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Planning for green infrastructure: The spatial effects of parks, forests, and fields on Helsinki's apartment prices

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ABSTRACT

As the importance of urban green spaces is increasingly recognised, so does the need for their systematic placement in a broader array of socioeconomic objectives. From an urban planning and economics perspective, this represents a spatial task: if more land is allocated to various types of green, how do the economic effects propagate throughout urban space? This paper focuses on the spatial marginal effects of forests, parks, and fields and estimates spatial hedonic models on a sample of apartment transactions in Helsinki, Finland. The results indicate that the capitalization of urban green in apartment prices depends on the type of green, but also interacts with distance to the city centre. Additionally, the effects contain variable pure and spatial spillover impacts, also conditional on type and location, the separation of which highlights aspects not commonly accounted for. The planning of green infrastructure will therefore benefit from parameterizing interventions according to location, green type, and character of spatial impacts.

1. Introduction: The Spatial Economic Context of Implementing Urban Green

Green infrastructure (GI), with its capacity to provide ecosystem services (ES) in a comprehensive manner across an urban area, has been proposed as a key element in sustainable urban planning, as well as in adaptation and resilience to the effects of climate change (Renaud et al., 2013; European Commission, 1994, 2011, 2013; IPCC, 2012; European Environment Agency, 2011). From a rational planning perspective, the implementation of GI in cities represents the task of modifying a tightly interdependent spatial system, where the typical underutilization of natural areas needs to be addressed in a way that urbanization's fundamental non-ecological benefits are also maintained. Additionally, since the urban economic system is as sensitive to land use choices as the provided mix of ES is, the further question arises of knowing the differences between the economic effects of alternative green solutions. Besides planned spatial interventions, the above questions are valid also in the context of unplanned changes in the natural stock of an area, e.g., due to species changes following gradual change in climate conditions or one-time extreme weather events.[1]

In practice, the systematic implementation of GI implies trade-offs with other urban functions, and poor evaluation of green interventions in relation to a broader array of socioeconomic objectives may bring adverse effects (Wolch et al., 2014; Perino et al., 2014). These relate to the fact that the configuration of urban land use follows a specific spatial optimization logic. In order to maintain a sufficient amount of agglomeration benefits, the allocation of space to highly productive and therefore competitive functions (e.g., housing, public services, and jobs) is favoured and, in turn, functions typically regarded as less competitive—including ecosystems—tend to be minimized, substituted, or expelled. So, in theory, the relative location and size of objects matter greatly for the socioeconomic prosperity of cities, since this spatial logic has historically delivered fundamental benefits, such as optimal provision of services and employment, tight social networks, and efficient distribution and exchange of goods. The need to reconsider this logic relates to its inherent externalities (e.g., pollution, flooding and inadequate handling of storm water, noise, health effects), the effects of which are exacerbated by the changing climate. Ultimately, the issue at stake is integration and evidence-based decision support. Even though the importance of GI is obvious, it is not as straightforward to understand what the increased allocation of space to previously expelled, space-competing functions entails for the urban economy.

The above questions involve phenomena at multiple spatial scales (James et al., 2009). This study focuses on finer scales and on plannable features inherent to apartment properties and their immediate surroundings. The study assumes that the spatial effects of urban green as measured in the housing market are useful in understanding trade-offs involved in the implementation of GI at fine spatial scales. The analysis estimates spatial hedonic models on a sample of apartment

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[1] An example is a recent drought in Helsinki that resulted in the loss of pines and their replacement either by species that are more heat-resistant, or by empty land and more droughts.

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transactions in Helsinki, Finland for the years 2000–2011. Firstly, the marginal effects of three types of green spaces (forest, park, and field) and their interaction with distance to the city centre are estimated and compared. Subsequently, the spatial spillover impacts (direct, indirect, and total) for the capitalization of forests, parks, and fields in apartment prices are calculated. These spillovers are qualitatively different from distance decay (from a green space) or geographically variable effects. They introduce an additional policy-relevant aspect, indicating the extent to which the benefits of a certain green type remain at (or originate from) the implementation location or diffuse to (and from) neighbouring ones. The focus on apartment prices is motivated in light of sustainable urban growth and mixed, denser solutions for housing, which almost invariably imply apartment solutions for the urban population. The following section discusses in brief the urban economic context of green amenities, overviews past hedonic valuation studies, and explains the focus on specific spatial effects.

2. Urban Green in Housing Price Formation and Differentiation

The provision of multiple (Davies et al., 2011; Givoni, 1998) and often non-substitutable (Hauru et al., 2012) ES by green spaces makes them influential amenities in the urban economic context. As such, their participation in the formation of residential property value can be approached by referring to a residential location model (Muth, 1969; Mills, 1967; Alonso, 1964), modified to reflect the structural role of natural amenities. Brueckner et al. (1999) show that, in addition to transportation cost and preferences on dwelling type and size, the spatial variation of amenities will co-determine the equilibrium outcome. Households seek to locate near exogenous natural and historical amenities, and the wealthy will typically outbid the rest for locating near these amenities. The outcome of this process is reflected in the observed morphology of housing prices; high values are typically associated with amenity-rich locations, such as the urban core, green spaces, and coastline.

Empirically, the participation of natural amenities in price formation and differentiation is detected in realized housing market transactions by estimating the sensitivity of property prices towards the quantity, type, and quality of amenities. For ecological amenities, De Groot et al. (2002) and Bateman et al. (2010) enumerate methodologies for linking ES to monetary value, with hedonic analysis being the most relevant approach in the housing market. Hedonic price theory suggests that housing is a composite commodity, representing for consumers more than just a shelter; proximity to amenities and services are examples of other attributes bundled together in housing. By estimating the market price of dwellings as a function of their attributes, it is possible to derive an implicit value for each attribute (Brueckner, 2011; Sheppard, 1999; Dubin, 1988; Quigley, 1982; Rosen, 1974). The estimated coefficients of the attributes are interpreted as their marginal values or effects. By analysing the variation of the type, quantity, and quality of hedonic attributes in relation to the corresponding variation in property prices, inferences can be made about the implicit value and relative importance that consumers tend to attach to ecological amenities, as well as the willingness to pay (WTP) for them (Freeman et al., 2014). The estimated effects are also useful in comparing different types of urban green with respect to relative importance and implicit value, as different types of green can be approached as distinct hedonic attributes.

In Finland, Tyrväinen (1997) reports that a 100 m increase in the distance of a dwelling to wooded recreation areas decreases its market price/m^2 by 42 FIM (€ 7.14) in the city of Joensuu, while Tyrväinen and Miettinen (2000) report that a 1 km increase in the distance of a dwelling to a forested park decreases its market price by 5.9% on average and a direct view to a forested area increases price by 4.9% in the city of Salo. In both studies as well as in international literature (e.g. Czembrowski and Kronenberg, 2016), the authors observe a notable dependence of the estimations on the type of green and the variable that represents it. The consensus in literature is that urban green is positively valued in the housing market; the meta-analysis studies of Brander and Koetse (2011), Perino et al. (2014), and Siriwardena et al. (2016) provide thorough summaries.

As the housing market has a strong geographical dimension, the hedonic approach is often augmented, among others, with the concepts of spatial non-stationarity and spatial spillovers. Spatial non-stationarity concerns the cases where regression coefficients vary across geographical space (Bivand et al., 2008; Lloyd, 2007; Schabenberger and Gotway, 2005; Fotheringham et al., 2002). For the present context, this suggests that the marginal effects of green will vary across different parts of the city and may be altogether zero in some locations, from a global point of view, regardless of the local distance decay function to individual green patches (e.g. Cho et al., 2011). For instance, empirical studies report a general decrease in the value of formal green patches as population density decreases (Brander and Koetse, 2011) or ownership of private green spaces increases (Tu et al., 2016). In addition, the first law of geography (Tobler, 1970; Miller, 2004) suggests that geographical locations are in fact interdependent so that a change in one location will affect neighbouring locations and vice versa. This implies that the marginal effects measured in hedonic regressions are the combination of pure effects due to the characteristics of a given property and spatial spillover effects due to interaction with neighbouring properties (LeSage and Pace, 2009; Anselin, 2003, 1995, 1988).

In summary, considering green spaces in connection to the spatial morphology of property prices, and drawing from the discussed literature, the estimations of this paper aim to explore the following three spatial effects of green interventions. Firstly, different types of green should be explored in more detail as amenities that are distinct from each other, which may entail different price effects, too. Secondly, different parts of the city, notably the core and periphery, are so fundamentally different, that a given solution will have geographically variable effects. Thirdly, as cities are systems of spatially interdependent locations, a green intervention at one location affects the rest of the system and vice versa. Green interventions will thus generate spatial spillover effects that propagate throughout the city in varying intensities and through varying channels. The first assumption is tested by estimating the marginal effects of distances to forests, parks, and fields; the second by including an interaction of the effects with distance to city centre; the third by separating pure from spatial spillover impacts.

3. Models and Assumptions

The particular view of green space assumed in the previous sections motivates the use of spatial regression models as better equipped to provide insights to the stated urban planning questions than non-spatial models. In addition, spatial regression models are capable of addressing estimation issues that are characteristic to spatial data analysis and hedonic datasets. Details about the foundations, methodology, and application of such models are found, among others, in Gerkman (2012), Anselin et al. (2010), LeSage and Pace (2009), Anselin (2003, 1988), and Dubin (1988).

Unobserved effects that exhibit spatial dependency are frequent in hedonic analysis due to hard-to-operationalize or non-decomposable spatial concepts like neighbourhood prestige or (un)attractive design. In that case, the residuals of ordinary least squares (OLS) estimations will be spatially autocorrelated and violate the i.i.d. error assumption. The first-order autoregressive spatial error model (SEM) addresses this problem by separating the residuals into a spatially autocorrelated component and an uncorrelated random error (model 1):

$$\mathbf{y} = \mathbf{X}\beta + \lambda\mathbf{W}\mathbf{u} + \epsilon, \tag{1}$$

where $\mathbf{X}$ is a matrix of hedonic attributes, $\mathbf{W}$ a spatial weights matrix, $\mathbf{Wu}$ a spatially autocorrelated error term, ϵ a random error term, and β, λ coefficients. The interpretation of coefficients in the SEM is the