Article

Urban Studies

Urban Studies
2019, Vol. 56(13) 2820–2836

DOI: 10.1177/0042098018800576
journals.sagepub.com/home/usj
SAGE

Unbundling negative and positive externalities of nature in cities: The influence of wild animals on housing prices

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Abstract
Proximity to nature is highly valued by urbanites, who demonstrate higher willingness to pay for housing at locations near open and green spaces. However, nature in cities can generate negative externalities as well. In this article, we illustrate the complex relationship between cities and nature and suggest that their balance is time and location specific. The article presents estimates of positive and negative externalities based on data about encounters of humans with wild animals in the city of Haifa, Israel, and residential property values nearby. The data were analysed to uncover spatial regularities and basic statistical relationships. The results reveal the presence of dominant positive externalities when the human–wild animals interaction is low, driven by proximity to open and green areas. However, in certain areas and under certain circumstances, the nuisance generated by higher probabilities of encounters with wild animals near dwelling areas is correlated with lower property prices, overcoming the positive externalities of location near natural areas.

Keywords
nature negative externalities, real estate value, wild animals in urban areas

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摘要

城市居民非常重视与自然的接近，他们对开放和绿色空间附近的地方表现出更高的住房支付意愿。然而，城市的自然也会产生负面的外部性。在本文中，我们阐述了城市与自然之间的复杂关系，并认为它们的平衡是取决于具体的时间和地点。本文根据以色列海法市人类与野生动物相遇的数据以及附近的住宅物业价值，提供了正面和负面外部性的估计。我们分析数据以揭示空间规则性和基本统计关系。结果表明，当人类与野生动物之间的相互作用较低时，由于接近开放和绿色区域，存在显著的正外部性。然而，在某些地区和某些情况下，居住区附近与野生动物相遇的可能性较高而产生的滋扰与较低的房价相关，这抵消了自然区域附近位置的正外部性。

关键词

自然负外部性、房地产价值、城市地区的野生动物

Received March 2018; accepted August 2018

Introduction

Urban spatial evolution is perceived commonly as the development of built-up areas that expand the outer boundaries of cities into the surrounding countryside (McKinney, 2006). According to this view, undisturbed open spaces and agricultural areas in and around cities are swallowed continually by successive building waves caused by the urban population growth (Radeloff et al., 2010; Seto et al., 2011). At a crude geographic resolution, excepting for large-scale planned parks and recreational areas, cities are conceived as continuous built areas in which there is little room for nature and open spaces (Hamidi and Ewing, 2014). However, when examined at a finer scale, it becomes evident that the urban landscape is *porous*, and is far from being a monolithic continuum of bricks and cement (Adolphe, 2001; Ng et al., 2011). *Porosity* means that the urban fabric is in fact a complex assemblage of built areas intertwined with planned open spaces, such as public parks, lawns, gardens and sports and recreation facilities, but also with non-built and unplanned patches of land, such as vacant lots, wastelands, creeks, flood plains, wetlands, roadside buffers and backyards. Urban porosity is a complex phenomenon that changes with time and varies with urban morphology and across the cityscape. Cities can be seen as a complex network of connected patches of different quality and quantity (Kong et al., 2010). Studies of continuous built spaces in urban areas at fine spatial resolution show that the connectivity among open spaces persists even as they shrink in absolute terms (Benguigui et al., 2000, 2001a, 2001b, 2004; Czamanski et al., 2014; Toger et al., 2015).

Public urban green spaces, such as parks, are considered beneficial for the quality of life of city dwellers, offering a wide range of environmental, psychological and social services (Chiesura 2004). In the ecosystem services literature, these benefits are called cultural services, which include non-material benefits obtained by people when they are in contact with ecosystems. This category includes recreation, as well as mental and physical health, when related to use of open and green spaces (TEEB, 2011). From an urban planning perspective, these services should be measured and taken into account in urban policy strategies (Chiesura and De Groot, 2003; Chiesura, 2004).

From an economic perspective, proximity to open spaces in general, and to spaces that are perceived to be natural areas, is highly valued by urbanites. The empirical evidence of this preference for proximity to natural areas is provided by the hedonic pricing modelling. Pioneered by Rosen (1974), hedonic pricing modelling is an approach which assumes that consumers' preferences can be revealed by their purchasing habits and attitudes. Rosen (1974) claimed that the price of a composite product, as a residential property, can be broken up into the sum of its constituents. Therefore, hedonic pricing modelling can provide an estimate of the price that consumers are willing to pay for an upgrade in any of the residential property's characteristics (for example, location, size, number of rooms, age, etc.). Our interest is focused on the value attached to property location nearby green and open areas, and we draw on the large body of research on this topic. There is evidence that proximity to these amenities has a large and positive impact on real estate values (Conway et al., 2010; Lutzenhiser and Netusil, 2001). Urban dwellers are willing to pay a significant positive premium for housing at locations near open and green spaces (Gibbons et al., 2014; Irwin and Bockstael, 2001; Luttik, 2000). Moreover, as the distance from open space amenities increases, residential prices tend to decline (Asaber and Huffman, 2009; Jim and Chen, 2006). Furthermore, property values are influenced by the quality of the visible landscape as well (Bourassa et al., 2004; Schläpfer et al., 2015). Thus, urban porosity suggests that *ceteris paribus* higher residential property prices should be expected near urban parks and coastlines and at locations within cities with proximity to other open spaces (Morancho, 2003).

While there is wide consensus about the positive effects of natural areas and open spaces on city dwellers, expressed by the willingness to pay for living near them (Daams et al., 2016; Earnhart, 2006), there is a lack of evidence concerning associated negative effects due to the fact that they serve as habitats for various animal species (Leong et al., 2016; McKinney, 2008). Some animal species (in particular birds) are generally considered as welcome neighbours, and are an integral part of the perceived 'natural environment' (Clergeau et al., 2001). However, extensive evidence points to the presence of wild animals that are perceived as less friendly (Adams et al., 2006; Matthies et al., 2013; VanDruff and Rowse, 1986). Some big wild mammals are considered to be a nuisance and even dangerous. For example, black bears penetrate into urban areas in North America, brown bears into some East European cities (Bateman and Fleming, 2012) and boars into Berlin (Jansen et al., 2007) and Barcelona (Navarro-Gonzalez et al., 2013). As wildlife presence within cities increases, so does the frequency of human–wildlife encounters and potential conflicts. Damage to properties and pets, perceived dangerous encounters with the residents and sanitation concerns are among the most common issues (Jansen et al., 2007; Lindsey and Adams, 2006).

In Mediterranean cities, wild boars are regularly observed roaming within urban areas. Boars are frequently seen during night hours foraging for geophytes in backyards, turning compost and rubbish bins upside down. They feature in traffic accidents and are linked to the spreading of certain diseases (Schierack et al., 2009). Furthermore, because of their ability to survive in urban areas, boars outcompete some native and endangered species (Cahill et al., 2012; Licoppe et al., 2013). The population size and frequency of interactions of larger wild mammals with residents may be overestimated by the media (Adams et al., 2006). However, the resulting perceptions of the nuisance levels may affect the demand for housing and therefore real estate values. The aim of this article is to present evidence about the complex interactions between positive and negative influences of natural areas and the presence of wildlife on urban dwellers. The article presents an analysis of the influence of wild boar nuisance within built-up areas on observed property prices. We demonstrate that the balance between positive and negative influences of nature on urbanites depends on fine-grain local specifications. Through a specific case study, using the local density of human–wild animal encounters as a proxy for closeness to green and open areas, we develop a simple method able to unbundle the positive and negative externalities of nature in urban areas.

The remainder of this article is as follows. The next section describes the materials used in this research. The methodology is then presented. In the following section we present the results of our analysis. Discussion of the results, and their significance, are presented in the subsequent section. Conclusions and some suggestions for future research are then discussed.

Research materials

The study uses data from the city of Haifa, located on the northern Mediterranean coast of Israel. Home to about 280,000 inhabitants (ICBS, 2014), it is the third largest city in Israel, after Tel Aviv and Jerusalem. Its urban area covers around 66 km^2 (Haifa Municipality, 2008) along the slopes of Mount Carmel, extending from sea level to an elevation of 450 metres. Its hilly topography is characterised by downward slopes towards the Mediterranean Sea, intertwined with relatively deep and green valleys that penetrate into the urban built fabric as green fingers within the built environment. These valleys are an integral part of the city's open space network (Toger et al., 2015). Figure 1 includes a general view of the city of Haifa. The mountain ridge of Carmel runs from the Mediterranean in the north-west, uphill towards the south-east, which is the highest point in the area. The northern slope of the mountain is the most heavily urbanised area, and the valleys intertwined among residential areas all over the mountain are clearly discernible.

The valleys in Haifa serve as habitat for wild boars as well as other animal species. Residents' complaints related to wild boars have become common in Haifa during recent years. The Haifa municipality systematically records citizens' complaints concerning the presence of wild boars. We compiled the reported data for the years 2011–2013. The data include the addresses and dates of 5120 observations. Using ArcGIS software (ESRI, 2012), the locations of these observations were geocoded.

In addition, we retrieved a dataset of 22,463 real estate transactions that took place in the city of Haifa during the period 2005–2014. The data include price per square metre and several details about the properties transacted, such as number of rooms, surface area and age. Figure 2 (left map) shows the spatial distribution of the geocoded wild boar complaints superimposed onto the locations of the recorded real estate transactions.

Methodology

To relate the dwelling prices to different potentially relevant characteristics, we assume that transaction price $P = f_1(X_1, \ldots, X_k, Z_1, Z_2)$ is related by certain function f_1 to the relevant variables. Of these control variables, X_1 to X_k represent property characteristics, location, etc., Z_1 represents the proximity to open spaces and Z_2 represents the presence of wild boars.

Based on the wide consensus about the positive effects of natural areas and open spaces on city dwellers (Daams et al., 2016; Earnhart, 2006), we assume that f_1 is the monotonically increasing function of Z_1. On

Figure 1. Aerial photograph and map of the study area of Haifa.

the other hand, since boars are considered a nuisance, f_1 is assumed to monotonically decrease with Z_2.

If both the proximity to open spaces and the presence of wild boars could be measured separately in such a way that combinations of their values (e.g. closeness to open areas with high/low boar density, distance from open areas with high/low boar density) appeared in the data, their direct influence on the prices might then be revealed.

However, in practice, measuring Z_1 and Z_2 can hardly yield all the different combinations of values, since the proximity to open spaces is usually accompanied by the presence of wild boars (formally, this relation can be expressed by $Z_1 = f_2(Z_2)$, where f_2 is the monotonically increasing function).

For this reason, the prices can be expressed as:

$$P = f_1(X_1, \ldots, X_k, Z_1(Z_2), Z_2) \\ = f(X_1, \ldots, X_k, Z_2)$$

that is, as the function of X_1 to X_k and Z_2 only (but not of Z_1). This means that in practice there is no need to use the proximity to open spaces, since the presence of wild boars incorporates that information as well. Following this logic, one should be aware that Z_2 may not monotonically affect P due to the implicit relation between Z_1 and Z_2. However, function f is not known. In order to keep the model clear and the estimation results interpretable, we explicitly assume that f is linear. The most intuitive candidate

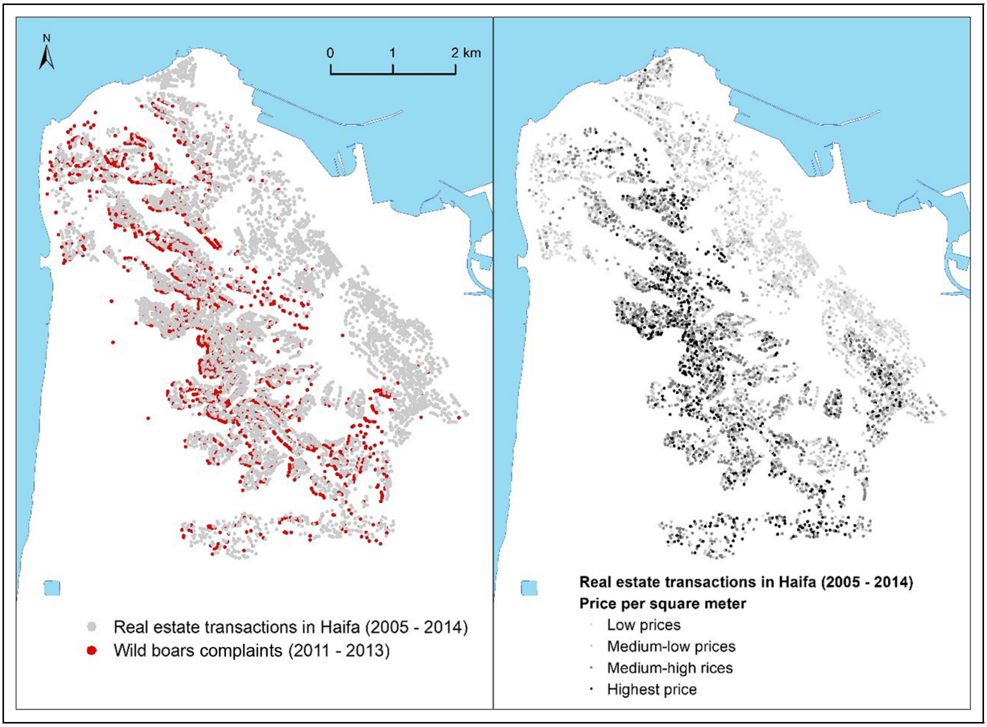

Figure 2. Left map – Recorded real estate transactions (grey dots) and wild boar complaints recorded by the municipality (red dots). Right map – Real estate transactions coloured by price per square metre by quartiles (the higher the price, the darker).

for this purpose is the linear regression model. Thus the critical factors in our model are transaction prices of housing (expressed alternatively by property values and price per square metre), property characteristics (area, number of rooms and age), transaction year, locational data (the neighbourhood in which the property is located) and the intensity of wild boar activity in the immediate surroundings.

In order to visualise the spatial morphology of residential prices in Haifa, we classified the transactions according to quartiles (the 25% of the transactions with the highest prices, the following 25%, etc., until the last 25% with the lowest prices). Figure 2 (right) presents the results. The highest dwelling prices quartile is concentrated in the lower-right quadrant of the map, coincident with the highest topographic altitude of the urban fabric and Mount Carmel. This area is also near one of the largest national parks in Israel, the Carmel Park, where it shares a boundary with the city. Along the Mount Carmel ridge, in a north-west direction, prices remain high (second and third quartiles), decreasing as the city approaches the Mediterranean Sea and downwards along the southern and northern slopes. The lowest quartile mainly includes properties located along the shore, both in the west and in the north, where large infrastructures (roads, railways and harbours) are located.

The left and right sections of Figure 2 suggest that the presence of wild boars is relatively low in neighbourhoods with low property prices. Only in neighbourhoods with property values in the upper three price quartiles is there high wild boar activity generating a significant volume of complaints. At the same time, it is evident that the presence of wild boars is related to proximity to open spaces and to distance from the deep valleys. Thus, the locations that are attractive to humans are attractive to wild boars as well. Humans prefer the aesthetic and recreational values of these locations, and boars seek available food in areas that are easily accessible to them. It is noteworthy that places with low property values in Haifa are characterised by a lack of open and green spaces and by limited landscape quality and closeness to industrial and transport infrastructure. These are the factors that also make them unattractive for wild boars, and therefore little or no activity is recorded there.

However, a visual inspection of the right and left sides of Figure 2 suggests that the correlation between locations that are highly attractive to humans and to boars is not perfect. In fact, this relationship is far from simple. We presume that a low intensity of boars does not constitute a problem for residents and does not affect the demand for housing. On the contrary, the presence of wild boars may be a sign of the nearness of open spaces and natural areas. Therefore, we hypothesise that, until a certain threshold, a higher presence of wild boars could be correlated with higher property prices. A negative impact on demand for and prices of housing requires that the presence of boars exceeds that unknown threshold value. Upon crossing this threshold, the negative externalities of nature overcome its positive ones.

Complaints recorded by the municipality are the only evidence available for the presence of wild boars in the reported location. This means that the specific recorded point is the location of the person who saw the boars and reported it. Since the exact location of each animal over time is not available, we assume that the reported points are merely indicators of a wider area where wild boars search for food and water. We used a kernel density (KD) smoothing procedure in order to create a continuous surface of assumed 'wild boar density function', and then normalised it to a range between 0 and 1. The KD method is a non-parametric method of extrapolating data over an area of interest without relying on fixed boundaries for aggregation (Carlos et al., 2010). The most important parameter of the KD surface is the kernel bandwidth, since it determines the degree of smoothness of the KD surface. Large bandwidths may result in over-smoothed surfaces, while smaller ones may produce large differences between close locations (Gatrell et al., 1996). In order to test the robustness of the suggested procedure, we used different bandwidths (100, 300, 500 and 700 metres) to calculate KD surfaces of wild boar density.

Once the normalised wild boar density surfaces were calculated, they were available for multivariate analysis. The next step consisted of linking the wild boar normalised density values to the real estate transaction dataset using the 'Extract Values to Points' tool in ArcGIS^{TM}10.x (ESRI, 2012).

Next, we proceed to prepare the variables for the multivariate regressions, in which the dependent value is the variation in the transaction prices of housing. In order to test the model's robustness with respect to the definition of the dependent variable, we use alternatively the property values and the price per square metre. In addition, in order to control for possible time lags in the effects of the presence of wild boars on transaction prices, we test the models using the full transaction dataset, and a restricted one. The restricted dataset includes transactions from the period 2011–2013, coincident with the period in which the complaints about

Table 1. Descriptive statistics of the non-dummy variables (N = 22,463).

Dataset	Average	Standard Deviation	Min	Max
Property values (NIS)	793,888	604,698	23,640	11,700,000
Price per square metre (NIS)	9528	4502	504	86,665
Area (square metres)	78.99	32.93	30	300
Number of rooms	3.35	1.08	2	10
Residence age	36	18	0	100
Transaction year	2010	2.5	2005	2014

wild boars were recorded. The use of the full dataset (transactions during the period 2005–2014) is justified by the assumption that wild boars were seen in the city before the municipality started to record complaints, and their impact on transaction prices becomes influential gradually over time.

The most important explanatory variable is the wild boar density value. But these values are unevenly distributed among the observed real estate transactions. The vast majority of the transactions are located in areas where the wild boar density is very low (less than 0.2), and only a few transactions are in areas with high boar density (more than 0.6). In order to control for this skewed distribution, we separate the data into quantiles of 20% (0 to 0.2, 0.2 to 0.4 and so on until 0.8 to 1). One of the quantiles (0.6–0.8) is set as the reference group, and for the other four we defined dummy variables. This choice was made based on a preliminary descriptive statistical analysis. A full description of the real estate transactions distribution into the quantiles defined here for each KD bandwidth is included in the Appendix (online).

Additional explanatory variables used in the regression are the real estate transaction characteristics included in the database as the property area, its number of rooms and its age. In addition, although yearly inflation is included in the transaction prices, the transaction year, as a macro-economic parameter, is relevant. Finally, an important control variable relevant for real estate transactions is the neighbourhood of the transaction. All the recorded transactions are in seven residential neighbourhoods. One of the neighbourhoods was set as the reference group and for the other six we defined dummy variables.

Table 1 includes the descriptive statistics of the variables used for this study that are not dummies (full details about the dummy variables are included in the Appendix). The variables that we attempt to explain by means of our model are, alternatively, the variation in the transaction prices of housing per square metre and the variation in the property values. We assume that the density of wild boars will display a negative impact on the dependent variable and that controls such as property characteristics (size, number of rooms and residence age) and the quality of the area (expressed by the neighbourhood) will be sufficient to account for the impact of various other characteristics of housing on its price.

The reference values are required in order to analyse the influence of the dummy variables on the transaction value.[1] The seventh neighbourhood is used as the reference group for the qualitative aspects of the area (Table A2 in the Appendix summarises the main neighbourhood's characteristics). We define the fourth quantile of the wild boar density (density higher than 0.6 but lower than 0.8) as the density reference group. We

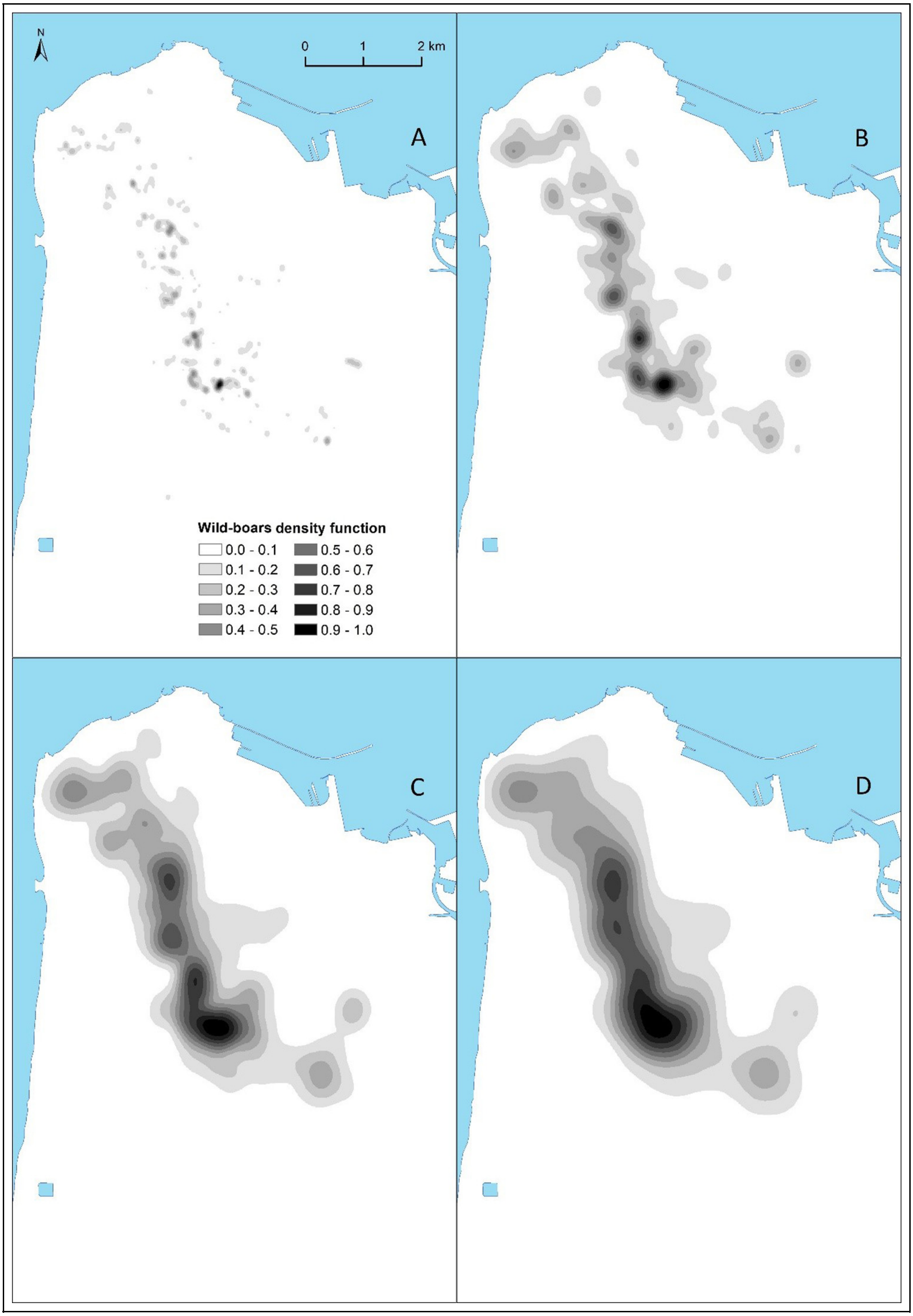

Figure 3. Map of the study area showing normalised wild boar density results for different KD bandwidths (A – Bandwidth = 100 m, B – Bandwidth = 300 m, C – Bandwidth = 500 m, D – Bandwidth = 700 m).

conjecture that the influence of wild boar density on housing prices is non-monotonic. We hypothesise that low density values (less than 0.6) as well as very high values (more than 0.8) correspond to lower prices per square metre, as compared with density values between 0.6 and 0.8 (Toger, 2016).

Results

We estimated four models, one for each wild boar density differentiated by their KD bandwidth. The best fitting and most conclusive model was achieved at a bandwidth of 500 metres. The results of the other models are less definitive and are included in a separate table in the Appendix. Figure 4 shows the average property prices per square metre in areas with different wild boar density.

It can be seen that, indeed, the low density values (less than 0.6) as well as very high values (more than 0.8) correspond to lower average prices per square metre, as compared to density values between 0.6 and 0.8. However, this figure alone is by no means conclusive, since the data used here do not control for any other features besides wild boar density, and the analysis is not accompanied by hypothesis testing. To address the last two issues as well, a multivariate regression model is fitted. Table 2 presents the regression results of four models, using the 500-metre bandwidth model.

In Model 1, a full transaction dataset (period 2005–2014) is used and the dependent variable is the price per square metre. Model 2 is similar, but the restricted transaction dataset (period 2011–2013) was used. In Models 3 and 4, the dependent variable is the property value, but they differ in the transaction dataset used (full and restricted, respectively).

All models have a good predictive power (from Adjusted $R^2 = 0.5289$ in Model 2 to Adjusted $R^2 = 0.7752$ in Model 4), and all the explanatory variables are significant ($p < 0.05$). In addition to the naïve test using individual p-values, we used the stringent Bonferroni correction. All the values remain significant after applying it (more details about this correction in the Appendix). The sign of the property characteristics makes sense, as the number of rooms (in Models 1 and 2) and the area (in Models 3 and 4) should have a positive effect on property prices, but the residence's age is expected to

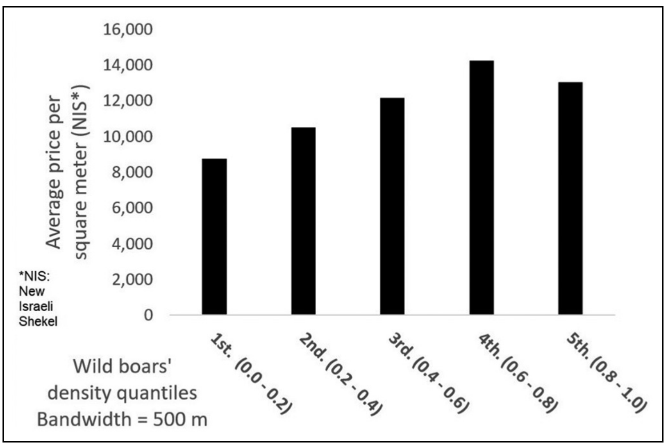

Figure 4. Average property prices and wild boar density quantiles.

Table 2. Factors affecting property prices using boar density calculated with bandwidth = 500 metres.

Predictors	Model 1 B (t)(a)	Model 2 B (t)(a)	Model 3 B (t)(a)	Model 4 B (t)(a)
Constant	−1,673,696 (−103.23)***	−1,667,901 (−18.84)***	388,016 (13.20)***	733,817 (16.68)***
Area			11,324 (123.49)***	12,692 (90.18)***
Number of rooms	236 (9.72)***	221 (5.18)***		
Residence age	−34 (−24.58)***	−33 (−14.54)***	−2433 (−15.04)***	−3513 (−15.21)***
Transaction year	840 (104.06)***	838 (19.04)***		
Neighbourhood 1	−5800 (−39.23)***	−7380 (−30.96)***	−451,135 (−26.80)***	−623,572 (−27.01)***
Neighbourhood 2	−3919 (−52.75)***	−4341 (−33.13)***	−300,246 (−34.64)***	−393,436 (−30.00)***
Neighbourhood 3	489 (7.33)***	584 (4.77)***	−15,300 (−1.99)**	−5262 (−0.44)
Neighbourhood 4	−5051 (−55.91)***	−5889 (−37.71)***	−398,369 (−40.09)***	−506,758 (−34.52)***
Neighbourhood 5	−3907 (−51.15)***	−4895 (−35.78)***	−326,757 (−37.76)***	−445,796 (−33.42)***
Neighbourhood 6	−992 (−11.86)***	−1267 (−8.26)***	−159,986 (−16.42)***	−220,599 (−14.37)***
Wild boar density, 1st quantile	−2723 (−21.53)***	−3955 (−17.79)***	−219,448 (−8.13)***	−398,292 (−9.87)***
Wild boar density, 2nd quantile	−2722 (−21.52)***	−3885 (−17.37)***	−197,963 (−7.22)***	−377,765 (−9.19)***
Wild boar density, 3rd quantile	−1322 (−9.38)***	−2085 (−8.15)***	−82,367 (−2.64)***	−172,086 (−3.67)***
Wild boar density, 5th quantile	−1050 (−4.13)***	−1207 (−2.49)***	−148,889 (−2.49)**	−265,787 (−2.63)***
No of obs.	22,463	8316	22,463	8316
R2	0.5523	0.5296	0.6654	0.7755
Adjusted R^2	0.5520	0.5289	0.6653	0.7752

Notes: (a) B and t statistic in parentheses. (*) Indicates a two-tailed 0.1 significance level. (**) Indicates a two-tailed 0.05 significance level. (***) Indicates a two-tailed 0.01 significance level.

have an opposite sign. The area and number of rooms are highly correlated (Pearson = 0.8265) and therefore one of them is omitted in each model. The values and the signs of each neighbourhood variable are consistent with their relative socio-economic level as compared with the reference neighbourhood (see Table A2 in the Appendix). In all the tested models, the sign of the 1st quantile of the wild boar density, as well as the sign of the 2nd, 3rd and 5th, are all negative. This is consistent with our hypothesis of the non-monotonic influence of wild boar density on housing prices. Although the absolute values of the 1st and the 2nd quantile are similar, the value of the 3rd quantile is larger. These findings together suggest that the price per square metre as a function of wild boar density has an inverse U shape.

Probably the main drawback of the models is their apparent heteroscedasticity, which makes the hypotheses testing questionable.

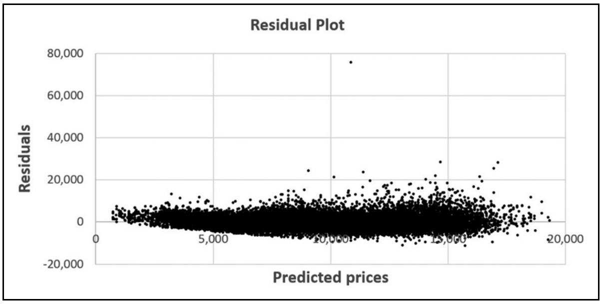

Figure 5. Residual plot of Model 1.

Notwithstanding, assuming that the models do not suffer from any major misspecification, the estimates of the coefficients may be seen as nearly unbiased, and due to the relatively large sample size should be considered as quite reliable. For example, Figure 5 illustrates the residual plot based on Model 1. The point disposition on the chart is far from a 'random cloud' as expected under the homoscedasticity assumption, but rather indicates one of the most unfortunate types of heteroscedasticity. For small predicted prices, the residual variance is small, then increases, and by the end decreases for large predicted prices. To address the heteroscedasticity problem, we made reasonable attempts, such as Box Cox transformations of the dependent variable and/or White adjustment. All these more or less successful attempts led us to different variations of the full model, although in none of them were we able to fully get rid of heteroscedasticity. This is not surprising, since non-monotonic heteroscedasticity as in our case can hardly be fixed by either stretching or shrinking transformation of data. Notably, any such model variation remained consistent with the increasing domain of the inverse U shape of the price per square metre as a function of wild boar density. The 500-metre bandwidth was the only one that resulted in a statistically significant result with $p < 0.05$ and a negative sign in all the tested models.

As described in the previous section, wild boar density calculations include the somewhat arbitrary definition of relevant distance between the reported boar location and the area in which the reported wild boar may cause disturbances. Thus, this distance, operationalised as the DK bandwidth, influences the results. A large bandwidth causes the wild boars' influence to fade out, while a short one exaggerates the immediate impact of each observation, as shown in Figure 3. Our results mean that, given the available datasets, only the 500-metre bandwidth model is able to identify correctly the threshold at which the negative externalities of nature overcome its positive externalities.

Discussion

All the above results assume that, up to some cut-off point, proximity to wild boars has indeed a possible negative, rather than positive, influence on house prices. However, due to available data restrictions, wild boar density measures were calculated based exclusively on complaints recorded by the municipality. The locational accuracy of this type of data is not necessarily very high, because the locations are recorded based on complainers' descriptions by phone. Therefore, more accurate measurements of boars' appearances as well as more data for areas with relatively high boar density are needed to obtain more conclusive results.

For example, data gathered by cameras located in places of interest would contribute to improving the accuracy of the analysis. In this study, we did our best to draw conclusions using the limited data available, using well established geographical and statistical techniques.

The well and widely documented higher willingness to pay by urbanites for properties located near open spaces within cities is considered an expression of the positive externalities of nature. However, as is well illustrated here, in some cases, physical proximity to natural areas may be a source of negative externalities as well. These may result from nuisances caused by wild animals. Using data about property prices and wild boar observations, we conclude that there is good reason to suggest that this is the case in Haifa, Israel. However, disentangling mixed positive and negative effects of proximity to nature in urban areas is a complex task due to several types of challenges. At first sight, it seems that the same factors that attract humans to certain areas make them attractive for wild boars too: nearby green and open spaces, abundant vegetation, closeness to valleys, etc. In addition, residential areas surrounded by wild boar habitats become even more attractive to the boars because of the abundance of available food and the safety of nearby natural areas. Furthermore, it very well may be that adjacent residences are home to people with a different sensitivity to the positive and negative effects of open spaces and the presence of wild boars, respectively. To fully untangle the two externalities, there is a need for a much more detailed characterisation of the residents, beyond neighbourhood dummies.

Assuming that a simple procedure for disentangling positive and negative effects could be conceived, an additional methodological challenge is posed by the fact that wild animals' nuisance effects are not necessarily linear. It seems that to be perceived as a nuisance, wild animals' presence has to be noticeable, continuous and to create some type of damage. Using different functions to model positive and negative effects may complicate the statistical model, but still, modelling curvilinear variables can shed light on the presumably non-linear relations between the animals' presence and the nuisances caused by them. A simple solution would be to try different data transformations of one or both measurement variables and then perform a linear correlation of the transformed data. A more elaborated option is to explore the fit of a curvilinear regression using functions as exponential, power or logarithm. Other concerns relate to the quality of the data. Wild boar presence data used here are based on reports by citizens. One would expect fewer reports in areas with fewer people. Boars observed in unexpected locations are more likely to be reported. In residential areas during work hours, the probability of boar reports is lower. Moreover, the probability of boars being reported depends on population density per area, which is heterogeneous.

Conclusion

It should be noted that our approach is conceptually different from the urban environmental perspective. Instead of focusing on the positive and negative influences of cities on their natural physical environments (as, for example, in Camagni et al., 1998), we are interested in the positive and negative influences of urban nature on urbanites' welfare. Our original contribution is to deal empirically with ecological disservices from nature, which negatively affect urban dwellers.

From an urban planning perspective, the results of the present research suggest that, contrary to what is usually thought, in certain situations more provision of natural environment in cities may be detrimental to urbanites' well-being. There is an almost unanimous consensus that attractive and accessible natural areas in cities enhance the quality of life (Van Herzele and Wiedemann, 2003), contribute to public health (Takano et al., 2002; Tzoulas et al., 2007) and entail psychological benefits (Fuller et al., 2007). However, there is little research about the optimal provision of green areas to a city, or, in other words, when a city is already 'green enough'. If the question is addressed (as in Wolch et al., 2014), the prism used for the analysis is related to social justice and gentrification, not to the quality of natural areas per se. But provision of open and green spaces in urban areas may also carry negative consequences, as exemplified previously, through the increasing presence of wild animals. On one hand, under certain circumstances there are positive effects of the interaction between urbanites and wildlife (Bjerke and Østdahl, 2004), but, on the other hand, there is evidence of the detrimental effects of wild animals on city dwellers when the animals become abundant and potentially aggressive (Bateman and Fleming, 2012). Since natural, green and open areas play an important role in the everyday urbanite's experience, urban planning policies need to carefully calibrate their provision while avoiding possible drawbacks. The analysis performed in this research is a first step towards the assessment of the negative externalities of nature in cities.

Despite the methodological issues in an effort to disentangle positive and negative externalities, the evidence we present suggests that estimates of the premium that people are willing to pay for proximity to green spaces may be the result of a misspecification error. We cannot suggest at present whether the estimates should be bigger or smaller than reported in the literature (e.g. Bertram and Rejdanz, 2015). Given the methodological and policy challenges of sorting the complex interactions between cities and nature, there is a need for further research.

Acknowledgements

We would like to thank Dr Danny Ben-Shahar for providing the property transactions data, Dr Dan Malkinson for providing the boar sightings data and the Israel Science Foundation, grant number 2025442, for partial funding.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was partially funded by the Israel Science Foundation, grant number 2025442.

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Note

1. For a regression model with intercept, the number of dummy variables is routinely defined as the total number of groups minus one (per each original qualitative variable). The group for which all dummy variables are equal to zero is called the reference/baseline group. A regression coefficient of each dummy variable reflects the difference of effect between the group for which the dummy variable equals one and the reference group.

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