & Buerger, 1989, p. 30). The aim of this article is to contribute to this knowledge base by assessing how a property's price is affected when the property is close to a significant crime hot spot.

This topic is relevant to criminological theory and methodology. First, crime hot spots are expected to be generated by specific criminogenic conditions that are particular and highly concentrated in space (Andresen & Malleson, 2011; Curman, Andresen, & Brantingham, 2014; Sherman et al., 1989; Weisburd, Morris, & Groff, 2009). The more

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one knows about the nature of these places, the easier it is to predict their effects. Second, studies on the impact of crime on housing prices in recent decades have relied on police reported crime rates, which may be problematic. The use of crime rates implies an assumption that crime risk is uniformly distributed in a particular area, with minor consideration given to potential intra-heterogeneity in the area or surrounding areas. Thus, as the goal is to assess the impact of crime on individual property prices by geographic coordinates of sales, this analytical framework imposes clear limitations. Third, this study provides estimates of the marginal willingness to pay for reducing a crime hot spot, which can be used in cost-benefit analysis of different types of crime prevention. By using the hedonic approach, we are indirectly estimating the implicit price of the negative externality of a crime hot spot and its societal cost. This is particularly relevant to stakeholders, such as decision-makers, urban planners, housing developers, police and safety experts, in residential areas where crime hot spots have the strongest impact on housing prices.

This analysis takes the central locations of crime hot spots as its reference and assesses whether housing prices decline when relatively closer to these statistically significant crime concentrations. Using Getis-Ord statistics, this measure takes into account both crime in the zone and the attributes of its 'neighbours in space' (in other words, how the neighbourhood structure is defined, for instance, neighbours are those polygons sharing boundaries or those areas that are close to each other given a distance of reference). Hedonic price modelling is then employed to estimate the impact of crime in the neighbourhood (using the distance to the cores of hot spots and police reported crime rates), controlling for other factors (property-related characteristics and neighbourhood, city and regional contexts).

This study builds on previous research (Ceccato & Wilhelmsson, 2011, 2012; Wilhelmsson & Ceccato, 2015) in Sweden but is set apart by four factors. The study assesses the effects on property prices of both crime hot spots and police reported crime rates, instead of limiting the analysis to police reported crime rates only. We estimate the effect of crime on both single- and multi-family homes (houses and flats). The study covers the whole Stockholm metropolitan region (consisting of 26 municipalities), while previous results were based on Stockholm municipality or a non-metropolitan municipality (Jönköping). Finally, the study employs updated datasets for housing sales and police reported crime.

Two main hypotheses were tested in this study. The first relates to crime impact on the prices of flats and single-family houses, that is, whether the police reported crime rate or the distance to crime hot spots is a more important indicator. Second, it was hypothesized that the impact of crime varies by type of offence and housing type.

Theoretical background

Crime and places

International research has long shown evidence that crime makes communities decline (e.g. Skogan, 1990; Wilson & Kelling, 1982). This decline can be seen in the presence of crime in public places as well as in minor signs of physical and social disorder. These environmental cues translate into residents' increasing desire to move away, also motivated by weakened social ties among residents (Cancino, 2005; Sampson, Raudenbush, & Earls, 1997). This negative process decreases the demand for properties in the area (Buonanno, Montolio, & Raya-Vílchez, 2012; Ceccato & Wilhelmsson, 2011; Congdon-Hohman, 2013; Ihlanfeldt & Mayock, 2010; Lynch & Rasmussen, 2001; Phipps, 2004) and consequently reduces housing values. This process happens partially because buyers are willing to pay more to live in a neighbourhood with less crime. Although research has shown evidence of the effects of crime and disorder on a housing market (for a review, see Ceccato & Wilhelmsson, 2018), little is known about what happens to housing values when properties are close to places with disproportionally high concentrations of crime, that is, hot spots.

Crime hot spots are places characterized by high crime frequency, and although the boundaries of these spots may not be visible to the eye, their extent and presence tend to be stable over time (Weisburd & Amram, 2014). This temporal and spatial stability has attracted the attention of many scholars to the point that some provide clear evidence of the so-called 'law of crime concentration at places' (e.g. Andresen & Malleson, 2011; Curman et al., 2014; Weisburd & Amram, 2014), which is thought to have an effect on housing markets and more directly on the mechanisms linking people's appraisals of prices to housing and neighbourhood qualities.

Crime hot spots are different from other places in the city because they have the capacity to attract and/or generate crime (Brantingham & Brantingham, 1995) or to be crime radiators and/or crime absorbers (Bowers, 2014). When compared with one another, crime hot spots share a number of commonalities in terms of socio-spatial dynamics (for instance, concentrations of violence in city centres) that can be helpful in crime control.

In one of the first studies about hot spots, Sherman et al. (1989) found that only 3.5% of the addresses in Minneapolis, Minnesota, accounted for 50% of all calls to the police. This concentration was even stronger for robbery, criminal sexual conduct and auto theft: only 5% of the 115,000 street addresses and intersections in the city produced 100% of the calls for those offences, usually perpetrated by strangers (Sherman et al., 1989, p. 30). Fifteen years later, Weisburd, Bushway, Lum and Yang (2004) reported that between 4% and 5% of street segments in Seattle, Washington, accounted for 50% of crime incidents for each year during a 14-year period. Similar crime concentration patterns were found in Sweden (e.g. Hoppe & Gerell, 2018) and in Stockholm, at various levels, in neighbourhoods (Ceccato & Haining, 2005; Ceccato, Haining, & Signoretta, 2002; Uittenbogaard & Ceccato, 2012; Wikström, 1991), around transport nodes (Ceccato, Cats, & Wang, 2015; Ceccato, Uittenbogaard, & Bamzar, 2013) and in micro-retail environments (Ceccato, Falk, Parsanezhad, & Tarandi, 2018). This criminogenic feature of crime concentrations affects these areas' overall quality and is absorbed into the dynamics of the housing market such that property prices are reduced, at least close to such areas. *A property close to a crime hot spot has a price that is lower than if the property had been located in an area far from a crime hot spot.*

Moreover, property prices are vulnerable to factors other than crime that, together with crime, help pull prices down and need to be controlled for (Ceccato & Wilhelmsson, 2011). For instance, high crime areas may also have few environmental amenities and poor accessibility to services, which also affect the perceptions of buyers. Thus, crime hot spots must be taken into account; otherwise the impact of crime on real estate prices may be overstated. However, it is not easy to assess the influence of different land uses on property values. One reason is that certain types of land use may affect a place both positively and negatively, making it difficult to assess. For example, although it is expected that urban parks increase property values, Troy and Grove (2008) show that parks' desirable effects are not incorporated into pricing in the housing market in a homogeneous way and are actually counteracted by crime at the park. The same applies to features such as transport nodes or schools (Bowes & Ihlanfeldt, 2001; Kane, Riegg, & Staiger, 2006).

Another reason for this difficulty is that different types of land use attract, generate and/or radiate different types of crime. Some crimes are bound to affect one area more than others. Lynch and Rasmussen (2001), for instance, weighted the seriousness of offences by the cost of crime to victims and showed that, although cost of crime had no impact on house prices overall, properties were cheaper in high-crime areas. In London, vandalism had the strongest impact on prices, while in Stockholm municipality residential burglary seems to have a similar effect (Ceccato & Wilhelmsson, 2011; Gibbons, 2004). Vandalism has a significant and independent effect on flat prices in Stockholm municipality even after the impact of fear of crime is controlled for. *Therefore it is hypothesized that the effects of crime vary by type of offence and housing type. Based on previous research, it is expected that hot spots of residential burglary and vandalism will have the strongest effect on prices.*

Hedonic modelling

We are using the hedonic modelling approach in order to estimate an individual's willingness to pay for a safe dwelling or willingness to accept the negative externality of a crime hot spot. The hedonic modelling approach is widely used as an indirect method to derive how much a household is willing to pay to reduce a negative externality. The method has a long tradition, but it was not until the seminal article by Rosen (1974) that we got a theoretical foundation for how to interpret the hedonic model. The decision to buy a property is complex, because the price that someone is willing to pay depends on the features of the property and the surrounding area and how those characteristics relate to the city in general (Thaler, 1978).

A hedonic equation is a regression of house prices against attributes that determine these prices. Regression coefficients are interpreted as estimates of the implicit (hedonic) prices of these attributes and moreover can be interpreted as the marginal willingness to pay for the attribute in question. In the case of housing, preferences for various attributes are revealed through the price one implicitly pays for these attributes. In the case of crime, prices would reveal how much buyers pay to avoid living near a crime hot spot.

Hedonic regression is a preferred method to estimate the demand or value of an item, product or commodity. The model breaks down the object into its components and estimates the contributory value of each component. Research in this area has long applied the concept of hedonic price to draw conclusions concerning the demand for certain qualities of housing (e.g. number of rooms) and the characteristics of the site and the neighbourhood (e.g. availability of public services). Differing land use and characteristics affect the values of different qualities: some characteristics affect the attractiveness of an area positively or negatively, some may have both effects simultaneously. What buyers pay for a property in an area with a low crime rate is hypothetically more than they would pay in an area of more crime, so the security (or lack thereof) is included in the market prices. The hedonic price equation is stated as:

$$P = \alpha + \beta X + \gamma HS + \epsilon \tag{1}$$

where P is a $1 \times n$ vector of observations of the dependent variable (normally in log form), β is a $k \times 1$ vector of parameters (regression coefficients) associated with exogenous explanatory variables, X, which itself is an $n \times k$ matrix. The parameter γ is the regression coefficient associated with the variable 'hot spot' (HS). The stochastic term ϵ is assumed to have a constant variance and normal distribution. Assume that all relevant attributes are included in the matrix X, that is, no omitted variable bias problem exists, as the omitted variables are orthogonal to the variables included in the matrix X. The matrix X can be decomposed into, for example, structural housing attributes and neighbourhood attributes.

One assumption is that X and HS are exogenously given. Our main interest in this study is the estimated parameter related to HS. Reasons why the variable might be endogenous include omitted variables, measurement errors and reverse causality. One indication that omitted variables are not present is a high goodness-of-fit measured by R-square. It is not a perfect indicator, but if R-square is high it is less likely that we have omitted important characteristics in our model. In the model, we estimate we are controlling for omitted neighbourhood characteristics by including fixed neighbourhood effects. Reverse causality may be present, of course, but that is more difficult to test. Here we are arguing that crime hot spots are more likely than not to causally affect house prices.

One commonly used method to reduce the problem of endogeneity is the instrument variable technique. This method has been used in Wilhelmsson and Ceccato (2015), which concludes that the estimates using ordinary least squares (OLS) are close to the estimates using a two-stage least square instrument variable estimation. Moreover, it is difficult to find valid and strong instrument variables. We have therefore chosen not to use the instrument variable approach here, but this method and others (such as propensity score) may be used in future research.

The study area

Stockholm's metropolitan area (or Stockholm county) is composed of the municipality of Stockholm (Sweden's capital) and 25 surrounding municipalities (Figure 1). The region is located on Sweden's south-central east coast, where Lake Mälaren, Sweden's third largest lake, flows into the Baltic Sea. It is the largest of the three metropolitan areas in Sweden, with an area of 6,519 km^2 and about 2.2 million inhabitants in 2014, half of them residing in Stockholm municipality. The area is served by an extensive public transportation system (three underground lines with more than 100 stations, 2,000 busses, 5,000 taxicabs, dozens of ferryboats and several tram routes) as well as roads, so the archipelago of islands that constitute the metropolitan area is well connected. Many residential areas are also exposed to a variety of environmental amenities, such as plenty of buildings facing bodies of water and forested areas, features that often

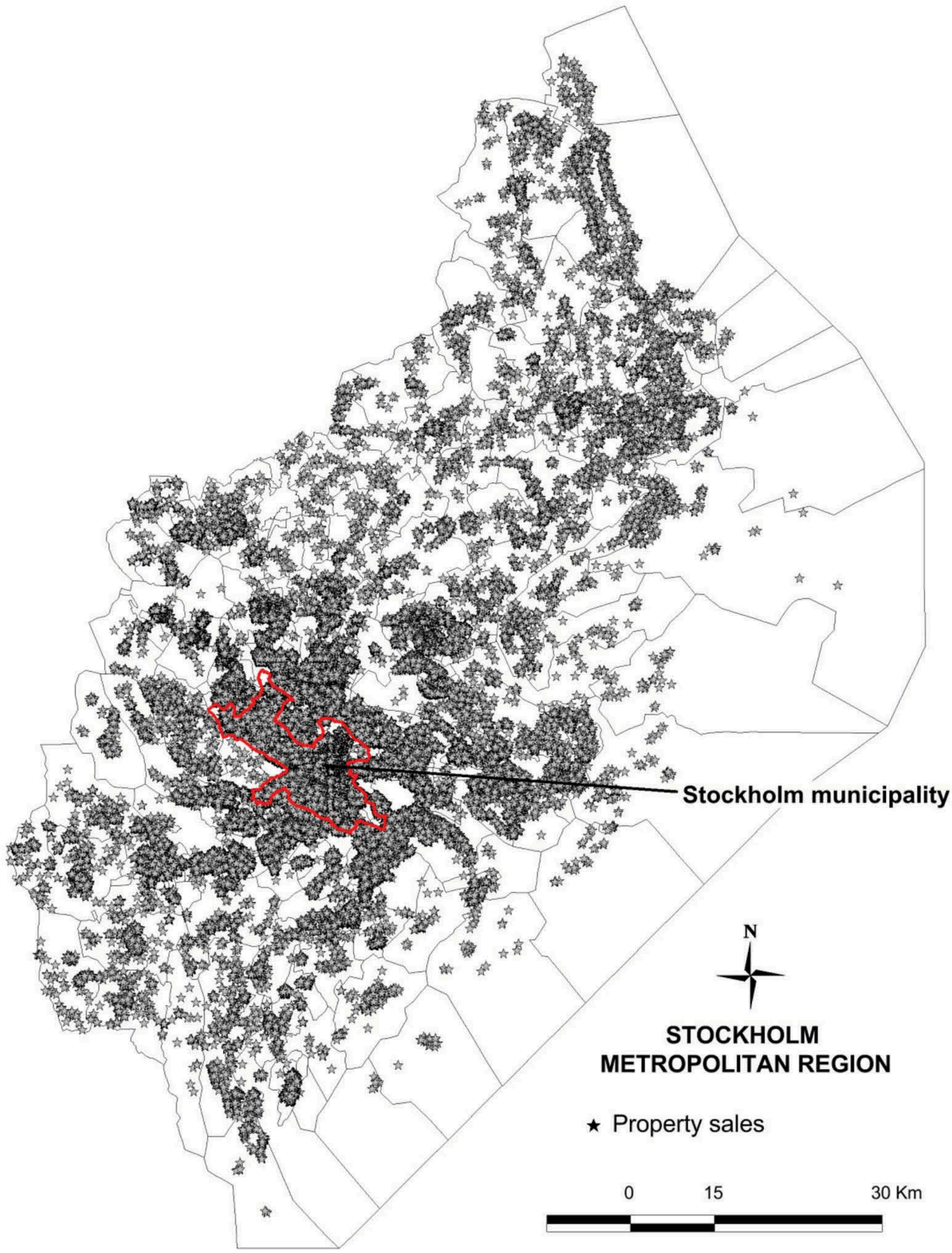

Figure 1. Stockholm metropolitan area: Study area.

translate into higher prices in the housing market. The city was selected for the European Green Capital Award in 2010 and has been considered one of the most accessible cities in Europe (EC, 2011, 2010). Although other types of housing tenure are also found, privately or co-operatively owned blocks of flats dominate the most central parts of the metropolitan area. Large sections of Stockholm's inner city have residential land use, where citizens enjoy a good quality of life with high housing standards. The same applies to inner centres in the municipalities that compose the Stockholm metropolitan area. Yet, there are flats built in the 1960s and 1970s throughout the Stockholm region that do not command high prices in the housing market. Some residential areas are often associated with modernistic architecture, lack of amenities and social problems, including crime.

In terms of crime reporting, the metropolitan region follows the national trend of increases in violence (13%) and vandalism (44%) and reduction in thefts, for instance for car-related theft (−66%) (Figure 2). The Swedish Crime Victim Surveys confirm a similar decreasing victimization pattern for the region (from 8.8% to 6.9% for violence, and from 12.1% to 10.7% for property crimes) as well as declared perceived safety (from 24% to 18% of the population declaring themselves afraid of going out in the evenings) between 2005 and 2013. In criminogenic terms, patterns of crime follow the urban/urbanized structure of the region. The geography of crime in the region has been changing since the early 1990s and has varied across space depending on crime type (for examples in Stockholm municipality, see Wikström (1991); Ceccato et al. (2002); Uittenbogaard and Ceccato (2012)). At least for flats, residential burglary, theft, vandalism, assault and robbery individually show a negative effect on prices in Stockholm municipality; a similar impact was confirmed for fear of crime (Ceccato & Wilhelmsson, 2011, 2012).

Crime concentrations are found in the urban centres of the region's municipalities, in transportation nodes, some shopping malls and retail outlets (e.g. Kista Galleria, Skärholmen centre, Kungens Kurva commercial area), but the largest and most stable hot spots are found in Stockholm's inner city areas (Figure 1), where the main public transport junction is located, as well as areas belonging to the city's central business district (CBD). No previous studies have dealt with the specific relationship between crime concentrations and housing prices or, in other words, whether people would be willing to pay more to live far from these hot spots of crime regardless of the municipality in which they live in the metropolitan region.

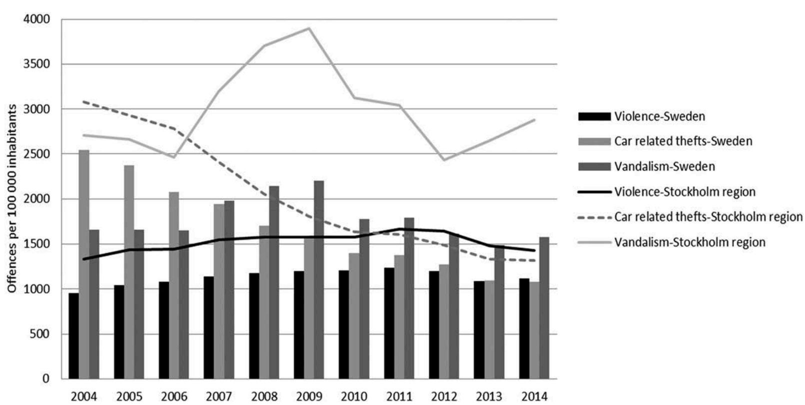

Figure 2. Police recorded offences, Stockholm metropolitan region and Sweden, 2004–2014.Data source: The Swedish National Council for Crime Prevention (Brå), 2016.

Data and methods

Table 1 below presents the data used to estimate the hedonic price models. The data cover a time span from January 2013 to December 2013 and consist of 118528 property sale transactions, both single- and multi-family homes (houses and condominium flats). The data come from the company Valueguard, which gathers data on prices and property attributes. The database contains property address, area code, parish code, selling price, floor space, year of construction, presence of balcony and elevator, price per square metre, date of contract, monthly fee to the homeowners' association, number of rooms, date of disposal, number of the floor of the specific flat, total number of floors in building, postal code and *x,y* coordinates.

The cross-sectional data have been merged with land use data from the Stockholm metropolitan area's database and with police records from Stockholm Police headquarters. Police records were mapped using *x,y* coordinates for each offence in 2013. The data for some of the control variables (for instance, indicators of urbanization and accessibility) come from the company WSP. The distance between property addresses

Table 1. Descriptive statistics (average and standard deviation).

	Flats/Condominiums		Single-family houses	
	Mean	Standard deviation	Mean	Standard deviation
Dependent variable				
Transaction price	2 756 114	1 833 382	3 890 844	2 563 779
Property attributes				
Living area	64.89	27.08	114.99	44.94
Other area	–	–	24.23	36.71
Monthly fee	3 476.39	1 450.39	–	–
No. of rooms	2.42	1.12	–	–
Building year	1962	36	1968	25
Quality index	–	–	24.55	10.51
Detached house	–	–	0.17	0.38
Semi-detached house	–	–	0.11	0.32
Waterfront	–	–	0.01	0.12
Water view	–	–	0.05	0.22
Lot size	–	–	1 446.13	8 827.91
Urbanization				
Share of built area	0.56	0.24	0.42	0.28
Share high-rise buildings	0.48	0.40	0.04	0.11
Share low-rise buildings	0.21	0.32	0.70	0.97
Share single-family houses	0.15	0.28	0.87	0.21
Accessibility				
Public transportation	113.43	7.65	99.21	11.34
Car	115.18	6.75	111.58	10.89
Distance to CBD	9 701	10 190	23 680	17 120
Crime rate				
Total	133.18	709.44	48.31	341.52
Residential burglary	0.90	4.73	0.50	3.55
Violence	0.61	1.49	0.39	1.02
Vandalism	9.79	42.69	3.36	15.11
Car thefts	3.97	42.66	0.53	3.61
Distance to hot spots				
Total	3 840	5 994	12 369	13 317
Residential burglary	3 017	5 504	9 302	10 166
Violence	3 049	5 249	10 031	12 816
Vandalism	3 152	5 520	10 467	12 988
Car thefts				
No. of observations	92 899		25 630	

and the Stockholm CBD has been estimated in GIS. Two types of crime variables were created: police reported crime rates (by resident population) and distance (in metres) to the centroid of a statistically significant police reported crime cluster generated using Getis-Ord statistics.

Police reported crime rates were calculated by using data by small unit area (*basområde*, the smallest geographical unit for which statistical data is available in Sweden) in a total of 1,298 units (Figure 1). The procedure was as follows. Rates per small unit area were calculated for total crime, residential burglary, violence, vandalism and car thefts. To link police reported crime rates to the *x,y* coordinates of each property sale, the Stockholm metropolitan map with 1,298 units was layered over the properties' *x,y* coordinates. All sales within the boundaries of a small unit area would get that small unit area's crime rates. This procedure was performed using the standard table join function in GIS. For more details, see Ceccato and Wilhelmsson (2011). Note that the reporting rates of crime to the police vary by crime type. While residential burglary is often reported to the police, vandalism has a dark figure (underreporting rate is large) which makes the analysis for vandalism less reliable (Ceccato, 2015; Ceccato & Haining, 2005b).

Pre-analysis of the crime data

To identify significantly high crime concentrations taking into account the whole distribution of offences in the Stockholm metropolitan region, a local indicator of spatial association was calculated in GeoDa (Anselin, 2003). Getis-Ord statistics (Anselin, 1995; Getis & Ord, 1992) were applied to the rates of crime per smallest unit of analysis (*basområde*) using resident population as the denominator. The choice of a suitable denominator for calculating these statistics is complicated. A 'good' denominator has to reflect the type of crime, the underlying land use types and the social interactions that happen over time in that particular place – a difficult task using official statistics. Wikström (1991) pointed out the difficulty of choosing plausible denominators. He suggested a list of 'best denominators' and those that are operational (that is, available for the calculation of crime rates). Although 'area' (of the administrative unit of analysis) is suggested as the best denominator for vandalism, for example, we argue that in the case of Stockholm, this denominator suffers from the same shortcomings as 'total population', because in inner city areas these zones are rather small, concentrating many crimes. Since we are analysing more than one crime, we decided to choose 'population' as the denominator although we are aware that this is far from ideal (since it is possible that values in inner city areas lead to an overestimation of crime risk).

Getis-Ord statistics are useful to detect local pockets of dependence that may not show up using global measures of spatial association (Getis & Ord, 1992; Karlström & Ceccato, 2002). Getis-Ord statistics can be described as the ratio of the sum of values in a neighbourhood of an area to the sum of all values in the sample. The significance of the *z*-value of each local indicator can be computed under the assumption that attribute values are distributed at random across the area. The formula is

$$G_i = \frac{\sum_j w_{ij}(d)x_j}{\sum_j x_j} \tag{2}$$

where the $w_{ij}(d)$ are the elements of the contiguity matrix for distance d, in this case, a binary spatial matrix. In a simple 0/1 matrix, '1' indicates that the areas have a common border, '0' otherwise. When the model provides a measure of spatial clustering that includes the observation ($j = i$) under consideration – in other words, when the core area is included – the model is called G_i*, as in this case. To express the spatial configuration of the study area, we used a weight matrix that was row standardized. A column was created to store the results of G_i * statistics by *basområde*. The value of interest was '1', indicating high-high values, namely statistically significant positive G_i* clusters, using randomization (99 permutations, with values smaller than 0.010). We calculated the distance in metres from the coordinates for each property sale to the centroid of each hot spot of crime (core polygon). Figure 3 illustrates the dataset used in the analysis: property sales, crime per coordinates and the results of Getis-Ord statistics by *basområde* in the background.

The hedonic price equation

A hedonic price equation is used here to assess property value and is based on the fact that the prices of goods in a market are affected by characteristics that can be revealed through observed differences in prices. Two main hypotheses were tested in this study. The first relates to crime impact on prices of flats and single-family houses, after controlling for attributes of the property and neighbourhood characteristics, and whether crime is indicated more reliably by using police reported crime rates or distance to crime hot spots. Second, it was hypothesized that the impact of crime varies by type of offence and housing type.

Two different data samples were used in this analysis. The first dataset was composed of sales of flats in multi-family dwellings (flats), and the second dataset constitutes transactions involving single-family or detached houses. Although flats have a lower price on average than single-family houses, the variation of the transaction prices is relatively high in both samples (Table 1).

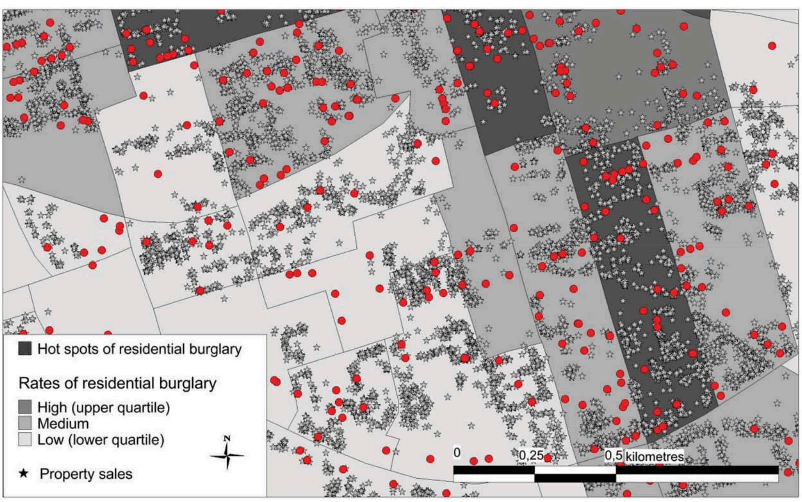

Figure 3. Sales (stars), Residential burglaries (circles) and hot spots of residential burglary (Getis-Ord statistics by *basområde*). Rates are calculated using police recorded data.

As already suggested by previous studies, there is no consensus on which set of relevant characteristics of the city structure and environments should be selected for hedonic modelling (Ceccato & Wilhelmsson, 2011), because it is difficult to control for all possible relevant neighbourhood factors (Can, 1990). Yet, characteristics of the property, characteristics of the property location and features of the neighbourhood are part of the common practice. In this study, five sets of attribute were used that explain the variation in prices.

The first set of attributes refers to the dwelling itself, such as size, building year and water view. There is a big difference in size between flats and single-family houses. The average single-family house is nearly twice as big as a flat. It was also observed that the flats were slightly older on average. All variables have a high variation (standard deviation) relative to the average. We can also observe that the average building year in the two datasets are 1962 and 1968, respectively. As discussed earlier, we are arguing that crime hot spots impact house prices and not the other way around. That is especially more likely as we are not analysing newly built housing, which is more prone to have been built in high-priced segments in areas further from crime hot spots. As stated, that is not the case here, because we are analysing transactions for homes built more than 50 years previous. The crime hot spots at that time would not have been the same as today's crime hot spots.

The second set of attributes refers to the degree of urbanization. Here we use the information about the proportion of built area, the proportion of high-rise and low-rise buildings and the proportion of single-family houses. It is perhaps obvious that flats are located in areas with a higher degree of high-rise buildings and a lower degree of single-family houses. Likewise, the opposite is true for single-family houses.

The third set of attributes relates to properties' accessibility, which was measured in three different ways. The first is based on a generalized travel cost for public transportation to work, and the second the same cost but by car. The third variable refers to distance to the CBD. Clearly, accessibility in the form of generalized travel costs is lower in the single-family sample, and the distance measured to the CBD is shorter in the sample for flats. The constant time and parish effects (fixed time effects/fixed parish effects) are included, as a way to remedy omitted variable bias, present in the models but not reported here.

The fourth set of attributes comprises crime rates as discussed above. On average, police reported crime rates are higher in the sample for flats than in the sample for single-family houses (Table 1). Crime rates were used to create crime clusters or hot spots defined by Getis-Ord statistics. Note that the testing of this 'blurred spatial average' of crime variable (W_X) as a way to flag for the effect of crime from neighbouring zones was suggested by previous literature (e.g. Ceccato & Wilhelmsson, 2011) but was deliberately avoided in this case since the procedure would be counterintuitive to the idea of using hot spots (the spatial average would 'smooth' the hot spot map and therefore be similar to the original police reported crime rates).

The last set of attributes used in the hedonic model is the distance to crime hot spots. This variable hot spot used in the hedonic model has been defined as the shortest distance between the observations' location (sales) and the centroid of the core of statistically significant hot spots of crime. The sample of flats is on average closer to a crime hot spot (around 3,000 m) than the observations in the sample for single-family houses (about 12,000 m).

Findings and discussion

Results are presented in two parts. First, the estimates of the hedonic price equation taking into account the effect of total crime on property prices (rates and distances to hot spots) are reported in Table 2. In the table we are presenting the estimated coefficients for all included variables except to the fixed effects, that is, the implicit price, together with *t*-value which is used to test the null hypothesis that the coefficient is equal to zero, that is, no effect. We are also presenting the goodness-of-fit measure R-square. Second, the estimates when testing the effects of different types of crime on prices are presented in Table 3 for both single-family and multi-family housing. Here we are only presenting the coefficients and *t*-value for the crime rate variable and the crime hot spot variable as well as *R*-square.

The model that explains the variation in flat prices in Table 2 has a very high power of explanation, given that it is cross-sectional data, with as much as 90% of the price variation explained by the independent variables. One of our interpretations is that it is not likely that we have a severe problem with omitted variable bias.

Overall, all coefficients have the expected sign, statistical significance and reasonable magnitude. For instance, an increase in flat size increases the price of the dwelling, while the value decreases if the fee to the association increases. One extra square metre of living area increases the expected price by about SEK 35,000 (EUR 3,263). Prices will increase by approximately 4.8% if the proportion of developed land (share of built area) in the neighbourhood increases by 1%. That indicates that prices of apartments are

Table 2. Results – total crime (OLS).

	Flats/Condominiums		Single-family houses	
	Coefficient	*t*-value	Coefficient	*t*-value
Property attributes				
Living area	0.0126	244.55*	0.0039	93.70*
Other area	–	–	0.0008	17.60*
Monthly fee	−0.0001	−84.45*	–	–
No. of rooms	0.0315	28.53*	–	–
Building year	0.0004	18.82*	0.0014	21.53*
Quality index	–	–	0.0109	32.30*
Detached house	–	–	−0.2320	−55.81*
Semi-detached house	–	–	−0.1421	−30.51*
Waterfront	–	–	0.6630	57.29*
Water view	–	–	0.1841	30.74*
Lot size 10^{-3}	–	–	0.0387	81.89*
Urbanization				
Share of built area	0.0486	15.60*	0.0254	3.09*
Share high-rise buildings	−0.0893	−34.61*	0.0642	2.86*
Share low-rise buildings	−0.0674	−16.92*	0.1026	14.87*
Share single-family houses	0.0428	8.01*	−0.0459	−6.03*
Accessibility				
Public transportation	0.0117	34.70*	0.0018	4.52*
Car	0.0039	12.39*	0.0072	9.54*
Distance to CBD 10^{-3}	−0.0280	−38.85*	−0.0253	−28.52*
Crime rate				
Total 10^{-3}	−0.0151	−38.85*	0.0059	1.50
Distance to hot spots				
Total 10^{-3}	0.0121	14.86*	0.0170	19.09*
R-square	0.899		0.877	

Note: Constant time and parish effects are included in the model but not shown in the Table. * Significant on a 5% level.

Table 3. Fitting OLS Hedonic model (Y = Logprice).

		Crime Rate (hotspot)		Crime Hotspot (distance)		
		Coefficient 10^{-3}	*t*-value	Coefficient 10^{-5}	*t*-value	*R*-square
Burglary	Multi-family	−1.2336	−3.19*	1.34	16.70*	0.8766
	Single-family	−3.1386	−2.10*	0.0148	0.21	0.8766
Violence	Multi-family	−0.0236	−7.72*	0.0763	1.00	0.8987
	Single-family	0.1216	0.33	1.34	14.37*	0.8767
Vandalism	Multi-family	−0.2104	−15.34*	1.96	26.47*	0.8995
	Single-family	0.0117	0.12	1.41	15.04*	0.8768
Car theft	Multi-family	−2.7826	−21.09*	−0.0442	−0.56	0.8992
	Single-family	0.1109	0.29	1.4	16.43*	0.8764

Note: Property attributes and accessibility variables as well as constant time and parish effects are included in the model but not shown in the table. * Significant on a 5% level.

higher in more densely populated areas. Compared to medium-sized buildings, both high-rises and low-rises have a negative impact on prices. An increase in the proportion of single-family houses also appears to increase flat prices. All coefficients regarding accessibility have the expected signs and are at a reasonable magnitude.

Of primary interest is our estimate of the crime variables. The proportion of crime in the area has a negative impact on the price. If the proportion of crime (the variable ‘crime rate’) increases by one percentage point, prices are expected to drop by 1.5%, approximately equal to a price decrease of only SEK 42 (EUR 3.9). The estimated parameter has high statistical significance, as the t-value exceeds the absolute value of 1.96. The impact of crime on housing prices in North American cities is greater than the effects found in Stockholm, even after considering differences in crime type and methodology. For instance, Lynch, Stretesky and Hammond (2000) found an elasticity of 0.05 for violent crimes in Jacksonville, Florida, while Naroff et al. (1980) reported an elasticity of 0.63 for total crimes in Boston. Our low estimate of total crime rate in the area is related to the fact that we are using two different variables measuring crime: total crime rate in the area and distance to crime hot spot.

Therefore, more interesting is the coefficient concerning distance to crime hot spot. If the distance to the hot spot increases by 1,000 m, prices are expected to increase by 1.2% (the coefficient concerning the variable ‘distance to hot spot’ 0.00212) or SEK 33,000 (EUR 3,076). The significance (*t*-value of 14.86 exceeds the threshold of 1.96) of the ‘distance to hot spot’ coefficient indicates that crime concentration increases housing price variations even when the total crime rate has already been shown to have a significant price effect. Even if the impact on housing prices can be considered low on each individual transaction or household, the total societal effect is substantial.

For the model of single-family houses (columns four and five in Table 2), the explanation power is very high for this type of analysis. Almost 88% of the price variation in single-family houses can be explained by the independent variables, indicating low risk for omitted variable bias. In this model, all coefficients have expected sign except one of the crime variables. Dwelling size increases the value of the home, increased quality increases the value, townhouses and semi-detached houses have a lower value relative to detached houses, and locations close to water increase the value. The degree of urbanization appears to increase the value of the home, which probably has to do with the level of urbanization being greater the closer the property is located to the CBD. The value of a single-family house increases with accessibility. Understandably, accessibility in the form of public transportation has a slightly lower effect on single-family house prices than on prices of flats.

As initially suggested, crime affects prices differently for single-family houses when compared to the model concerning flat prices. Results suggest that the distance to crime hot spots is the only crime variable that can explain the price variation. The further away a property is from a crime hot spot, the higher the value of the single-family house. This impact also seems to be of higher magnitude for single-family houses than for flats. The average distance to crime hot spots is four times higher for single-family houses and flats, which makes the total impact on house prices twice as much for single-family houses as for flats. If the distance to the hot spot increases by 1,000 m, prices are expected to increase by SEK 66,000 (EUR 6,153). That is, a property close to a crime hot spot on average will have a price about SEK 660,000 (EUR 61,527) less than a property 10 km from the hot spot – a non-negligible effect for the individual household and for society as a whole. Moreover, for single-family houses the average crime rates in the area have a minor impact or have no impact at all (t-value below 1.96, indicating the estimated parameter is not significantly different from zero).

Table 3 presents the results of estimations regarding the types of crime separately.

The various types of crime have been estimated separately, i.e. the first regression refers to burglary, the dependent variable referring to flat prices (multi-family). The model includes all the variables on the type of flat, accessibility and area attributes. Also included are the two crime variables, crime rate and the shortest distance to a hot spot. The models are thus likely to show whether the distance to a hot spot can better explain the effect of crime on prices. As expected, the sign of the coefficient for the crime rate is negative, while the distance to the hot spot is anticipated positive. The results indicate that all types of crime have a negative impact on the price of flats. For single-family houses, the results are more mixed. Crime rates seem to have a clearer impact on flat prices than on prices for single-family houses. Distance to a hot spot has the expected sign and is statistically significant in many cases though not in all cases.

Vandalism increases the coefficient most, in both the multi-family model and the single-family model. The distance to the hot spot in both models has a statistically significant impact, that is, the farther away from a crime hot spot a home is located, the higher the price, all other factors being equal. Yet, the magnitude of the impact of distance to the hot spot is not similar for the two housing types. The impact on flats is slightly higher than on single-family houses. However, note that vandalism rates do not have a negative impact on prices of single-family houses, only on flat prices.

Conclusions

Previous research has shown that properties are more discounted in areas with high crime rates. Instead of using police recorded crime rates, this study assesses the relationship between housing prices and the location of crime hot spots detected using Getis-Ord statistics. Two main hypotheses were tested in this study. The first relates to crime impact on flat prices after controlling for attributes of the property and neighbourhood characteristics, whether crime is measured as the crime rates or distances to crime hot spots. Findings show that being close to crime concentrations has a depressive effect on the housing market independent of crime rates, but this effect is particular for single-family houses. The overall effect of crime on house prices is relatively small if the measure is crime rates, but if the variable is distance to a crime hot spot the effect is non-negligible. By moving a house 1 km further away from a crime hot spot, its value would increase more than SEK 30,000 (SEK 2,797). One explanation of this difference is that the areas in which single-family houses are located have crime rates that are lower than the areas with flats. Thus, if a crime hot spot is close to single-family houses, buyers should perceive it more negatively than in areas where there are many crime hot spots.

The second hypothesis was that the impact of crime varies by type of offence and housing type. Results show that vandalism is the type of crime that most affects prices for both multi- and single-family housing, but such an effect decreases with distance from a crime hot spot. These results corroborate other findings found elsewhere in the recent international literature, for instance, for the case of vandalism in London (Gibbons, 2004) and partially in Stockholm municipality (Ceccato & Wilhelmsson, 2012, 2011).

Vandalism impacts an area in different ways. First, it affects the appearance. House buyers read vandalism and incivilities as a sign that nobody is in control of the area, an indicator of neighbourhood decline (Wilson & Kelling, 1982), so they avoid these areas if they can. Moreover, events of vandalism impact on property prices, because they induce fear of crime. Previous research suggests that fear of crime is highly affected by physical damage (for example, Killias and Clerici (2000)), a crime common in many municipalities of the Stockholm region. Second, as stated by Sampson, Morenoff and Felton (1999, p. 609), 'vandalism may not directly "cause" other more serious crimes but they do share the same explanatory processes, with the difference that vandalism can be observed by everybody in the area: residents, visitors and potential offenders', as well as property buyers. In Stockholm (but not in London), evidence shows that vandalism is associated with other crimes. The highest correlation is found between hot spots of vandalism and high concentrations of violence and car theft ($r = 0.72^{**}$ and $r = 0.40^{**}$); for residential burglary, the correlation is $r = 0.12^{**}$. This suggests the links between vandalism and other types of crime are present throughout the Stockholm metropolitan region.

Although not all results about vandalism and its impact on housing values are in line with what was expected for Stockholm, more knowledge would be needed to assess the mechanisms linking house prices, crime and inequality in different societal contexts. A comparison with another study case, perhaps in the Nordic countries, with similar country context using exactly the same methodology would be needed for us to extrapolate these findings to other housing markets.

Overall, these findings have potential to inform the criminological research devoted to the nature of hot spots of crime (e.g. Andresen & Malleson, 2011; Curman et al., 2014; Sherman et al., 1989; Weisburd et al., 2004), in particular showing that the detection of crime concentrations is important not only for policing (Braga et al., 1999) but also for the analysis of housing markets and urban planning.

The current study is not without its limitations. First, it remains to be tested whether estimates concerning crime hotspot substantially diminish as other features of neighbourhoods are controlled for. Another issue is the causal relationship between housing prices and residential burglary that seems to go in both directions, introducing the problem of endogeneity. Thus, areas with high property prices may attract residential burglary, and therefore the number of burglaries will be high in high-priced neighbourhoods. One way forward is to add an instrumental variable to crime by purging its correlation with unobservable influences on flat prices, using variables that are correlated with hot spots of residential burglary but not with flat prices. Previous research indicates that robbery, car theft, violence and vandalism may be more exogenous and thereby less complicated when it comes to the estimation of the hedonic price equation (Ceccato & Wilhelmsson, 2011). Something that is also missing in this study is a test of the potential effects of crime 'cold spots' (in contrast to hot spots) on the housing market, not yet tested in the international literature. A cold spot refers to spatial clusters of low values, in this case areas with low crime rates surrounded by areas with low crime rates. In the same way we test for the depreciating effect of high crime concentrations on house prices, we could hypothetically assess whether cold spots of crime have the opposite effect.

Future research should assess whether crime effects are consistent across space. This is because the prices of different property attributes are a function of many different demand and supply factors. Ceccato and Wilhelmsson (2011) suggest that if the average income among households is higher in one area, it could be expected that the price of having a property not close to a crime hot spot is higher than in an area where household incomes are lower. Moreover, even if all demand factors do not vary in space, the implicit price may fluctuate with the supply of attributes. The relative scarcity of properties in the inner city that are also far from a crime hot spot would suggest the price of properties there is high compared to the suburbs, where hot spots of crime are fewer and dispersed (places far from crime hot spots are abundant). Future studies should investigate whether the price of a property far from a crime hot spot is higher in the inner central areas as a result of higher income and relative scarcity of residential areas far from a crime hot spot. Finally, it would be worth testing whether it is not the absolute number of crimes committed in a place that is most important for perceptions of crime problems but rather crime per capita, as was done in this study.

This study is not merely about assessing the effect on housing prices in relation to individual buyers (that is, that some properties will decrease in value) but rather an indication of the overall price that society has to pay when crime concentration affects communities and, indirectly, the way people assess the quality of properties and neighbourhoods. A study of this kind might be useful for stakeholders on how much it is worthwhile for them to spend on safety. If crime pulls down housing prices and its occurrence is predictable over time, at least in these hot spots, we take the view that public policies should focus on these particular places to better tackle safety problems, strengthen housing markets and consequently improve residents' quality of life.

Disclosure statement

No potential conflict of interest was reported by the authors.

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