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The impact of crime on apartment prices: evidence of Stockholm, Sweden

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The impact of crime on apartment prices: evidence of Stockholm, Sweden

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Abstract

This study uses data of about 9000 apartment sales in Stockholm, Sweden, to assess the impact of crime on property prices. The study employs hedonic pricing modelling to estimate the impact of crime controlling for other factors (property and neighbourhood characteristics). Geographic Information System (GIS) is used to combine apartment sales by co-ordinates with offences, land-use characteristics and demographic data of the population. The novelty of this research is threefold. First, it explores a set of land-use attributes created by spatial techniques in GIS in combination with detailed geographical data in hedonic pricing modelling. Second, the effect of crime in neighbouring zones at one place can be measured by incorporating spatial lagged variables of offence rates into the model. Third, the study provides evidence of the impact of crime on housing prices in a capital city of a welfare state country, information otherwise lacking in the international literature. Our results indicate that apartment prices in a specific area are strongly affected by crime in its neighbouring zones, regardless of crime type. When offences were broken down by types, residential burglary, theft, vandalism, assault and robbery individually had a significant negative effect on property values. However, for residential burglary such an effect is not homogenous across space, and apartment prices in central areas are often less discounted by being exposed to crime than those in the city's outskirts.

Keywords: offences, residential property value, hedonic modelling, GIS, spatial modelling.

1. Introduction

Researchers have long suggested that high crime levels cause communities to decline. This decline may translate into an increasing desire to move, weaker attachments of residents and lower house values. This is because buyers are willing to pay more for livings in neighbourhoods with lower crime rates or, alternatively, buyers expect discounts for purchasing properties in neighbourhoods with higher crime rates. In Sweden, security is the factor that people value the most when they are choosing a place to live (Fransson et al., 2002: 57, Magnusson and Berger 1996:27¹). Do these security concerns translate into differences in house prices in Sweden?

International literature, heavily based on North American and British evidence, shows contradictory or less conclusive findings (Thaler, 1978; Buck et al., 1991, Bowes and Ihlanfeldt, 2001, Lynch and Rasmussen, 2001, Gibbons, 2004, Tita et al., 2006, Toy and Grove, 2008, Munroe, 2007, Marques et al., 2009, Hwang and Thill, 2009). Little empirical evidence exists under the Swedish conditions, but there are reasons to believe that the impact of crime on residential property prices may differ in Sweden from the rest of the Western world. There is a need to extend the empirical evidence to include cases studies embedded in more socially oriented forms of capitalism, such as in Sweden. Stockholm is appropriate in this criterion since it is the capital city of a country with a more socially oriented form of capitalism, in which the planning system incorporates strong welfare principles (Rothstein, 2001) which affect the way policies are shaped both towards housing and urban security. Thus, this study aims to assess the impact of crime on apartment prices using Stockholm City as the study area.

In order to estimate the impact of crime on property values, other conditions that, together with crime, contribute to lowering property prices must be taken into account, otherwise, such an impact may be overstated (Cohen, 1990). For instance, neighbourhoods with high crime also may experience fewer environmental amenities (e.g., close to parks, lakes, playgrounds, good schools), isolation (poor accessibility), proximity to major highways and transport nodes (with noise and air pollution) industrial land use or commercial/entertainment areas (e.g., close to bars, restaurants, pubs). In this analysis, land use and socio-economic dynamics will be captured by using spatial analysis in combination with GIS. These techniques allow more in-depth geographical analysis of different parts of the city than were done in previous studies of this area. GIS facilitates the integration of many types of data into a common spatial framework and opens up the possibility for detailed spatial analysis, which is often necessary for assessing the impact of crime on housing prices.

A hedonic pricing modelling is employed in this study to estimate the impact of crime controlling for other factors (property and neighbourhood characteristics). The effect of crime on housing prices is tested both on total crime and on a set of selected individual property and violent offences.

¹ 85% of the interviewed population in Fransson et al. (2002), and in Magnusson and Berger (1996), safety was ranked as 4.1 in a scale from 0 to 5.

The novelty of this study is threefold. First, this analysis explores a set of land use attributes created by spatial techniques (e.g., buffer and distance analysis and inclusion of neighbouring structure). The neighbourhood context is incorporated into the model by attaching to each sold apartment sold (by co-ordinates) information that characterises a finely detailed statistical unit of analysis (basområde). Then, if a low crime area is surrounded by high crime, criminogenic conditions in that area may be underestimated because of the high levels of crime in neighbouring zones. GIS and spatial statistics techniques are then used to tackle this problem, so the neighbourhood structure is added to the model to capture crime conditions in each unit of analysis and in its neighbouring units. Finally, the article provides evidence of the impact of crime on housing prices in a capital city of a welfare state country, information otherwise lacking in the international literature.

The paper is organized as follows. In section two we discuss the theory linking property prices to crime in Western European cities and hypotheses of study for the case of Stockholm. This is followed by a description of the study area in section three. The data used in the analysis and modelling work needed to meet the objectives of the paper are presented in section four, together with the discussion of the results. A discussion of the implications of the findings and directions for future work is presented in section five.

2. Property prices, crime and city structure: theory and hypotheses of study

Traditionally, hedonic price models are used to analyse property values. They are based on the principle that goods are not homogenous and differ in numerous attributes, which can be implicitly revealed by observed differences in prices (Rosen, 1974). In the case of housing, preferences for various attributes are revealed through the price one implicitly pays for these attributes, which can be expressed as:

$$y = \beta x + \varepsilon \quad (1)$$

where y is a vector of observations on the sales price; X is a matrix observations on the property attributes, β is the associated vector of regression coefficients (the marginal implicit price of each attribute) and ε is a vector of random error terms. According to Taylor (2008), where housing prices are concerned, the choice of attributes often involves characteristics of the property, characteristics of the property location and features of the neighbourhood. There is no consensus on which set of relevant characteristics of the city structure and environments should be selected for price determination. They are often related to different environments to which the property is exposed, and how these may add to or subtract from the value the property. It is difficult, however, to control for all possible relevant neighbourhood factors (Can, 1990). An apartment facing a lake may add value to a property, whilst one close to an industrial site or close to a sex offender residence may have its price discounted (see e.g., Larsen et al., 2003, Linden and Rockoff, 2006, Karlsson, 2008, Kryvobokov and Wilhemsson, 2007).

How land use influences property values is not always easy to assess. One reason is that mixed land use affects an area's attractiveness both positively and negatively. To take the

example of a transport node (a bus stop or a rail station or an underground station): easy access to places is good because it reduces commuting costs and attracts other activities to the area, but it may be less desirable since stations cause noise to local residents, disrupt the landscape and may attract the activities of undesirable groups (criminals) and affect property values. Studies in the US and in the UK have shown mixed effects, but in general rail stations have a positive impact on nearby property values (Davis, 1970, Davis, et al., 1990, Voith, 1993, Amstrong Jr, 1997, Gibbons and Machin, 2004). In a more recent study in Atlanta, Bowers and Ihlanfeldt (2001) show that rail transport stations act as crime magnets and affect housing prices negatively, but this effect depends on contextual factors, such as neighbourhood median income and distance to the city centre. Another reason is the fact that spatial patterns and processes tend to operate on a variety of scales or extents (Orford, 2002). According to Munroe (2007), individual properties within a neighbourhood might vary highly in their values, while at the same time more general patterns of high or low values may occur in different parts of the city.

Another reason for this difficulty is that non-residential land uses interact with other attributes that indirectly affect house prices. The study by Troy and Grove (2008) is a good example of this phenomenon. Although it was expected that parks would affect positively property values, results show that its desirable effect is not incorporated by the housing market in a homogenous way, and is actually mediated by crime levels. If local crime levels are above the national average, then park proximity has a negative impact in property values; but if it is below that threshold, then housing prices go up with presence of parks. Also, quality of schools is influenced by neighbourhood quality, which in its turn affects housing prices (e.g., Kane et al. 2006). These results illustrate that, regardless of the mechanisms linking crime and housing prices, safety does play an important role in affecting the property market. We will now discuss in more detail the nature of this impact and how it may differ by crime types.

Differences in land use are also important because they shape a city's dynamics and determine both the activities found in an area and the composition of the population at any given time. Spatial variation in land use affects the geographical distribution of the number of human interactions that are criminologically relevant in the sense that they could lead to offences (Wikström, 1991). The identification of criminologically relevant interactions rests on specifying the routine activities of offenders and victims that generate 'suitable targets' (Cohen and Felson 1979) and the spatial awareness of offenders, in particular their cognitive awareness of criminal opportunities (Brantingham and Brantingham, 1981). In brief, offences occur where criminal opportunities intersect with areas that are cognitively known by the offender and these are in turn influenced by land use patterns. The prevalence of non-residential land use is of particular importance in this context. Evidence shows that mixed land use influences actual and perceived neighbourhood incivilities and crime (Taylor, 1995, McCord, et al., 2007, Ceccato, 2009,) place attractiveness and consequently, house market values.

The effect of crime on housing prices is well documented in the North American literature. Since the seminal work by Thaler (1978) showing that property crime reduces house values

by approximately three per cent (in Rochester, New York), subsequent studies have shown evidence of similar effects. Evidence from the last three decades confirms that crime has a significant impact on house prices (Hellman and Naroff, 1979, Rizzo, 1979, Dubin and Goodman, 1982, Clark and Cosgrove, 1990, Feinberg and Nickerson, 2002, Titta et al., 2006, Munroe, 2007). Hellman and Naroff (1979) reported an elasticity of 0.63 for total crimes in Boston. Lynch and Rasmussen (2001) find an elasticity of 0.05 for violent crimes in Jacksonville, Florida. Bowes and Ihlanfeldt (2001) reported that an additional crime per acre per year in census tracts in Atlanta decreases house prices by around 3% whilst Gibbons (2004) in London, found that a one-tenth standard deviation increase in the recorded density of incidents of criminal damage has a capitalised cost of just under 1% of property values. These studies often relied on crime rates as an indicator of safety, and this indicator seems to be a good measure of criminogenic activities in an area. Lynch and Rasmussen (1989), for instance, instead of using crime rates, tested to weight the seriousness of offences by the cost of crime to victims. Findings showed that although cost of crime had no impact on house prices overall, properties were cheaper in high-crime areas. Moreover, evidence shows that crime in neighbouring places has a similar negative effect on property values as well as crime in the same neighbourhood (Burnell, 1988). Titta et al. (2006) have demonstrated that crime impacts differently in different types of neighbourhoods and that violence crime impacted most significantly.

In the UK, the effect of crime on property prices does not seem the same across crime types. Gibbons' (2004) study showed that residential burglary had no measurable impact on prices, but criminal damage did affect negatively housing prices. One explanation for this is that vandalism, graffiti and other forms of criminal damage motivate fear of crime in the community and may be taken as signals or symptoms of community instability and neighbourhood deterioration in general, pulling housing prices down.

Crime levels and geography are also dependent of regional and national contexts. Inequality, ethnic and spatial segregation relate to differentiated levels of crime (offending and victimisation) (Blau and Blau, 1982, Wohlfarth et al., 2001). We take the view that effect of crime on housing prices would be higher in places characterised by higher income, ethnical and socio-spatial inequalities (and consequently more criminogenic, particularly with violence) than in less unequal societies, such as in welfare state countries. Alternatively, segregation levels are "lower where welfare state models are characterized by strong redistribution regimes and more moderate social inequality" (Musterd, 2005:342). In Sweden, for example, income disparities are less pronounced than in countries with a more market oriented economy (for instance, Gini coefficient for Sweden in mid 2000s was 0.23 whilst in the UK and USA was 0.34 and 0.38, respectively, OECD, 2009). This pattern goes down to the city level. Despite of an increase of ethnical segregation in Stockholm during the last decades (Biterman, 1994, Hårsman, 2006), the combination of housing, immigration and local land use policies have played an important role in moderating the effect of the market in strengthen inequality and spatial segregation (e.g., via rental control) (Hårsman, 2006). Neighbourhoods in Stockholm often have a mix of rental and owner-occupied apartments, which arguably generate less segregated housing patterns than those found in cities of market-

oriented countries. Such moderate heterogeneity in terms of types of tenancy and income inequality is expected to have an effect on crime levels and geography (and consequently on property prices) that may differ from other cities embedded in more unequal contexts.

For the purpose of this study, we follow the recent strand of Western research on crime and housing and hypothesise that for the case study of Stockholm:

- (1) Crime impacts negatively on apartment prices after controlling for attributes of the property and neighbourhood characteristics.
- (2) Different types of crimes affect property values differently. As in the UK, we believe that in Sweden criminal damage has the highest effect in housing price determination because its occurrence is visual and indicates community instability and loss of social control.
- (3) The price of an apartment is dependent on the crime levels at its location as well as the crime levels in the surrounding areas. This effect varies by offence type because different types of crimes are generated by different mechanisms.
- (4) Crime impacts negatively on apartments prices differently in different parts of the city.
- (5) The effect of crime on housing prices is lower in Stockholm (a city embedded in a welfare state country) than in cities of countries with a more market oriented economy.

Before testing these assumptions empirically, we will describe Stockholm as a case study and its recent structural developments.

3. Framing Stockholm as a case study

Stockholm is the capital and largest city of Sweden. The city of Stockholm had over 810 000 inhabitants in 2008, while the Greater Stockholm area had over 1.9 million inhabitants. The case-study area is limited to the city of Stockholm, which means the inner-city area and those suburbs belonging to the city of Stockholm.

Water occupies a large part of the urban landscape in Stockholm since the city spreads over a set of islands on the south-east coast of Sweden. The islands are well connected by roads and an efficient public transportation system, comprised of buses, Stockholm Metro, rail systems and commuting trains. The main public transport junction is located in the Central Business District (CBD) area, in the central area of the inner city; this area is characterised by office buildings and a number of large department stores. As well as governmental and ministerial buildings, the area also contains the major shopping amenities of the city, theatres, museums, restaurants, bars and cinemas. All underground lines pass through the Central Station, which is the main railway station of the capital, making this area a place where many travellers and workers pass daily. Close by, Segerls torg, a central square and one of the main meeting points of the city, is a relatively high criminogenic area (Ceccato et al., 2002).

Unlike many Western European cities, large parts of Stockholm inner city are residential, where citizens enjoy a good quality of life, with high housing standards. For instance, one of the most prestigious and expensive residential areas is composed of apartments facing the water at the heart of the Swedish capital. Although other types of housing tenancy can also be found in the inner city areas of Stockholm, privately or cooperatively owned apartments dominate. Since the early twentieth century, modernism characterized the development of the city as it grew, and new residential areas were added to the growth. Some of these areas may be valued highly in the housing market, especially those developments following the underground system. All over the country new residential areas were built with clear welfare principles in mind.

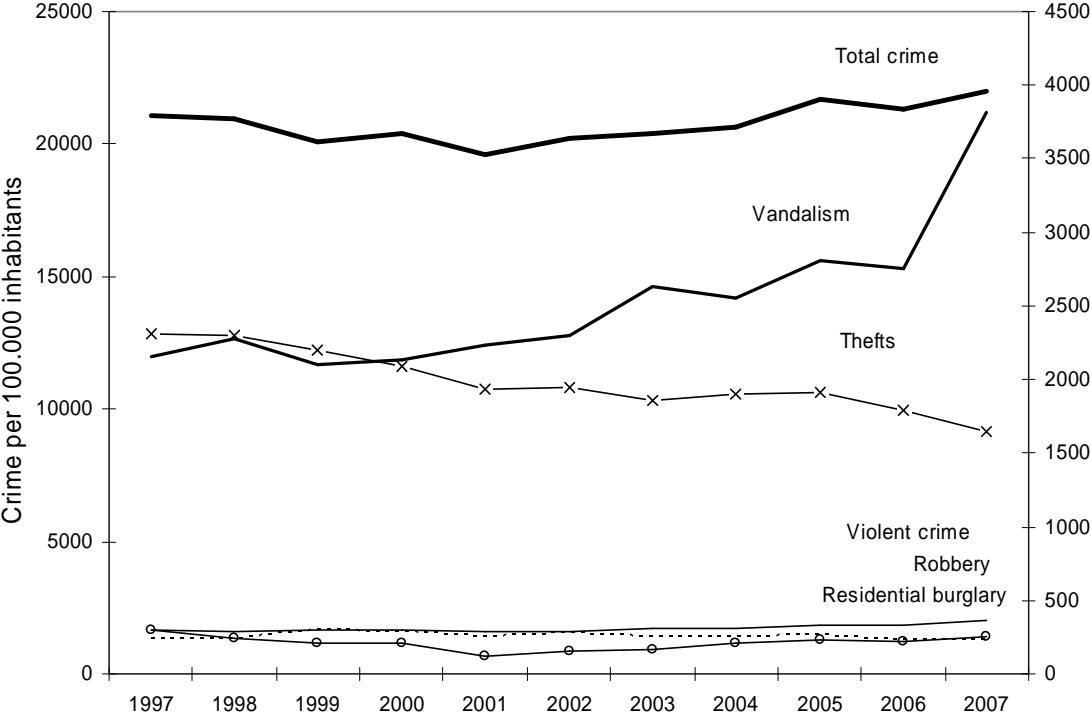


Figure 1 – Crime rates in Stockholm city, 1997-2007

However, the industrialized and mass-produced blocks of flats built in the 1960s and 1970s do not perform equally well in the market. Low prices are often linked to poor architecture, lack of amenities and social problems, such as crime, public disorder and fear of crime. Despite the fact that total number of recorded offences in Stockholm city was not significantly higher in 2007 than in 1997, there are certain parts of Stockholm where people feel less safe (USK, 2008). This may indicate that there have been changes in offence type. Police recorded statistics show significant increases in violent offences and vandalism. The latter has almost doubled between 1997 and 2007 for Stockholm City (Figure 1). But crime, particularly property crime, is not concentrated in these mass-produced blocks of flats. Highly desirable housing central areas are often targeted by crime. Some of them are new apartment developments that took over old industrial areas of Stockholm, offering buyers both good

accessibility and urban sustainability principles (including safety design features) in a single package.

The geography of residential burglary has been changing since the early 1990s. Wikström (1991) showed that residential burglaries (excluding burglaries in attics and cellars) in Stockholm tend to occur mostly in some outer city wards of high socio-economic status (with single-family houses), and especially in districts where there are high offender-rate areas nearby. Using data from 1998, Ceccato et al. (2002) showed that high relative risks of residential burglary tended to occur both in the more affluent areas and in the more deprived areas. On the one hand, the higher the income the higher the relative risk rate of residential burglary. This fits into the Swedish pattern for this type of offence noted by Wikström (1991), which supports the view that an area's attractiveness affects its rate of residential burglary. On the other hand, the results also point to another component of the offence pattern. The higher the percentage of multi-family houses and the higher the percentage of people who are born abroad, the higher the rate of residential burglary. Since the late 1990s, no new evidence has been put forward. What can be said, however, is that between 2002 and 2007, police recorded data show high concentrations residential burglary in central areas as well as in the outskirts of Stockholm. In 2002, high rates of residential burglary were found, for instance, in the central areas in Hörnstull and Thoridsplan, while in 2007 some high rates occurred in the Northern parts of the city, such as Odenplan-Norrmalm. In 2007, a couple of areas in the outskirts of Stockholm had the highest rates, particularly at Northwest, North and Southeast, such as Norra Vällingby, Akalla, Åkeshov and Skarpnäck.

The feeling of being safe is an important quality of a home and its setting (Lind and Bergenstråhle (2002). Security plays an important role when people in Sweden are choosing a place to live (Fransson et al., 2002, Magnusson and Berger, 1996, Björkund and Klingborg, 2003, Werner, 2003). Lack of security can affect housing quality in so many ways (for a discussion, see Björkund and Klingborg, 2003). Although these studies are more concerned on how people assess housing qualities in general, they clearly indicate that security is a factor of importance in their choice. In Magnusson and Berger (1996), for instance, safety was ranked as 4.1 in a scale from 0 to 5 whilst in Fransson et al., (2002), 85% of the interviewed population regarded safety as a quality that they take into consideration before choosing a place to live. That's why the so-called "smart homes" appears to be attractive to a broader range of consumers because they potentially make people feel safer (Werner, 2003, Sandström, 2009). None of these studies however deal with the specific relationship between lack of safety (crime) and housing prices, or in other words, whether people in Stockholm would be willing to pay more to live in safer neighbourhoods.

4. The Econometric Analysis

In this section, the econometric analysis will be presented. We will start by presenting the data used in the analysis and show some descriptive statistics. Before we estimate the hedonic price equation, a pre-analysis of the crime data will be performed. The rest of the section will be devoted to the estimation of the hedonic price equation. We will estimate a benchmark model and test for parameter heterogeneity in space and control for endogeneity.

The Data

The data derive from a number of different sources. The empirical analysis, the estimation of the hedonic equation, in this paper is based on a cross-sectional data that includes arm's-length transactions of condominiums in Stockholm, Sweden. The data cover a time span from January 2008 to December 2008 and consist of 9,622 transactions of condominiums. The data source is Broker Statistics (Mäklarstatistik AB), a real-estate broker association that covers around 70-80 percent of all broker transaction in Stockholm. The database contains property address, area code, parish code, selling price, living area, year of construction, presence of balcony and elevator, price per square meter, date of contract, condominium fee, number of rooms, date of disposal, number of the floor of the specific apartment, total number of floors, post code and x,y coordinates. For simplicity of the spatial analysis (weight matrix), we excluded seven per cent of multiple addresses; in other words, we kept only one transaction for x-y coordinates. Our final database consists of 8938 transactions of condominiums.

The average price is SEK 2.3 million and the variation around the average price is substantial. The typical apartment in the sample is 50 years old, with approximately 62 square meters of living space over 2.3 rooms. Only two per cent of the sample is newly built apartments. More than half of the apartments are located in buildings built between 1900 and 1945. The fee paid for maintenance is about SEK 3000 per month. Approximately 20 per cent are located on the first floor and around 25 per cent on the top floor. Almost 11 per cent of the apartments have an elevator and more than half of the apartments are located in properties with an elevator.

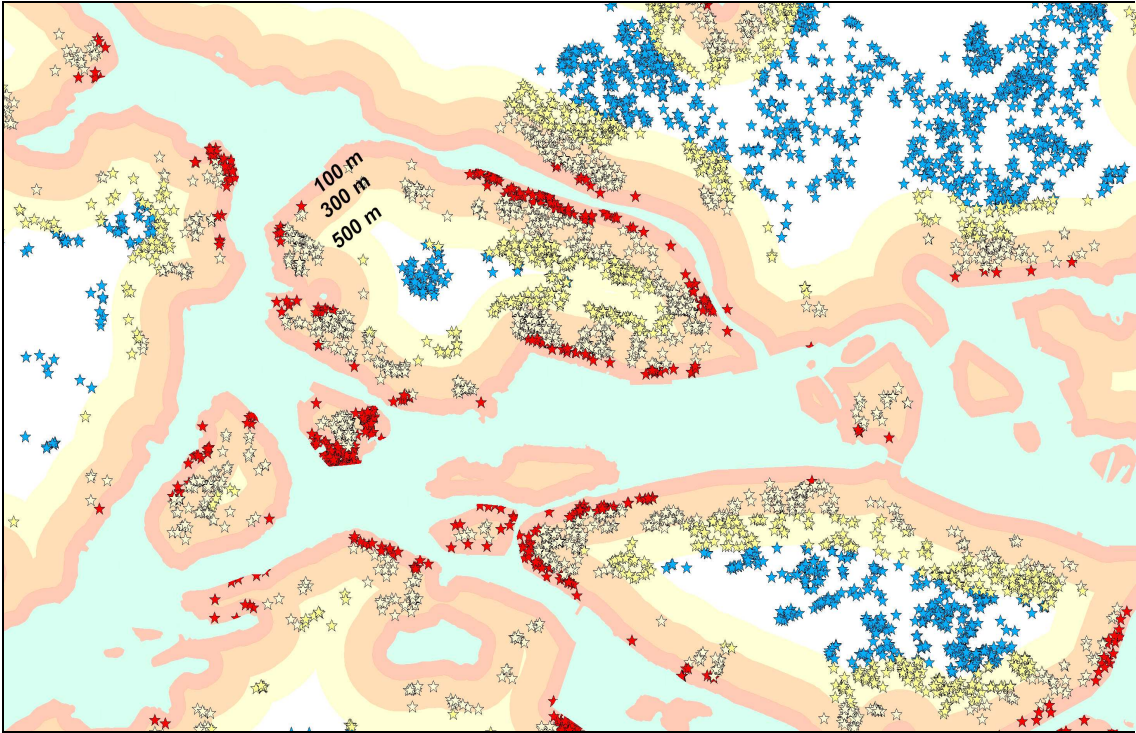
The cross-sectional data have been merged together with data from Stockholm Statistics (USK), Stockholm city (Stadsbyggnadskontoret) and Stockholm Police. The former consists of information concerning neighbourhood characteristics such as proximity to waterfront and subway stations, and the latter about crime statistics such as number of burglaries per 10,000 inhabitants.

In order to characterize the differences by sub-markets in Stockholm, a set of land use variables were created using GIS from the original layers of land use data over Stockholm city (Appendix). The distance between apartment and CBD has been estimated. On average, the apartments are located around 5.1 kilometres from CBD and the standard deviation is high (3.5 kilometres). We have also divided the city of Stockholm into four quadrants with CBD in the centre. More than 60 per cent of the apartments are located in the north part of the city and especially in the north-west part of the city (36 per cent).

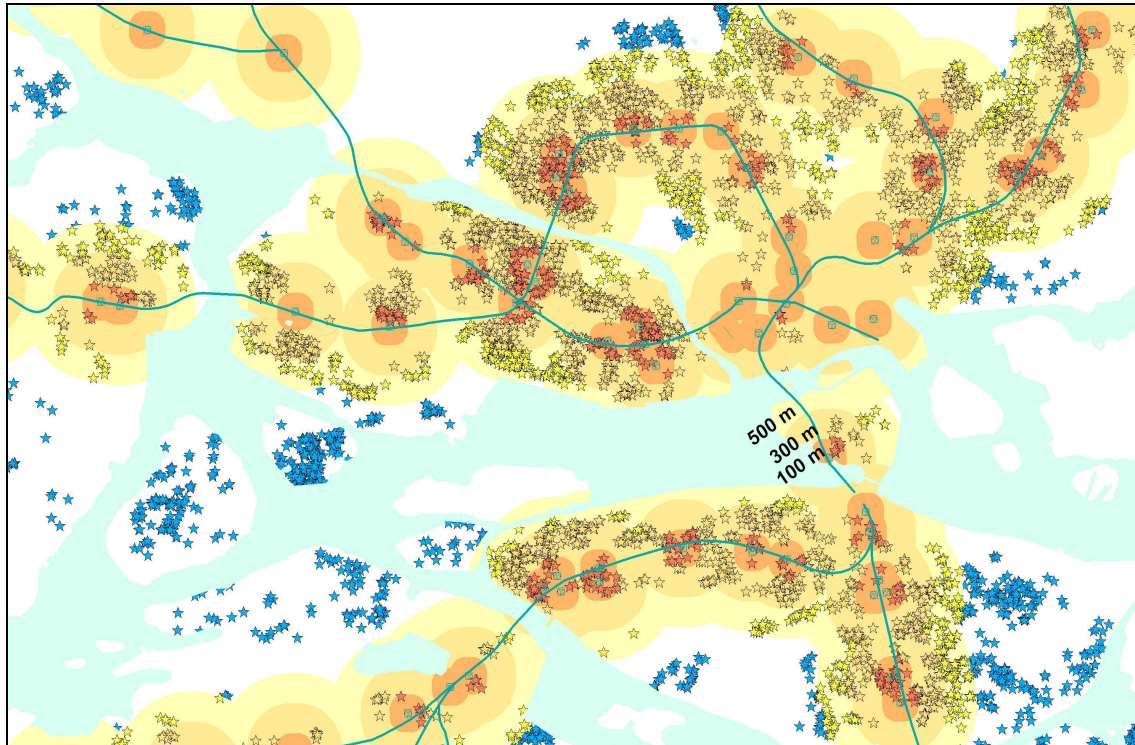
Buffer analysis was used in GIS to indicate the apartments that were more or less exposed to different types of environmental characteristics, such as property facing water, distance to roads, main motorways, metro and train stations. Instead of defining a fixed distance, different distance bands were tested. The distance bands of 100 meters, 300 meters and 500 meters showed more distinct results; after 500 meters, some of the buffers would begin to overlap. For example, eight per cent of the apartments are located in the 100 meter buffer zone from water, 31 per cent in the 300 meter zone and almost half of the apartments in the 500 meter buffer zone from water. The hypothesis is that proximity to water has a positive, but

declining, impact on apartment prices. As Figure 2 illustrates, some of these variables would have a very local effect whilst others would follow a centre-periphery model.

Almost 10 per cent of the apartments are located near a subway station (within 100 meters) and almost 75 per cent are located not further than 500 meters from a subway station. However, the distance to commuting train station is much longer. Less than one per cent of the apartments are located within 100 meters of a train station. On the other hand, in our sample, the suburbs of Stockholm are not included and the distance to a commuting train station is probably of lesser importance. Our hypothesis is that proximity to subway stations are much more important than to commuting train stations, resulting in higher implicit (hedonic) prices. It could even be that the negative externality (e.g. noise disturbance) of being close to a train station dominates over the positive externality (increased accessibility), resulting in negative implicit prices close to a train station. All the above location data has been included in the hedonic price equation.



(a)



(b)

Figure 2 (a) Sold apartments in relation to water bodies, buffer of 100 meters (red), 300 meters (orange) and 300 meters (yellow); (b) Sold apartments in relation to subway stations, buffer of 100 meters (red), 300 meters (orange) and 300 meters (yellow)

It has been documented in many studies that traffic noise has a negative impact on property values (see e.g. Wilhelmsson, 2000). Here we have included proximity to traffic roads in two ways. The first is the buffer zones around highways. However, very few of the properties are located close to a highway. Approximately seven per cent are located within 300 meters. On the other hand, more than 60 per cent of the apartments lie in buffer zone 300 meters from a main road. Main roads also attract services and commercial activities, with undesirable effects on residents' quality of life. Roads have also a criminogenic impact. The closer to main roads, the easier it is for offenders to escape. Beavon et al. (1994) found that crime was higher in more accessible and highly used areas and lower in less accessible and lesser used areas. Regardless of the dynamics, our hypothesis is that, all other factors being equal, proximity to road traffic has a negative effect on apartment prices.

The effect of crime in neighbouring zones on a specific place can be measured by incorporating spatial lagged variables of offence rates into the model, so the variable can be tested for a 'spill-over' effect. This is particularly important since offenders' behaviour is often motivated by local factors, but sometimes shows elements of a spatially contagious process, spilling over into nearby areas. Spatially lagged variables are weighted averages of the values for neighbouring locations, as specified by a spatial weights matrix. In this case, a queen-based contiguity spatial weights matrix (Queen's matrix is set to 1 if the pair of cells share a common edge or vertex and 0 otherwise, first-order criterion). First, the x-y

coordinates of each apartment were transformed into Dirichlet polygons using GIS and then imported into GeoDa 0.9.5–1 (Anselin 2003) to generate the weight matrix, which was later used to create the lag variable. The lag variable was regarded as an exogenous covariate and was therefore created based on the natural log of the original crime rate. This was done by using Lag operations available in GeoDa since the software has capabilities to create variables using neighbourhood structure provided by a weight matrix of Stockholm units.

Crime data for 2008 were provided by Stockholm Police by small unit areas (basområde) in a total of 408 units (Appendix). Rates per small unit areas were calculated for total crime, robbery, vandalism, violence, residential burglary, and shoplifting as well as drug-related offences, thefts, theft of cars, theft from cars, and assault. With no better available denominator, total population was replaced by ‘area’ of the unit in the cases of vandalism and thefts. The discussion of the inappropriateness of total population as denominator when calculating rates for these crimes has already been discussed in detail by Wikström (1991).

Pre-analysis of the crime data

A number of different types of crimes are presented above. However, the correlation among some of them is substantial. By performing a principal component analysis (PCA), the ‘most important’ crime types can be identified. PCA is a statistical method that from a number of variables develops a smaller set of variables (called principal components). These account for the variance in the original variables, and all the principal components are a linear combination of the original variables. The technique can be used for variable reduction, but we have used it in a way to mitigate the problem of multicollinearity between the crime variables (see Dunteman, 1989). The constructed principal components are defined so that they do not correlate to each other. A real estate application of the principal component analysis can be found in, for example, Bourassa et al (2003).

In the appendix the result of the principal component analysis is presented. The result indicates that the first components (combination of robbery and drug related crimes) explain around 50 per cent of the total variance among all the crime variables, and the first four (theft and vandalism, burglary and violence, and assault) explain more than 90 per cent of the variation. We have therefore decided to use only robbery, vandalism, burglary and violence, together with the total crime rate, in the hedonic analysis.

The hedonic price equation

The benchmark hedonic model uses all property and apartment attributes described earlier together and time period dummies (month) and location variables discussed earlier. The model is estimated using OLS. The model includes a crime variable by including total crime rate per 10,000 inhabitants together with the crime level in the neighbouring areas. It is included in order to capture some of the diffusion. The second model is also an OLS model, but it is a two-stage least square model including the same variables as model 1. However, as we may have problems with endogeneity, an instrument variable approach has been utilized. Our first model can be specified as equation 2 below and testing our hypotheses 1 and 3.

$$y = \beta_1 x + \beta_2 C + \beta_3 WC + \varepsilon \quad (2)$$

where y is a vector of observations on the sales price; X is a matrix observations on the property attributes, β_1 is the associated vector of regression coefficients and ε is a vector of random error terms. The variable C is the crime rate and W is a spatial weight matrix multiplied with C and measuring the crime rate in the neighbouring areas. The coefficients β_2 and β_3 is the associated coefficients to crime and crime in neighbouring areas.

Burglary is the only crime related variable that is directly related to apartments, but it is also the variable that may have the biggest problem with endogeneity among the used crime variables. The causal relationship between apartment prices and robbery seems to go in both directions. That is to say, areas with high apartment prices may attract burglars and therefore the number of burglaries will be high in high-priced neighbourhoods. When it come to robbery, violence and vandalism, it seems that these are more exogenous and thereby less complicated when it comes to the estimation of the hedonic price equation.

Gibbons (2004) conclude that “recorded crime rates will be endogenous to housing prices unless all housing attributes are observed”. We cannot guarantee that we have included all relevant independent variables. Hence, the exclusion of relevant variables will not only create omitted variable bias, but also endogeneity among the independent variables. According to Tita et al. (2006), murder is an ideal instrument. Gibbons (2004) argue that crime rates in the surrounding area are a good candidate as an instrument. The first IV model includes the endogenous variable crime rate instrumented with homicide in the area. The idea is that homicide is highly correlated with crime rate, but not with apartment prices. Controlling for endogeneity does not, however, improve the statistically significance of the total crime per 10,000 inhabitants. The model estimated is equal to equation 3.

$$\begin{aligned} y &= \beta_1 x + \beta_2 \hat{C} + \beta_3 W\hat{C} + \varepsilon \\ \hat{C} &= \delta z \end{aligned} \quad (3)$$

where variable z is the used instrument variable (murder) and \hat{C} is therefore equal is expected crime rate. Hence, first we regress crime against murder and, second, we regress apartment price on property and apartment attributes as well as expected crime rate given murder rates (the so-called two-stage least squares procedure). If there is strong relationship between murder and crime rate, it is considered to be a strong instrument. However, to be considered to be valid instrument, murder must not be correlated to the error term (ε) in equation 2. See Murray (2006) for a discussion about invalid and weak instruments.

The third and fourth models are a spatial lag model and a spatial error model. The reason we have applied the spatial econometrics is that spatial dependency is present on the residuals. A binary weight matrix based on shared common boundaries or vertex was created using GeoDa 0.9.5–1 (Anselin 2003) to represent the spatial arrangement of the city. Based on the spatial diagnostics of the residuals of the OLS model, the lagged response and spatial error models

were also fitted (Haining, 2003, pp. 312–316). Our spatial lag and spatial autocorrelated model is equal to equation 4 and 5 below.

$$y = \beta_1 x + \beta_2 \hat{C} + \beta_3 W\hat{C} + \lambda W y + \varepsilon \quad (4)$$

$$\begin{aligned} y &= \beta_1 x + \beta_2 \hat{C} + \beta_3 W\hat{C} + \varepsilon \\ \varepsilon &= \rho W \varepsilon + \eta \end{aligned} \quad (5)$$

The choice of functional form is more an empirical choice than a theoretical one (see Halvorsen and Pollakowski, 1981). We have transformed all continuous variables by taking the natural logarithmic. The justification for using the logarithmic form is that it is a common practice in this type of research, and as the Box-Cox transformation indicates (not shown here), it is easy to interpret the results as all estimates are in elasticity form.

In order to distinguish between the models, the measure AIC (Akaike Information Criterion) is used for model selection. Just as adjusted R-square, AIC takes into consideration the trade-off between the number of independent variables in the equation and the number of observations. According to the statistics, a spatial error model with instruments seems to be preferred (Table 1). The spatial lag model did not appear to be very informative and we shall not discuss them further in Tables 2 and 3.

Table 1 - Hedonic price equation

	OLS		OLS & Instrumental		Lag & Instrumental		Error & Instrumental	
	Coefficient	t-values	Coefficient	t-values	Coefficient	z-values	Coefficient	z-values
Area	.7043	53.37	.7054	53.19	.5919	53.64	.6360	65.91
Room	.1889	15.85	.1878	15.68	.2013	20.66	.1898	22.73
Fee	-.1195	-18.97	-.1194	-18.95	-.0723	-14.05	-.0513	-11.07
Age1	.1938	13.58	.1931	13.52	.1213	10.42	.0603	4.98
Age2	.1142	13.35	.1119	12.47	.1169	15.98	.0240	2.85
Age3	-.0277	-3.00	-.0277	-3.00	.0282	3.74	-.0073	-.85
Age4	-.2044	.01	-.2047	-18.12	-.1030	-11.11	-.0631	-5.80
Age5	-.1729	.01	-.1739	-13.74	-.1149	-11.10	-.1194	-8.78
New	.1117	4.77	.1157	4.83	.0674	3.46	.1134	5.50
Elev	-.0389	-4.69	-.0392	-4.68	-.0493	-7.22	-.0301	-4.51
Elev*floor	.0164	9.10	.0163	9.07	.0158	10.81	.0157	12.31
Balc	-.0103	-.98	-.0101	-.957	-.0028	-.33	.0038	.53
Elev*Balc	-.0084	-1.04	-.0086	-1.07	-.0139	-2.16	-.0049	-.87
First	-.0345	-4.65	-.0345	-4.64	-.0292	-4.83	-.0216	-4.36
Top	.0245	3.56	.0243	3.54	.0224	4.01	.0289	6.21
Water100	.1054	9.33	.1051	9.30	.0398	4.32	.0335	2.31
Water300	.0218	2.48	.0202	2.63	.0210	2.88	.0117	.92
Water500	.1005	12.84	.1010	12.87	.0609	9.49	.0721	5.95
Sub100	.0186	1.89	.0210	2.04	.0047	.57	.0207	1.66
Sub300	.0451	6.25	.0461	6.29	.0294	4.93	.0265	2.70
Sub500	.0305	3.85	.0318	3.94	.0323	4.92	-.0070	-.56
Train100	-.0236	-.71	-.0230	-.69	-.0351	-1.31	-.0223	-.97
Train300	-.0725	-3.64	-.0734	-3.68	-.0737	-4.55	-.0334	-.16
Train500	.0292	2.23	.0315	2.35	.0338	3.10	-.0029	-.13
Road100	-.0986	-2.98	-.0976	-2.95	-.0637	-2.37	-.0325	-.97
Road300	.0116	0.80	.0122	.84	.0272	2.30	-.0032	-.16
Road500	.0326	3.28	.0304	2.94	.0214	2.55	-.0022	-.13
Main100	.0159	2.25	.0164	2.31	-.0001	-.1708	.0010	.12
Main300	.0493	5.81	.0481	5.60	.0362	5.18	.0479	4.22
Main500	-.0835	-8.84	-.0818	-8.46	-.0481	-6.10	.0058	.41
Distance	-.3599	-70.43	-.3600	-70.43	-.1926	-38.82	-.2630	-23.82
Total crime	.0011	.20	-.0089	-.79	.0068	.74	-.0418	-2.79
W_tot crime	-.0479	-6.61	-.0455	-8.53	-.0314	-7.24	-.0229	-2.71
W_Y	-	-	-	-	.4936	64.68	-	-
Lambda	-	-	-	-	-	-	.8024	104.31
R-square	.7674		.7675		.8453		.8850	
Adj R-square	.7662		.7662		-		-	
AIC	863		863		-2348		-4026	
Moran's I	.50		0.50		-		-	

Note: Dependent variable=natural logarithm of transaction price. All continuous independent variables are transformed to natural logarithm. Parameter estimates concerning sub-markets and time are not presented in the table as well as estimates concerning floor, number of floor, missing information about floor, number of floors, elevator and balcony. Moran's I = presence of autocorrelation on residuals (significant at 99% level)

Results indicate that more than 85 per cent of the variation in apartment prices can be explained by the included hedonic attributes. According to the spatial error model, all estimated parameters concerning property and apartment attributes have correct sign and are of reasonable magnitude. The only exception is elevator that seems to have a negative impact on apartment price. However, when elevator is interacted with number of floor, a positive

effect from floor 3 is estimated. It indicates that elevator is capitalized positively into price if the apartment is located on, for example, floor 6 by approximately 9 per cent $[-0.03+(6*0.02)]$.

Unsurprisingly, proximity to water has a clear positive effect on apartment prices. The interpretation of the estimates of water means that an apartment located 50 meters from the water is expected to sell for almost 12 per cent ($e^{0.1173}-1$) more than an apartment located, for example, 600 meters from the water, all else being equal. The result of proximity to water is consistent with other studies. To be very close to a subway station (within 100 meters) is regarded as positive. It is clear that the negative externalities, such as, for example, noise and vibrations, surrender over the positive. Not expectedly, proximity to commuting train stations has no effect on apartment prices in the range 0-500 meters. Moreover, apartments close to a highway are not more likely to have lower prices than those that are not close to those roads. Main streets seem to have a positive effect on price if the apartment is located not too far away from the main street, but no negative effect if it is located close to a main street.

It is interesting to observe that the estimated parameters concerning location variables become insignificant, less significant or even switch sign if we compare the spatial error model with the OLS models. In the OLS models, almost all estimates for the location variables are significant, but not in the spatial models. The price gradient is also highly affected. As Wilhelmsson (2002) concludes, the choice of spatial structure affects the interpretation of estimates for variables with which it is correlated.

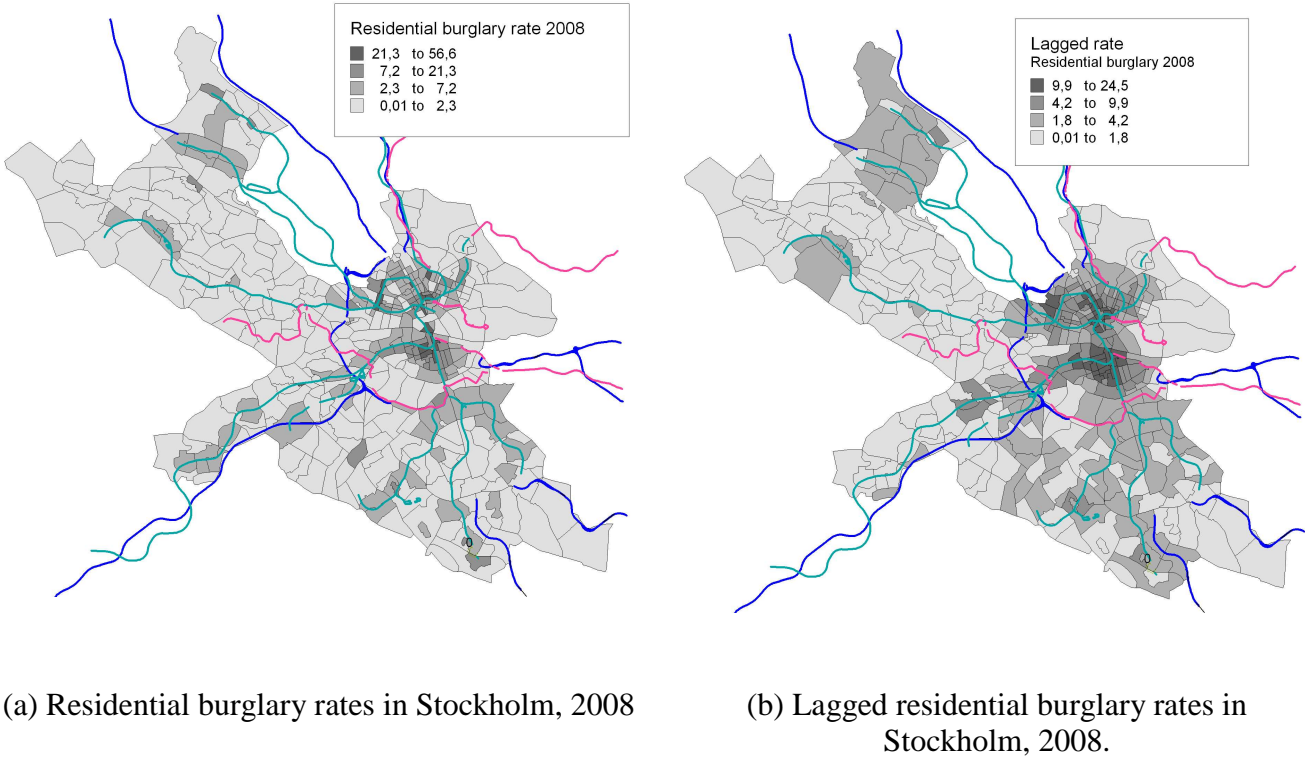


Figure 3

The results indicate that total crime rate has no impact on apartment prices (the coefficient is not statistically significant different from zero) in the OLS models and in the spatial lag model. However, in the spatial error model both crime and crime rate in neighbouring areas are negatively related to apartment price. The interpretation is that if the total crime rate in the area increased by one per cent, apartment prices would be expected to fall by 0.04 per cent.

We have also analyzed whether different types of crime are more suitable in explaining apartment prices, thus, testing hypothesis 2. The five different types of crime used are those chosen from the principal component analysis, namely, robbery, vandalism, burglary, theft and violence. We have not included all the types in one hedonic model; instead we have included each of the types separately into different models. The basic equation estimated is equation 3 and 5 above. We have included the crime variable which measures the crime rate in the area where the apartment is located. For example, in the first model we have included robbery per 10,000 inhabitants in the area where the apartment is located. We have also included a variable measuring the rates of robberies in the neighbouring areas (variable name W_Robbery) in a way to investigate whether robberies in surrounding areas affect the robbery rates in a specific area. The results are shown in Table 2. Because of space limitations, we are presenting only the estimated parameters concerning the different crime types. All the coefficients concerning property, apartment and location variables are of the same magnitude as in Table 1. Figure 3 illustrates the geography of residential burglary (and in its lagged form) that significantly affects apartment prices.

Table 2 – Different measures of crime – OLS and Spatial Error Models with Instrumental

	Robbery		Vandalism		Burglary		Assault		Theft	
	Coefficient		Coefficient		Coefficient		Coefficient		Coefficient	
	OLS	Error	OLS	Error	OLS	Error	OLS	Error	OLS	Error
Robbery	-.0049	-.0037		-		-		-		-
	(-.45)	(-2.43)								
W_Robbery	-.0470	-.0028		-		-		-		-
	(-15.7)	(-4.64)								
Vandalism		-	-.0340	-.0058		-		-		-
			(-2.27)	(-2.80)						
W_Vandalism		-	-.0184	.0035		-		-		-
			(-4.83)	(4.32)						
Burglary		-		-	-.1468	-.2110				-
					(-2.14)	(-2.16)				
W_Burglary		-		-	-.0514	-.0044				-
					(-13.27)	(-5.16)				
Assault		-		-			.0013	-.0503		
							(.0923)	(-2.45)		
W_Assault		-		-			-.0358	-.0213		
							(-13.05)	(-3.80)		
Theft									-.0792	-.0563
									(-6.20)	(-3.26)
W_Theft									.0442	.0832
									(9.74)	(8.92)
R-square	.7720	.8848	.7662	.8854	.7702	.8849	.7700	.8457	.7681	.8854
AIC	691	-4036	914	-4035	762	-4041	768	-4030	843	-4094
Moran's I on residuals	0.49		0.50		0.50		0.49		0.50	

Note: t and z-values with brackets, respectively. Parameter estimates concerning housing attributes, land-use characteristics and time dummies are not shown in the table.

Crime rate in surrounding areas plays a different role depending on the type of crime. The reasons behind such dynamic are difficult to know for certain but there might be several different processes going on between neighbouring areas which affect buyers' perception differently. Thefts in neighbouring areas, together with vandalism, seem to be positively correlated to apartment prices. Buyers may interpret the relatively high criminogenic conditions in nearby areas as a quality they would rather avoid but which, by comparison, makes their own neighbourhood look more attractive (as in "at least we have it better than them" effect). For instance, the impact of vandalism on housing prices has extensively been documented by Gibbons (2004), but previous literature in urban criminology illustrates the dynamics behind property value depreciation through the interpretation of vandalism and incivilities. Buyers read into the presence of disorder, vandalism and incivilities that residents and authorities have lost control of the community and are no longer in a position to maintain order (Hunter, 1978). Incivilities may also symbolize the erosion of commonly accepted standards and values, norms concerning public behaviour and loss of social control (Lewis and Salem, 1986, Skogan, 1990, Lagrange et al., 1992).

Residential burglary, together with robbery and assault, in neighbouring areas has a negative effect on apartment prices. The depreciated effect on apartment prices in an area and its neighbouring zones may related to spill-over processes (offenders act both where they live and in nearby areas) but also copy-cat dynamics ('violence begets violence' in the sense of a spatially contagious process). The seriousness of the offence makes buyers perceive violence differently from acts of vandalism: whilst the first pushes the property prices up at the location and down in the surrounding areas, the second pushes apartment prices down both at the location and its hinterland.

Parameter heterogeneity in space

Despite the fact that residential burglary is the second best model according to AIC measure, we continued, nevertheless, with that offence in order to analyze parameter heterogeneity in space. The reason we have used the variable is that it is more directly connected to the apartment market and it is the variable among the crime variables that has the largest price sensitivity to apartment prices. On average, if the number of burglaries increases by one per cent, apartment prices are expected to decrease by 0.21 per cent. In an attempt testing hypothesis 4 we have investigated whether the estimated parameters concerning residential burglary and burglary in neighbouring areas are different in different parts of Stockholm. The model that we have estimated is equal to equation 6 below.

$$\begin{aligned}
 y &= \beta_1 x + \beta_2 \hat{C} + \beta_3 W\hat{C} + \beta_4 \hat{C}I + \beta_5 \hat{C}N + \varepsilon \\
 \varepsilon &= \rho W\varepsilon + \eta
 \end{aligned}
 \tag{6}$$

We have divided Stockholm into the North and the South part (variable name N) and into inside and outside the inner circle (I) of Stockholm (in this case 3 kilometres). Both the variable N and I is multiplied with burglary (C) and if β_4 and β_5 is statistically different from

zero, burglary rate impacts negatively on apartment prices differently in different parts of the city. The results of that test are presented in Table 3.

Table 3 - Parameter heterogeneity (Burglary) – OLS and Spatial Error Model

	Inside inner circle		North		Inside inner circle and north	
	Coefficient		Coefficient		Coefficient	
	OLS	Error	OLS	Error	OLS	Error
Burglary	-.3730 (-5.43)	-.2487 (-2.59)	-.2002 (-3.00)	-.1836 (-1.92)	-.3716 (-5.38)	-.2353 (-2.45)
W_Burglary	-.0358 (-9.31)	-.0345 (-4.27)	-.0372 (-9.61)	-.0353 (-4.33)	-.0357 (-9.26)	-.0345 (-4.26)
Burglary *Inner	.2500 (9.92)	.1093 (3.79)	-	-	.2508 (9.81)	.1159 (3.97)
Burglary *North	-	-	.0300 (1.41)	-.0270 (-.85)	-.0040 (-.19)	-.0392 (-1.45)
Adj R-square	.7893		.7870		.7893	
R-square	.7880		.7857		.7880	
AIC	1.35		97.8		3.32	
Moran's I	0.47		0.47		0.48	

Note: t and z-values respectively in brackets. Parameter estimates concerning housing attributes, land-use characteristics and time dummies are not shown in the table. White's robust estimation of the standard deviation. Inner circle is equal to within 3000 meters from CBD and North is equal to all areas north of CBD, including peripheral western and eastern areas of the city.

The results seem to indicate that the impact of burglary on apartment values is different depending in which part of the city we can observe the burglaries. It can be noticed that burglary in the central part of the city does have a lesser effect on apartment prices, while burglaries outside the inner circle has a higher negative impact on price. It is also evident that burglaries in the north part of Stockholm have a higher effect on price (not significant on a 5% level). Hence, burglary has a negative impact on apartment prices and seems to be highest north of the inner circle (more than 3 kilometres from CBD). Burglaries in the central city appear to be expected and are capitalized less into price. The effect is visualized in the figure below.

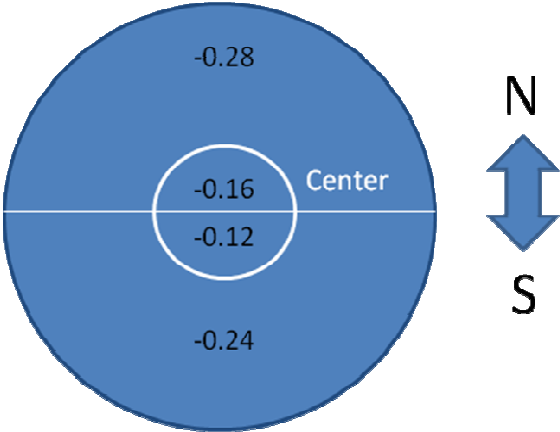


Figure 4 – The effect of residential burglary on property prices

The impact of crime on housing prices in North American cities is not much greater than the effect found in Stockholm, even after considering differences in crime type and methodology. For instance, in Boston, Hellman and Naroff (1979) reported an elasticity of 0.63 for total crimes whilst Lynch and Rasmussen (2001) found an elasticity of 0.05 for violent crimes in Jacksonville, Florida. Our findings indicate that if total crime increases by one per cent in Stockholm, apartment prices are expected to fall by 0.04 per cent. This decrease is slightly higher if considers the effect of residential burglary only. If residential burglary increases by one per cent, apartment prices are expected to fall by 0.21 per cent. Although these results are in line with what was expected (Stockholm, a city embedded in a typical welfare state economy), a comparison with another case study (of a market oriented economy) using exactly same methodology would be needed to fully test the hypothesis 5. Moreover, more knowledge would be needed to assess the mechanisms linking house prices, crime and inequality in different societal contexts. Here we assumed that the impact of crime on housing prices would be lower in Stockholm as a result of welfare policies interventions that moderate negative effects of market economy.

5. Final considerations

The objective of this paper is to analyze the relationship between apartment prices and different measures of crime. Researchers have long suggested that high crime levels make communities decline. This decline may translate into an increasing desire to move, weaker attachments of residents and lower house values. This is because buyers are willing to pay more for living in neighbourhoods with lower crime rates or, alternatively, buyers expect discounts for purchasing properties in neighbourhoods with higher crime rates. There is an urgent need of empirical evidence in this field under Swedish conditions since very little evidence is found in the international literature.

Our study contributes to existing literature in numerous ways. First, the article provides evidence of the impact of crime on housing prices in a capital city of a welfare state country such as Sweden. Second, the study explores a set of land use attributes not communally used in hedonic pricing modelling. The neighbourhood context is incorporated into the model by attaching, to each sold apartment, information that characterises a finely detailed statistical unit of analysis using GIS. Moreover, if a low crime area is surrounded by high crime, then criminogenic conditions in that area may be underestimated because of the high levels of crime in neighbouring zones. GIS and spatial statistics techniques are then used to tackle this problem, so the neighbourhood structure is added to the model to capture crime conditions in each unit of analysis but also in its neighbouring units.

We are testing five main hypotheses. First, crime impacts negatively on apartment prices after controlling for attributes of the property and neighbourhood characteristics. Second, different types of crimes affect property values differently. As in the UK, we believe that in Sweden criminal damage has the highest effect in housing price determination because its occurrence is visual and indicates community instability. Third, the price of an apartment is dependent on the crime levels at its location as well as the crime levels in the surrounding areas. This effect varies by offence type because different types of crimes are generated by different mechanisms. Fourth, we tested the hypothesis that crime effect on apartment prices is different in different parts of the city. We have used a cross-sectional data set from the year

2008. We have examined apartment sales and recorded the transaction price of nearly 9000 observations in the city of Stockholm, Sweden. We have a number of apartment attributes such as living area, number of rooms, monthly fee and age as well as elevator, balcony and floor level. We have also included location attributes such as distance to CBD, distance to water, subway station, commuting train station, highway, and Main Street. The third group of data we are utilizing is crime data such as total crime rate, robbery, vandalism, violence, residential burglary, shoplifting, and drugs, as well as theft, theft of cars, theft from cars, assault. Finally, by comparing Stockholm with other cases studies in the literature, often embedded in more market oriented economies, we found that the impact of crimes on apartment prices is often smaller in Stockholm than the one found elsewhere.

The estimation procedure is first to estimate a simple OLS model. However, as there may be a problem of endogeneity between apartment prices and crime rates, we are using a two-stage instrument variable approach. We also tested for spatial dependency and found such. In order to remedy the problem, two different spatial models have been estimates. The first is a spatial lag model and the second a spatial error model. Findings indicate that if total crime increases by one per cent, apartment prices are expected to fall by 0.04 per cent. To fully test hypothesis 5, future studies should devote time to assess the mechanisms linking house prices, crime and inequality in different societal contexts.

Contrary to what was initially hypothesized, residential burglary (not vandalism) seems to have the greatest effect on property values, but theft seems to have the statistically strongest effect. If residential burglary increases by one per cent, apartment prices are expected to fall by 0.21 per cent. It seems that the expected 'visual effect' of vandalism on people's perception of an area is not strong enough to affect property prices in the case of Stockholm. A possible reason for this is that public disorder and vandalism (typically inner-city offences) are not equally reported to the police as more serious crimes. Thus, in areas where vandalism is the only problem, vandalism alone is not enough to affect people's perception and pull the prices down. However, in areas where all sorts of crimes are part of everyday life, vandalism (together with other problems) contributes to lowering property prices. Another possible reason that residential burglary has a stronger effect on apartment prices than vandalism is because the two offences are quite different in nature. Whilst targets of vandalism and criminal damage belong to a more public sphere and outdoors (bus stops, fences, gates), targets of residential burglary are always the intimacy of a private property (the apartment and objects in it). This difference between public and private should affect how people perceive residential burglary in relation to vandalism, the first being more serious and more intrusive than the second.

Results show also that the magnitude of the effect of residential burglary on apartment prices is highest in the northern part of Stockholm than in the South. Apartments in inner-city areas are also less discounted than the ones located in the central areas. Although it is difficult to indicate definitively the reasons behind the North-South divide, it is possible to say that Northern Stockholm includes areas that are both high and low in crime, which would make the comparison between these areas easier, and so affecting more strongly the market for

apartments in this area. In the Southern parts, although most of the areas are regarded as non-problematic, these areas tend to have a more homogenous crime rate, disturbed occasionally by pockets of high crime. This means that people buying apartments in the South, where apartments are usually cheaper than in the North, are not able to use crime rates to negotiate better prices. Inner-city areas are often more valued regardless of crime rates because these areas offer amenities (e.g., location, good quality of life) that are more valued by those buyers. Findings show evidence that inner-city amenities compensate for 'lack of security', a quality that is not taken into consideration by buyers determined to live in Stockholm inner city.

One of the most important findings of this research is the indication that the price of an apartment is dependent on the crime levels at its location as well as the crime levels in the surrounding areas, regardless of crime type. This evidence lends strength to the argument that future research dealing with the assessment of property prices must take the spatial arrangement of the data into account. These findings have both methodological and criminological implications. First, the way we assess an area goes beyond its administrative or analytical boundaries, so if apartment prices are related to the crime of its area only, we are missing the effect of the surroundings, and our model is mis-specified. Second, if lag dependent variables are not incorporated into the models as independent variables, there is no way to test for spill-over effect, and consequently some of this variance will erroneously be captured by other variables of the model that have similar geography.

This article makes contributions to the way property values are influenced by environmental and security conditions. This study is innovative in its exploration of different scales of analysis by incorporating the effect of crime rates at an area and in its neighbouring locations. Another important feature of this study is the testing of measures of different buffer zones using GIS from land use factors, such as underground and train stations, water bodies. However, the analysis shares limitations with other analyses relating to crime and property prices, which are important to mention here. One limitation is that the modelling section is based on the database from 2008 only, which is too narrow a time period for drawing final conclusions on the relationship between the effect of crime rates and apartment prices. Future research should devote time to elucidate the processes through which apartment prices interact and are influenced by crime using long-term data series. Challenges for future research should also include the testing of crime ratios instead of crime rates (as applied in this study) or other denominators for burglary, such as total number of properties in the area. Data permitting, there is also a need to test the effect of different strategies to ensure the modelling robustness, such as testing different types of weight matrices (such as distance-based, instead of binary ones) and other instrumental variables (instead of homicide, as used in this study). Another remaining research question is to assess whether fear of crime has the same effect on apartment prices as do crime rates. Despite these limitations, we believe the results from this study can enhance current research on relationships between crime rates and apartment prices by providing empirical evidence from a Scandinavian capital city.

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Appendix - Principal Component Analysis

A. Explanatory power of each factor

Component	Eigenvalue	Proportion	Cumulative
M1	6.141	0.512	0.512
M2	2.847	0.237	0.749
M3	1.006	0.084	0.833
M4	0.858	0.072	0.904
M5	0.510	0.043	0.947
M6	0.379	0.032	0.999
M7	0.245	0.020	0.999
M8	0.009	0.001	0.999
M9	0.003	0.001	0.999
M10	0.001	0.001	1.000
M11	0.000	0.000	1.000
M12	0.000	0.000	1.000

B. The nature of the factors

Component	Description	Variable loading (>0.40)	
M1	Robbery	Robbery	.402
		Drug	.401
M2	Theft and vandalism	Theft	.518
		Theft from cars	.523
		Theft of Cars	.471
		Vandalism	.479
M3	Burglary	Burglary	.988
M4	Violence and assault	Violence	.559
		Assault	.574
M5	Cars	Theft of cars	.752
M6	Vandalism	Theft from cars	.443
		Vandalism	.596
M7	From cars	Theft from cars	.688
M8	Shoplifting and drugs	Shoplifting	.461
		Drugs	.516
M9	Shoplifting	Shoplifting	.563
M10	Theft	Theft	.569
M11	Violence	Violence	.721
M12	Crime	Crime	.545

Appendix: The database of study

<i>Data Type</i>	<i>Source</i>	<i>Variable</i>	<i>Description</i>	<i>Unit</i>	<i>Average</i>	<i>Standard deviation</i>
Apartment sales	Broker Statistics (Mäklarstatistik)	Price	Transaction price	SEK	2336776	1413819
		Area	Living area	Square meter	62.25	26.76
		Room	No. of room	Number	2.33	1.02
	Year: 2008	Fee	Monthly fee	SEK	3127.21	4853.02
		Age1	Before 1900	Binary	.0523	.22
		Age2	1900-1930	Binary	.3475	.48
		Age3	1930-1945	Binary	.2204	.41
		Age4	1945-1965	Binary	.0846	.28
		Age5	1965-1993	Binary	.0621	.24
		Age6	1990-	Binary	.2330	.42
		New	Sale year = building year	Binary	.0206	.14
		Elev	Elevator in the house	Binary	.5856	.49
		Balc	Balcony in the apartment	Binary	.1087	.31
	First	First floor	Binary	.2048	.40	
	Top	Top floor	Binary	.2668	.44	
	Externality data and sub-market characteristics	Distance	Distance	Distance to CBD	Meter	5137.03
NE			North-east quadrant	Binary	.2515	.43
NW			North-west quadrant	Binary	.3580	.48
SW			South-west quadrant	Binary	.1322	.34
Stockholm's housing office (Stadsbyggnadskontoret)		Water100	100 meter buffer from water	Binary	.0829	.28
		Water300	300 meter buffer from water	Binary	.3072	.46
		Water500	500 meter buffer from water	Binary	.4821	.50
		Sub100	100 meter buffer from subway station	Binary	.0983	.30
		Sub300	300 meter buffer from subway station	Binary	.4623	.50
		Sub500	500 meter buffer from subway station	Binary	.7070	.46
		Train100	100 meter buffer from commuting train station	Binary	.0085	.09
		Train300	300 meter buffer from commuting train station	Binary	.0391	.19
		Train500	500 meter buffer from commuting train station	Binary	.0858	.28
		Road100	100 meter buffer from highway	Binary	.0072	.08
		Road300	300 meter buffer from highway	Binary	.0655	.25
		Road500	500 meter buffer from highway	Binary	.1535	.36
		Main100	100 meter buffer from main street	Binary	.2641	.44
		Main300	300 meter buffer from main street	Binary	.6439	.48
		Main500	500 meter buffer from main street	Binary	.8012	.40
		Crime	Stockholm Police	Crime	Crime rate per 10,000 inhabitants	Ratio
Robbery	Robbery per 10,000 inhabitants			Ratio	93.776	3141.251
Vandalism	Vandalism per square meter of area			Ratio	4.306	5.158
Violence	Outdoor violence per 10,000 inhabitants			Ratio	281.5881	8905.225
Burglary	Residential burglary per 10,000 inhabitants			Ratio	51.481	92.930
Shoplifting	Shoplifting per 10,000 inhabitants			Ratio	1880.947	95930.84
Drugs	Drug related crimes per 10,000 inhabitants			Ratio	434.534	13668.88
Theft	Theft per square meter of area			Ratio	8.715	11.222
Theft of cars	Theft of cars per square meter of area			Ratio	.406	.304
Theft from cars	Theft from cars per square meter of area			Ratio	1.053	.786
Assault	Assaults per 10,000 inhabitants			Ratio	188.569	5988.247