THE IMPACT OF CRIME ON APARTMENT PRICES: EVIDENCE FROM STOCKHOLM, SWEDEN

by
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ABSTRACT. This study uses data of about 9,000 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 coordinates 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 traditional welfare state, 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.

Key words: GIS, hedonic modelling, offences, residential property value, spatial modelling, Stockholm

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 living in neighbourhoods with lower crime rates or, alternatively, buyers expect discounts for purchasing properties in neighbourhoods with higher crime rates.

However, the literature is not conclusive (Thaler 1978; Buck *et al*. 1991; Bowes and Ihlanfeldt 2001; Lynch and Rasmussen 2001; Gibbons 2004; Tita *et al*. 2006; Munroe 2007; Troy and Grove 2008; Hwang and Thill 2009; Marques *et al*. 2009). As some of this literature explicitly recognizes, conditions other than mere crime rates might conceivably contribute, together with crime, to lowering property prices. If so, this must be taken into account, otherwise the impact of crime on real estate prices may be overstated (Cohen 1990). For instance, neighbourhoods with high crime also may experience fewer environmental amenities (close to parks, lakes, playgrounds, good schools, etc.), isolation (poor accessibility), proximity to major highways and transport nodes (with noise and air pollution); industrial land use or commercial/entertainment areas (for example, close to bars, restaurants, pubs). Yet, there are reasons to believe that the impact of crime on residential property prices may also differ among nations since they are contextualized in different forms of capitalism. For this reason, evidence based on a limited set of societies – and the literature leans heavily on studies carried out in North America and the UK – must be treated with caution unless similar outcomes can be observed in settings where conditions differ in critical respects.

The current use of neoliberalism as a blanket term for the changes that have taken place over the past two or three decades – deregulation of markets, reduced levels of state intervention, new forms of urban governance, and so on – is of little help here, as it has tended not only to affix the same label to all and sundry, but also caused us to neglect non-random variation across countries so characterized. As Barnett (2005, p. 8) observes, neoliberalism may '[arrive] differently in different places, combining with other processes to produce distinctive manifestations of what, nevertheless, remain varieties of a single *genus*.' Against this background Castree's (2006) suggestion that we talk about neoliberalization is a step in the right direction, but adds little in the form of systematic ways of addressing specificity.

One way of making amends is to take current "varieties of capitalism" into account (Soskice 1990, 1991; Hall and Soskice 2001; Peck and Theodore 2007). Such an approach is helpful since it allows for systematic comparisons across different types of societies that share many traits, yet are different with respect to the influence of markets and how these markets (and also non-market modes of resource allocation) are governed. Thus, Soskice (1990, 1991) makes a distinction between *liberal market economies* and those characterized as *co-ordinated market economies*. It is under these contextual differences that the impact of crime on housing market has to be considered. A core argument here is that events can be compared among countries since institutional settings generate differences in strategies and investments (Rafiqui 2010), which in turn may affect the way society is organized at various spatial scales.

At the urban level, a city like Stockholm is an appropriate case study to be analysed under typical *co-ordinated market economy* conditions. As is the case in many other cities, fear of crime ranks high among the concerns of those active in the market for housing. Indeed, in Sweden security is the factor that people value the most when they are choosing a place to live (Magnusson and Berger 1996, p. 27; Fransson *et al*. 2002, p. 57). Do such security concerns translate into differences in house prices also in what is otherwise a more egalitarian society than most?

In this analysis, in addition to noting the institutional or other peculiarities of this co-ordinated market economy (tenancy forms, income distribution, etc.), land use and socio-economic dynamics will be taken into account. The latter are 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.

The novelty of this study is thus three-fold. First, it provides a systematic assessment of the effect of crimes on real estate prices in a setting that differs in important respects from that where most previous work has been conducted. Second, as it does so it also explores a set of land use attributes created by spatial techniques (for example, buffer and distance analysis and inclusion of neighbouring structure). Finally, the neighbourhood context is incorporated into the model by attaching to each apartment sold (by coordinates) information that characterizes a finely detailed statistical unit of analysis. 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.

At a practical level, or at the level of policy, a study of this kind might be useful for property owners, insurance companies, urban planners and the police on how much it is worthwhile for them to spend on safety. For home insurance companies there is a high value in knowing that crime affects housing prices and that this effect may vary geographically over a city, and/or between them. Thus, excess charges might be defined differently from what is done today. In other words, the negative effect of lack of security can be incorporated differently in different parts of the city. Moreover, bank loans might use these results to predict levels of mortgage in different parts of the city. Also, for urban planners, police and other actors involved in crime prevention, having detailed geographical knowledge of a city's criminogenic conditions and their effects is therefore important. From a physical planning point of view, if a place is highly targeted by crime, questions can be asked about the nature of that area and the activities that they attract. From a social point of view, some of high crime areas concentrate other social problems that on a long run lead people to move out, and if no intervention is made, the area tends to decay even more. Low housing prices is just an indication of this decay.

The article is organized as follows. In the next section we discuss the theory linking property prices to crime. We then move on to detail the institutional peculiarities that set co-ordinated market economies apart, in particular those that are relevant to how the Swedish housing market is organized and governed. At the end of this section, the hypotheses to be tested are outlined. This is followed by a description of the study area, Stockholm city. The data used in the analysis and modelling work needed to meet the objectives of the article are then presented, together with the discussion of the results. A discussion of the implications of the findings and directions for future work ends the article.

Property prices, crime and city structure

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:

$$y = \beta x + \varepsilon \tag{1}$$

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). Facing a lake may add value to an apartment, while being close to an industrial site or close to a sex offender's residence may discount an apartment's price (see, for example, Larsen *et al*. 2003; Kryvobokov and Wilhemsson 2007; Karlsson 2008; Linden and Rockoff 2008).

Housing markets are typically segmented into a number of different sub-markets and if these are not included in the hedonic estimation process, parameter estimates will be biased. Sub-markets are typically defined as areas in which the implicit prices and/or the quantity of different housing attributes differ from those of another area. Implicit prices varies in space because housing is spatially constrained(difficult to move an apartment from one sub-market to another), which makes the supply of housing inelastic. As demand for different attributes may fluctuate over space, there is no reason why the implicit prices should be equal across sub-markets (Day 2009). The task and problem of dividing a large housing market into sub-markets has been addressed in a number of papers (see, for example, Straszheim 1974; Goodman and Thibodeau 1998; Bourassa *et al*. 1999; Wilhelmsson 2004).

The price of different apartment attributes is a function of many different demand and supply factors. If the average income among the households is higher in one area we would expect that the implicit price of the attribute *no crime* to be higher than in an area where the income is lower. On the other hand, even if all demand factors do not vary in space, the implicit price may fluctuate as the supply of attributes may vary in space. The relative scarcity of *no crime* areas in the inner city would suggest that the implicit price of *no crime* to be high compared to the suburbs where the attribute *no crime* is abundant. That is, our hypothesis is that the implicit price of crime to be higher in the inner centre due to higher income and relative scarcity of residential areas with low crime.

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; Voith 1993; Gibbons and Machin 2005). In a more recent study in Atlanta, Bowes 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 property values positively, results show that parks' 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 the presence of parks. Also, quality of schools is influenced by neighbourhood quality, which in its turn affects housing prices (for example, 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.

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 impact of crime on housing prices in different settings

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 3 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; Tita *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 per cent while Gibbons (2004) in London, found that a one-tenth standard deviation increase in the recorded density of incidents of criminal damage has a capitalized cost of just under 1 per cent 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 (2001), for instance, instead of using crime rates, weighed 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 less expensive 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). Tita *et al*. (2006) have demonstrated that crime impacts differently in different types of neighbourhoods and that violence impacted most significantly. In the UK, the effect of crime on property prices does not seem to be the same. Gibbons' (2004) study showed that residential burglary had no measurable impact on prices, but criminal damage did negatively affect 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.

Previous examples of the effect of crime on housing prices are based on the so-called liberal market economies (as first suggested by Soskice 1990). The remaining question is whether crime affects property prices in the same way in countries that do not share the same type of regulatory environment and the same views on social welfare. Focusing on a co-ordinated market economy, Sweden, we make use of the comparative capitalism paradigm[1] (for example, Hall and Soskice 2001; Peck and Theodore 2007) that provides a framework to illustrate how societies are organized, institutions' differentiated role in relation nation-states, their capacity to deal with challenges and their impact on social life.

Using a case study in Sweden means that mechanisms linking social disorganization to crime may be different from the ones found in the UK or US. They may differ because as Messner and Rosenfeld (1994, 1997) suggest, in more market oriented forms of capitalism social institutions tend to be devalued in comparison to economic institutions (what has been called institutional anomie) and lose their power to positively influence criminogenic conditions. Conversely, in countries with a more pro-social oriented form of capitalism, high levels of social redistribution (egalitarian societies), mutual benefit schemes come together with generous social policies; guarantee for housing. This safety net is potentially effective in attenuating the effects of social problems (such as unemployment, housing shortage, crime) particularly among the most vulnerable groups, by keeping them away from crime and boosting overall sense of safety.

Moreover, income disparities are less pronounced than in countries with a more market-oriented economy. For instance, according to OECD (2010), the Gini coefficient for Sweden halfway into the first decade of the new millennium was 0.23 while in the UK and USA it was 0.34 and 0.38, respectively. Indeed, as assessed over most of the post-war period, or so Weeks (2005, p. 6) contends, the 'countries with trends towards greater inequality are those which pursued a broadly similar policy programme that has come to be called "neo-liberal"', primarily the US, UK, Australia and New Zealand.[2] These countries, Weeks (2005, p. 5) goes on to argue, also saw deteriorating income equality manifesting itself 'during the years when that broadly similar policy agenda was pursued most vigorously, especially the 1980s, but also the 1990s. In each of these countries, the decade average inequality for the 1980s and 1990s was higher than in the pre-liberalization 1960s and 1970s.'

In Sweden, this pattern of relative equality goes down to the city level. Despite an increase of ethnical segregation in metropolitan areas including Stockholm over the past decades (Biterman 1994; Hårsman 2006), the combination of housing, immigration and local land use policies (for example, via rent control, Hårsman 2006) have played an important role in moderating the market's effect of strengthening inequality and spatial segregation. Although many (for example, Carson 2001; Turner and Whitehead 2002) would argue that Sweden has moved away from a socially inclusive housing policy, Sweden is yet to see radical deregulation or a wholesale shift to a for-profit housing sector. For instance, condominiums have only been allowed on the market since 2009 and not surprisingly as yet remain very rare.

Instead, rental housing and co-operative societies dominate those locations where privately owned one-family houses are not the preferred type of housing, such as in densely built-up inner city areas. Rental housing can be private, owned by foundations or by the local municipality (typically through fully-owned limited share companies, colloquially and collectively known as *allmännyttan*, literally for the common good). Unlike many other countries, council housing is not only or primarily occupied by poorer segments of the population (even though poor and vulnerable households are often over-represented among residents; see, for example, Magnusson and Turner 2008). In the central parts of Stockholm the reverse is rather true; rent control where location has traditionally not been factored into rental rates in full makes centrally located rental housing attractive for many segments of the population, access to such housing being the main bottleneck (which in turn might spill over to other parts of the housing market). For those who can afford it this is particularly so if the municipality decides to divest itself of a building, allowing the residents the privilege of turning it into a co-operative housing society. Under the latter type of housing tenure, known as *bostadsrätt*, members own a share in the co-operative that entitles them to an apartment within the commonly owned stock. However, most co-operative housing societies have been organized as such from the outset, at the time of building. While not strictly speaking owner-occupied, residents may occupy the flat for as long as they see fit and they are free to sell. In other respects, however, such as renting it out second hand or making major alterations, actions are subject to the control of the co-operative. Residents also pay a monthly fee to the society for daily up-keep and long-term maintenance, the size of the fee in turn influencing the sales price of apartments in this segment of the market (and therefore needs to be controlled for in any analysis).

Neighbourhoods in Stockholm often have a mix of rental, co-operative housing societies and owner-occupied one-family houses (the former two of which dominate the central parts of Stockholm), 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 cities embedded in more unequal contexts. If social disorganization breads crime, hypothetically, less deprivation and fewer social problems would lead to less criminogenic environments and therefore, housing would be less discounted.

The way crime is treated in countries like Sweden should also make a difference on how crime affects overall society. For instance, social crime prevention is sought as an integral part of long-term social policies, such as education, employment, and not as a matter of increasing formal social control in the streets (for example, the Street Crime Initiative in the UK, on which see Machin and Marie 2005). Moreover, attempts to minimize adversities caused by crime led to creation of agencies aiming to support offenders but particularly victims of crime (for example, Brottsoffermyndigheten, i.e., the Crime Victim Compensation and Support Authority). This exemplifies the closer link between quotidian problems dealt by public authorities, which paradoxically lead to relatively high crime reporting rates but not necessarily declared insecurity (Brå 2009). We take, therefore, the view that the effect of crime on housing prices would be lower in countries characterized by less inequalities (as they are less criminogenic, particularly in relation to violence), than in more liberal forms of capitalism.

For the purpose of this study, we follow the recent strand of research on crime and housing and hypothesize 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 apartment 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 form of capitalism that is different from the USA or the UK) than in cities of countries with a more liberal market economy.

In case hypotheses 1 to 4 are not confirmed, this is likely to be a consequence of the difference that a co-ordinated market economy makes compared to the standard case investigated in the previous literature, the liberal market economy. If the hypotheses are confirmed, on the other hand, it goes to prove that perhaps the institutional context is of lesser consequence than believed on a priori grounds. It may still be a difference of intensity, though, and towards this end hypothesis 5 should ideally be addressed. This cannot be done in full, however, as this study only takes one case into consideration and, therefore, will have to rely on previous studies for the comparative component. Since however the methods used here are different from that employed in the previous literature, and we would argue more appropriate to the task at hand, comparisons should ideally be done using the same approach as here applied to Stockholm. Before testing these hypotheses empirically, we will describe Stockholm as a case study and its recent structural developments.

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 that administratively belong 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, the underground, 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 characterized by office buildings and a number

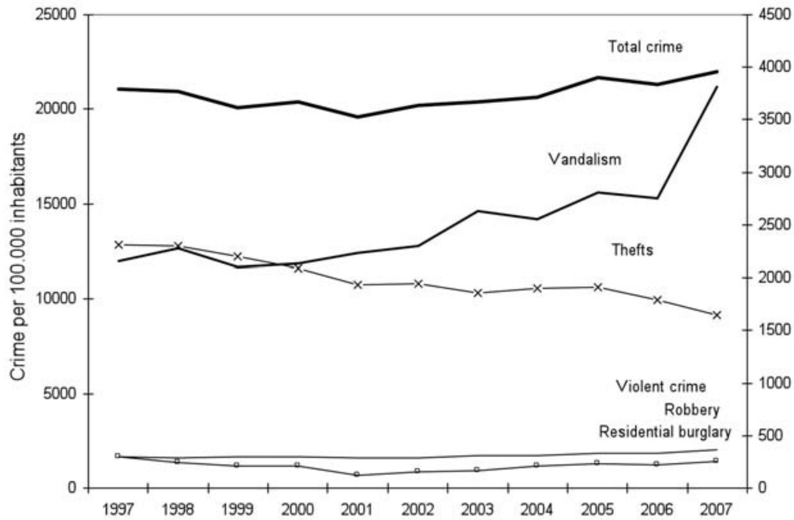

Fig. 1. Crime rates in Stockholm city, 1997–2007.

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, Sergels torg, a central square and one of the main meeting points of the city, is a relatively high criminogenic area (Ceccato *et al*. 2002).

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 tenure can also be found in the inner city areas of Stockholm, privately or co-operatively owned blocks of flats 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.

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 (Roth and Sandahl 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 (Fig. 1). But crime, particularly property crime, is not concentrated in these mass-produced blocks of flats. Highly desirable housing in areas in more central locations 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 of 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 Hornstull and Thoridsplan, while in 2007 some high rates occurred in the northern central parts of the city, such Odenplan-Norrmalm. In 2007, a couple of areas on the outskirts of Stockholm had the highest rates, particularly in the 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 (Magnusson and Berger 1996; Fransson *et al*. 2002; Björklund and Klingborg 2003; Werner 2003). Lack of security can affect housing quality in so many ways (for a discussion, see Björklund and Klingborg 2003). Although these studies are more concerned with 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 on a scale from 0 to 5 whilst in Fransson *et al*. (2002), 85 per cent of the interviewed population regarded safety as a quality that they take into consideration before choosing a place to live. That is why the so-called smart homes appear 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.

The econometric analysis

In this section, we present the econometric analysis. We 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 article is based on cross-sectional data that includes arm's-length transactions of apartments in co-operative housing societies (*bostadsrätter*) in Stockholm, Sweden. The data cover a time span from January 2008 to December 2008 and consist of 9,622 transactions of apartments. The data source is broker statistics supplied by Mäklarstatistik AB, a real-estate broker association that covers around 70–80 per cent 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 metre, date of contract, monthly fee to the co-operative, 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 7 per cent of multiple addresses; in other words, we kept only one transaction for x,y coordinates (the first transaction in 2008). Our final database consists of 8,938 transactions involving the sale of apartments.

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 metres of living space over 2.3 rooms (number of rooms excluding kitchen). Only 2 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 3,000 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 a balcony 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 underground stations, and the latter about crime statistics such as number of burglaries per 10,000 inhabitants.

In order to characterize the differences by submarkets in Stockholm, a set of land use variables were created using GIS from the original layers of land use data over Stockholm city (Appendix 1). 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 northern 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, underground and train stations. Instead of defining a fixed distance, different distance bands were tested. As Fig. 2 illustrates, some of these variables would have a very local effect while others would follow a centre-periphery model.

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*, which is the smallest geographical unit one can get statistical data for in Sweden) in a total of 408 units (Appendix 1). Rates per small unit area 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). In order to link crime rates by area to the x,y coordinates of each apartment sale, the map of Stockholm city with 408 units was layered over the apartments' x,y coordinates. All sales that were within the boundaries of a polygon would get its respective crime rates. This procedure was performed using the standard table join function in GIS.

Pre-analysis of the crime data

A number of different types of crimes are used in this study. 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 as 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) and Mandell and Wilhelmsson (forthcoming).

The result of the principal component analysis is presented in Appendix 2. 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, theft and violence, and assault) explain more than 90 per cent of the variation. We have therefore decided to use only robbery, vandalism, burglary, theft and

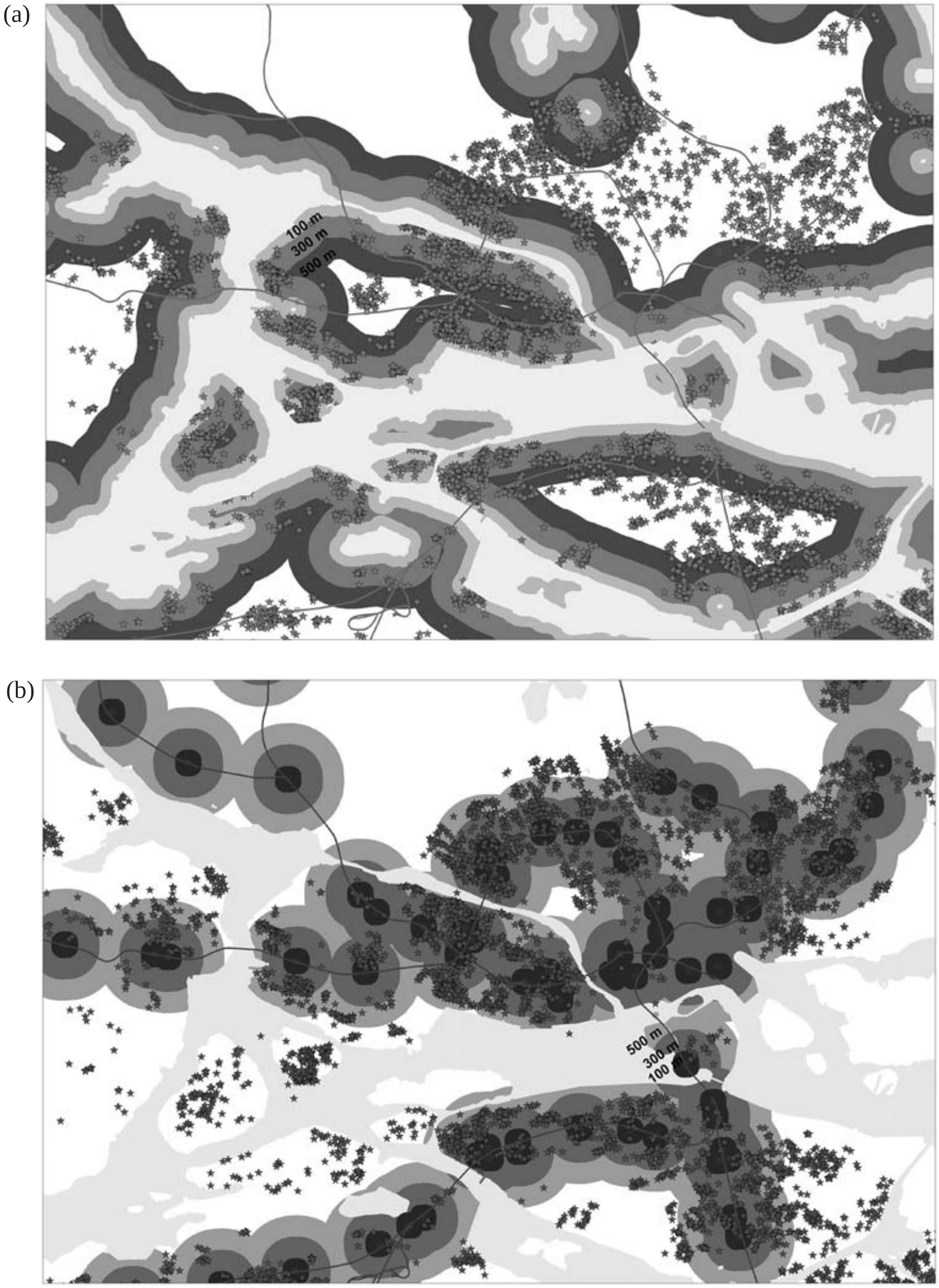

Fig. 2. (a) Sold apartments in relation to water bodies, buffer of 100 metres (dark grey), 300 metres (medium grey) and 300 metres (light grey); (b) Sold apartments in relation to underground stations, buffer of 100 metres (dark grey), 300 metres (medium grey) and 300 metres (light grey).

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, testing our hypotheses 1 and 3.

$$y = \beta_1 x + \beta_2 C + \beta_3 WC + \varepsilon \tag{2}$$

where y is a vector of observations on the sales price; X is a matrix of 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 burglary 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. With respect 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, p. F444) concludes 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. To address endogeneity bias we need to instrument crime by purging its correlation with unobservable influences on apartment prices, using variables that are correlated with crime but not with apartment prices. Gibbons (2004) argues that crime rates in the surrounding area are a good candidate as an instrument. As we have included the crime rates in surrounding areas as a determinant in the hedonic price equation, however, it has not been used as an instrument here. Instead we note that, according to Tita *et al*. (2006), murder is an ideal instrument. The validity of this instrument depends if murder is correlated to crime, but not apartment prices. 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. The model estimated is equal to Equation 3.

$$\begin{aligned} y &= \beta_1 x + \beta_2 \hat{C} + \beta_3 W\hat{C} + \varepsilon \\ \hat{C} &= \delta_1 z + \delta_2 x \end{aligned} \tag{3}$$

where variable z is the used instrument variable (murder) and $\hat{C}$ is therefore equal to the 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 a strong relationship between murder and crime rate, it is considered to be a strong instrument. Bound *et al*. (1995) and others recommend that an F-test is conducted on the instruments in the crime equation (or a t-test if only one instrument variable is used). If murder rates can explain the variation in crime rates controlling for all other included variables in the hedonic price equation, murder rates are not weak instruments. Moreover, to be considered to be a valid instrument, murder must not be correlated to the error term (ε) in Equation 2. It is much harder to test for invalidity. One commonly used test is the Sargan's over-identification test. However, as we only use one instrument variable, the test cannot be applied here. Bound *et al*. (1995) suggest an F-test (or t-test) of the effect of the instrument variable on the price residuals in order to make certain that the instruments are not directly correlated with the apartment price once the other determinants are included. If the instruments are weak and invalid, the

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[1]	.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	
t-test (weak)			–1.54					
t-test (valid)			25.75					
Moran's I	.50		0.50		–		–	

Notes: 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). t-test (weak) tests whether murder in the first stage is correlated with crime rates. t-test (valid) tests whether murder can explain apartments prices controlling for property and apartments determinants as well as crime rate. The test statistics indicate that the instrument variable is strong and valid. [1] This area is the apartment area. Note that the land area of the geographical units was also tested but did not affect the results.

ordinary least square can be even more biased than not controlling for endogeneity. 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. There are two reasons for using spatial lag and error models. One reason is theoretically driven. Crime at one location might affect housing prices in neighbouring areas. Crime goes beyond a specific area (there is evidence of a spill over effect or diffusion for certain types of crime) because offenders and victims/targets are mobile. Spatial lag models could be efficient to indicate pockets of offences that go over polygon boundaries. Thus, lots of crime events in one area predict an increased likelihood of similar events in neighbouring areas. The spatial error model could help to evaluate the extent to which the clustering of housing prices not explained by measured independent variables can be accounted for with reference to the clustering of error terms. In this sense, 'it captures the spatial influence of unmeasured independent variables' (Baller *et al*. 2001, p. 567). Another reason for using spatial lag and error models is data driven, because outputs may be indicative of data problems. As Anselin (2002) suggests, for example, the scale and location of the process under study does not necessarily match the available data. This mismatch will tend to result in model error structures that show a systematic spatial pattern. Moreover another problem is that spatial autocorrelation on residuals goes against the basic assumptions of OLS regression. One way to deal with it is to use spatial lag and spatial error models. The use of these models is necessary to ensure more reliable results, in other words, to obtain unbiased and efficient estimates for the regression parameters in the model.

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 error models are equal to Equations 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.

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.

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 metres from the water is expected to sell for almost 12 per cent ($e^{(0.0335+0.0117+0.0721)}-1$) more than an apartment located, for example, 600 metres from the water, all else being equal. The result of proximity to water is consistent with other studies. To be very close to an underground station (within 100 metres) is regarded as positive. It is clear that the negative externalities, such as, for example, noise and vibrations, do not outweigh the positive. Not expectedly, proximity to commuting train stations has no effect on apartment prices in the range 0–500 metres. 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.

The results indicate that total crime rate has no impact on apartment prices (the coefficient is not statistically significant different from zero) in the

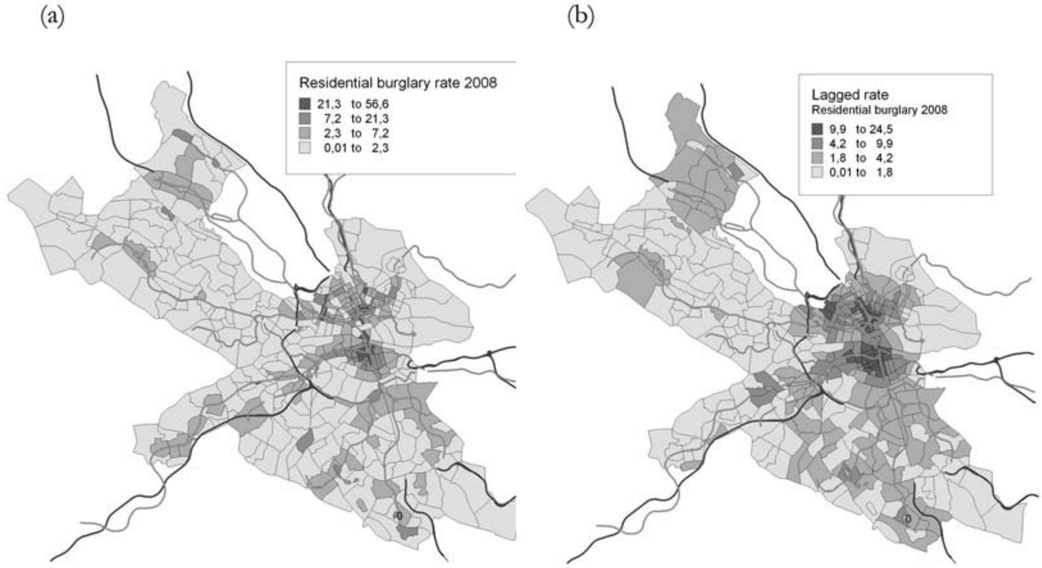

Fig. 3. (a) Residential burglary rates in Stockholm, 2008; (b) Lagged residential burglary rates in Stockholm, 2008.

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 1 per cent, apartment prices would be expected to fall by 0.04 per cent.

We have also analysed 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 equations estimated are Equations 3 and 5. 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) as 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.

Crime rate in surrounding areas plays a different role depending on the type of crime. The reasons behind such a 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

Table 2. Different measures of crime – OLS and spatial error models with instrument variables.

	Robbery coefficient		Vandalism coefficient		Burglary coefficient		Assault coefficient		Theft coefficient	
	OLS	Error	OLS	Error	OLS	Error	OLS	Error	OLS	Error
Robbery	–.0049 (–.45)	–.0037 (–2.43)		–		–		–		–
W_Robbery	–.0470 (–15.7)	–.0028 (–4.64)		–		–		–		–
Vandalism		–	–.0340 (–2.27)	–.0058 (–2.80)		–		–		–
W_Vandalism		–	–.0.184 (–4.83)	.0035 (4.32)		–		–		–
Burglary		–		–	–.1468 (–2.14)	–.2110 (–2.16)				–
W_Burglary		–		–	–.0514 (–13.27)	–.0044 (–5.16)				–
Assault		–		–			.0013 (.0923)	–.0503 (–2.45)		
W_Assault		–		–			–.0358 (–13.05)	–.0213 (–3.80)		
Theft									–.0792 (–6.20)	–.0563 (–3.26)
W_Theft									.0442 (9.74)	.0832 (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	

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

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 be related to spill-over processes (offenders act both where they live and in nearby areas) but also copy-cat dynamics (crime begets crime 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 analyse 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 1 per cent, apartment prices are expected to decrease by 0.21 per cent. In an attempt at 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. Our approach is not to derive the optimal number of sub-market. Instead, our attempt is to investigate whether we can observe an inner city sub-market as well as a north and south sub-market. The model that we have estimated is equal to Equation 6:

$$y = \beta_1 x + \beta_2 \hat{C} + \beta_3 W\hat{C} + \beta_4 \hat{C}I + \beta_5 \hat{C}N + \varepsilon \qquad (6)$$
$$\varepsilon = \rho W\varepsilon + \eta$$

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

Table 3. Parameter heterogeneity (burglary) – OLS and spatial error model.

	Inside inner circle coefficient		North coefficient		Inside inner circle and north coefficient	
	OLS	Error	OLS	Error	OLS	Error
Burglary	–.3730	–.2487	–.2002	–.1836	–.3716	–.2353
	(–5.43)	(–2.59)	(–3.00)	(–1.92)	(–5.38)	(–2.45)
W_Burglary	–.0358	–.0345	–.0372	–.0353	–.0357	–.0345
	(–9.31)	(–4.27)	(–9.61)	(–4.33)	(–9.26)	(–4.26)
Burglary *Inner	.2500	.1093	–	–	.2508	.1159
	(9.92)	(3.79)	–	–	(9.81)	(3.97)
Burglary *North	–	–	.0300	–.0270	–.0040	–.0392
			(1.41)	(–.85)	(–.19)	(–1.45)
Adj R-square	. 7893		.7870		. 7893	
R-square	.7880	.8857	.7857	.8857	.7880	.8857
AIC	1.35	–4246	97.8	–4233	3.32	–4246
Moran's I	0.47		0.47		0.48	

Notes: 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 metres from CBD and North is equal to all areas north of CBD, including peripheral western and eastern areas of the city. The predicted value of the burglary variable in the different parts of the city was estimated in the first stage. The predicted variables are used on the second stage.

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.

The results seem to indicate that the impact of burglary on apartment values is different depending on which part of the city we 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. The result also weakly suggests 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). The lower implicit price in the inner city is not anticipated as both the household income is higher and the scarcity of residential areas with low crime rates is lower. It appears that burglaries in the central city is in some sense expected and are, therefore, capitalized less into price. Hence, it seems that households in different parts of the city have different tolerance levels towards crime, that is, some sort of household sorting according to levels of risk-taking behaviour. Differences in life styles and household composition in different parts of the city might be behind individuals' differences in tolerance level towards crime (see, for example, Ekstam and Sandstedt 2010). However, the observed parameter heterogeneity across space could also be a result of omitted variable bias. If burglaries is positively related to an omitted variable, such as the number of restaurant per capita, and this variable is positively related to apartment prices, the impact of burglaries in the city centre on prices is upward biased. As we are controlling for distance to city centre, sub-markets and spatial interdependence, we are less worried that our results suffer from omitted variable bias.

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 while 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 1 per cent in Stockholm, apartment prices are expected to fall by 0.04 per cent. This decrease in prices is slightly higher if one considers the effect of residential burglary only. If residential burglary increases by 1 per cent, apartment prices are expected to fall by 0.21 per cent.

Although these results are in line with what was expected for Stockholm, a comparison with another case study (of a liberal market economy) using exactly the same methodology would be needed to fully test hypothesis 5. Moreover, more knowledge would be needed to assess the mechanisms linking house prices, crime and inequality in different societal contexts. This could be tested in Stockholm by forecasting the effect of increased relative deprivation on criminogenic conditions and its turn on its impact on housing prices. Here we take the view that the impact of crime on housing prices would be lower in Stockholm as a result of policies interventions that moderate the negative effects of a market economy.

Final considerations

The objective of this article was to analyse 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 expects discounts for purchasing properties in neighbourhoods with higher crime rates. There is an urgent need of empirical evidence in this field under conditions that differ from those in the US or the UK since very little evidence is found in the international literature.

Our study contributes to the existing literature in numerous ways. First, the article provides evidence of the impact of crime on housing prices in a capital city of a country embedded in a co-ordinated market economy (Hall and Soskice 2001), so far lacking in the international literature, highly dominated by cases from British and North American cities. Second, the study explores a set of land use attributes not commonly used in hedonic pricing modelling. The neighbourhood context is incorporated into the model by attaching, to each sold apartment, information that characterizes 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 tested five main hypotheses. First, crime impacts negatively on apartment prices after controlling for attributes of the property and neighbourhood characteristics and the present endogeneity. 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 used a cross-sectional data set from the year 2008. We examined apartment sales and recorded the transaction price of nearly 9,000 observations in the city of Stockholm, Sweden. We consider 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 also included location attributes such as distance to CBD, distance to water, underground station, commuting train station, highway, and main street that were similarly controlled for. 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 used 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 estimated. The first is a spatial lag model and the second a spatial error model. Findings indicate that if total crime increases by 1 per cent, apartment prices are expected to fall by 0.04 per cent. To fully test hypothesis 5, future studies should devote further effort 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 1 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. While the targets of vandalism and criminal damage belong to a more public sphere and outdoors (bus stops, fences, gates), the 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 weakly show also that the magnitude of the effect of residential burglary on apartment prices is higher in the northern part of Stockholm than in the south. Not anticipated, apartments in inner-city areas are also less discounted than the ones located in the peripheral 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 less expensive 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 (for example, location, good quality of life) that are more valued by those buyers. Our 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. On the other hand, controlling for all the amenities an area offer, we expect crime to be a negative externality valued more than in the suburbs due to higher incomes and scarcity of residential areas with low crime rates. In that case, our findings may be a result of omitted variable bias, that is, the variable crime rate is a proxy for nearness to, for example, cinemas and restaurants and will therefore be biased upward. Another reason causing the difference in parameter heterogeneity in space could be that individuals risk preference towards crime is different across space and that individuals living in the city centre fear crime less.

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 the spill-over effects that may exist, and consequently some of this variance will erroneously be captured by other variables of the model that have similar geography.

What does this study tell us about the impact of crime on housing prices in Sweden? Findings are indicative that offences when broken down by types show a significant negative effect on property values, with residential burglary having the highest impact. The study also shows that prices are affected by crime conditions at one location but also its surrounding areas. In an international perspective, these findings are also important because they show that crime also affects property prices in a country that experiences conditions that are different from the ones found in British and North American cities. Although these results are in line with what was hypothesized, future studies should compare the Stockholm study with another case study (of a liberal market economy) using exactly the same methodology.

In summary, the article makes contributions to the way property values are influenced by environmental and security conditions. It 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 – which is different from the traditional hedonic price modelling. 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. Hedonic price modelling as implemented in this study has been shown to be a useful and efficient analytical strategy when the goal is to access quantitatively the effect of a specific attribute controlling for the characteristics of the property and neighbourhood features. Alternative approaches to hedonic price modelling could be qualitative surveys in which the willingness to pay is measured for instance by a set of preferences and assessments residents declare about different parts of the city in relation to a selected number of attributes, such as safety.

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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Notes

1. Originally the comparative capitalism paradigm dealt with the geography of firms and the role of nation-state as a facilitator for strategic interaction between them (e.g., Soskice 1990, 1991; Peck and Theodore 2007). Most of this literature relates to comparisons performed at the levels of nation-state, but there are exceptions (e.g., Rafiqui 2010). Although this framework has evolved and been further refined by sociologists and political scientists over the past two decades, it is surprisingly little known or used in human geography.
2. It should also be noted that he finds that Canada is more similar to the European welfare states than the 'Anglo-Saxon neoliberal four'. Data for Australia, however, while indicating a trend of towards greater income inequality over the past few decades, is not a particularly striking example of sharp deterioration and the country registered a lower Gini than most over the period assessed.

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APPENDIX 1: THE DATABASE OF STUDY

Data Type	Source	Variable	Description	Unit	Average	Standard deviation
Apartment sales	Broker statistics	Price	Transaction price	SEK	2336776	1413819
	(Mäklarstatistik AB)	Area	Living area	Square metres	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		Distance	Distance to CBD	Metres	5137.03	3554.02
sub-market characteristics		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	Water100	100 metre buffer from water	Binary	.0829	.28
	(Stadsbyggnadskontoret)	Water300	300 metre buffer from water	Binary	.3072	.46
		Water500	500 metre buffer from water	Binary	.4821	.50
		Sub100	100 metre buffer from underground station	Binary	.0983	.30
		Sub300	300 metre buffer from underground station	Binary	.4623	.50
		Sub500	500 metre buffer from underground station	Binary	.7070	.46
		Train100	100 metre buffer from commuter train station	Binary	.0085	.09
		Train300	300 metre buffer from commuter train station	Binary	.0391	.19
		Train500	500 metre buffer from commuter train station	Binary	.0858	.28
		Road100	100 metre buffer from highway	Binary	.0072	.08
		Road300	300 metre buffer from highway	Binary	.0655	.25
		Road500	500 metre buffer from highway	Binary	.1535	.36
		Main100	100 metre buffer from main street	Binary	.2641	.44
		Main300	300 metre buffer from main street	Binary	.6439	.48
		Main500	500 metre buffer from main street	Binary	.8012	.40
Crime	Stockholm Police	Crime	Crime rate per 10,000 inhabitants	Ratio	7963.494	254881.1
		Robbery	Robbery per 10,000 inhabitants	Ratio	93.776	3141.251
		Vandalism	Vandalism per square metre 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 metre of area	Ratio	8.715	11.222
		Theft of cars	Theft of cars per square metre of area	Ratio	.406	.304
		Theft from cars	Theft from cars per square metre of area	Ratio	1.053	.786
		Assault	Assaults per 10,000 inhabitants	Ratio	188.569	5988.247

APPENDIX 2: PRINCIPAL COMPONENT ANALYSIS (PCA)

(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