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Preferences for forest proximity and recreational amenities revealed by the random bidding model

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Abstract

In the context of increased political focus on improving the quality of urban environments, knowledge of household preferences for recreational environments is needed. This research note seeks to reveal the willingness to pay (WTP) for forest proximity and its amenities in housing choice location based on the random bidding model. Four major findings are obtained: (i) The WTP for urban park proximity is globally non-significant compared with that of forest areas; (ii) When forests are recreational green spaces, the WTP is positive for more affluent socio-professional category (SPCs) and higher for the oldest households but negative for less affluent social groups; (iii) When forests are natural protected areas, the WTP is globally negative, especially for less affluent groups; and (iv) Forest amenities, such as hiking and biking paths, positively affect the WTP for almost all SPCs, especially the youngest households.

Keywords: Forest proximity; recreational amenity; random bidding model; heterogeneous preference

JEL codes: D44, Q57, R21

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1. Introduction

With the growing political focus on improving the quality of the urban environment, forest areas have been receiving considerable attention for the evaluation of various spatial planning and development policies, particularly in relation to the real estate market and housing. In this context, urban planners and forest managers need information on preference heterogeneity in environmental and economic analyses to better understand the social demand for green spaces in territorial planning (Geneletti, 2016). For example, as a planning tool, the Paris Region Strategic Plan (IAURIF, 2015) is based on a land-use model of real estate policies and their interactions with the well-being of ecosystems and populations. This type of urban planning tool needs empirical information on housing choice determinants to facilitate a more holistic model. However, empirical studies on this topic are still lacking (Aissaoui et al., 2015; Salbitano et al., 2017). Accordingly, this research note seeks to reveal the willingness to pay (WTP) for forest proximity and its amenities in housing location choices based on the random bidding model.

This research note extends a previous empirical study that used the first step of the hedonic method to obtain marginal prices of forest housing attributes in the Paris region (Tuffery, 2017). Based on the results of the hedonic function, the second step estimates the inverse demand function and aims at revealing households' willingness to pay (WTP) (Rosen, 1974). Although this two-step method is academically well accepted and frequently used in environmental assessments, two econometric problems remain unsolved: parameter identification, which is linked to housing market sorting issues; and endogeneity, which is associated with households simultaneously choosing housing attribute quantities and marginal prices (Mendelsohn, 1987).

In this study, we use an alternative to the two-step hedonic method known as the random bidding model (RBM), which was proposed by Ellickson (1981) and developed by Lerman and Kern (1983). Ellickson's original model is based on the idea that an individual chooses the dwelling for which he has the winning bid. Lerman and Kern (1983) note that this model requires information on paid auctions, i.e., the price of the observed transaction. Contributions based on the RBM are rare because it requires data that are not readily available, i.e., prices of transactions and socio-economic attributes of purchasers. Examples in the literature include Gross (1988) and Gross *et al*. (1990) in Louisiane, Horowitz (1986) in Baltimore, Gin and Sonstelie (1992) in Philadelphia, Chattopadhyay (1998) in Chicago, Kazmierczack-Cousin (1999) in Brest (France) and, more recently, Hurtubia and Bierlaire (2014) in Brussels. All of these studies show that the RBM generates better results than the hedonic model.

Despite the current political challenges faced by cities in linking the development of the real estate market with green spaces, the literature on this topic is lacking. This led us to estimate the WTP for proximity to a forest and related recreational amenities in the housing location choice framework. Our work is the first empirical analysis of heterogeneous WTP for access to forest areas using the RBM.

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2. Method

2.1. The Random Bidding Model and Estimation

The real estate market is characterized by competition for the acquisition of dwellings between purchasers who have different WTP for a specific dwelling. Each dwelling is defined by a vector of attributes x. The set of attributes of each purchaser q determines his preferences. At equilibrium, this competition leads to the acquisition of each dwelling by the agent with the highest WTP.

We now assume that we are able to make homogeneous categories of purchasers in terms of resources and preferences. The observed endogenous variables, defined by the transaction attributes, are the categories of purchaser $k = 1, \dots, K$ and the observed price of the transaction i, P_i. According to the theory, we assume that the observed price is equal to the bid auction, which corresponds to the end point of the negotiation between the seller and the purchaser. The final price corresponds to the maximum WTP by the purchaser (Ellickson, 1981; Lerman & Kern, 1983). Thus, the observed price is the upper envelope of random bidding functions E:

$$P_i = max_k E_i^k \quad (1)$$

where E_i^k is the bid of the purchaser included in category $k = 1, \dots, K$ for dwelling $i = 1, \dots, I$.

Lerman and Kern's method, as an extension of Ellickson's model, introduced the observed price in the estimation of the random bidding function. This generalized Tobit model can be defined as the joint probability that the bid of the housing purchaser is equal to the observed price of the dwelling, and the bids of the potential purchasers belonging to other categories are lower.

For the econometric resolution, we choose a log-linear functional form, as recommended in the literature (Chattopadhyay, 1998; Kazmierczack-Cousin, 1999; Bayer *et al.*, 2005; Flachaire *et al.*, 2007). The specification of the model is as follows:

$$lnE_i^k = x_i \beta_k + \sigma_k \varepsilon_i^k \quad (2)$$

where x_i is the row vector of attributes for dwelling i, and β_k is the vector of parameters associated with each attribute. σ_k is a parameter that defines the standard deviation of the error term, and ε_i^k is the independent and identically distributed error term for the category of purchasers k.

We do not observe the WTP. E_i^k are therefore the latent endogenous variables of the model whose observables are, for each transaction i, price P_i and the category of purchaser k_i. The latter being the highest bidder, we obtain:

$$k_i = \arg max_k E_i^k$$
$$lnP_i = max_k E_i^k = E_i^{k_i} \quad (3)$$

Therefore,

$$P_i = \beta_{ki} x_i + \sigma_{ki} \varepsilon_i^{k_i}$$
$$P_i > \beta_k x_i + \sigma_k \varepsilon_i^k, \text{with } k \neq k_i \quad (4)$$

and

$$\varepsilon_i^{k_i} = \frac{P_i - \beta_{k_i} x_i}{\sigma_{k_i}}$$
$$\varepsilon_i^k < \frac{P_i - \beta_k x_i}{\sigma_k}, \text{with } k \neq k_i \quad (5)$$

We obtain the log-likelihood function via the Maximum Likelihood (ML) estimate:

$$lnL = \sum_{i=1}^{I} \sum_{k=1}^{K} u_{k_i}(k) lnf\left(\frac{P_i - x_i \beta_k}{\sigma_k}\right) + (1 - u_{k_i}(k)) lnF\left(\frac{P_i - x_i \beta_k}{\sigma_k}\right) \quad (6)$$

where $u_{k_i}(k) = 1$ when $k = k_i$ and 0 otherwise. The probability distribution has a cumulative function $F(\varepsilon)$ and a density function (ε).

2.2. Dataset and Variables

To address this issue, we studied housing transactions and forest areas in the eastern part of the Paris region, the *département* of Seine-et-Marne. This area is characterized by an urban sprawl type of development and a real estate market typical of a metropolitan area. Moreover, it offers a real diversity of forest areas (Filoche *et al.*, 2010).

2.2.1 Housing transactions, district and neighborhood variables

The Notarial Property Database (BIEN, 2001-2008) is used to obtain information on housing transactions over the time period 2001-2008 (*e.g.,* price, surface area, and house/apartment). The dependent variable is the price per square meter in constant euros. Finally, we obtain 39 354 transactions.

The population census and facilities database (INSEE, 2007, 2010a, 2010b, 2010c) allowed us to define the urban environment of the dwelling by providing information on the number of shops, the number of bakeries, the presence of cinemas (dummy) and the median income (in constant euros) at the IRIS level (IRIS is the smallest level of French national statistics, including approximately 2000 persons), and the distance to employment areas. The distance to various facilities (train stations, high schools, hospitals, malls and urban parks) is derived from National Institute for Geographic Information data. All distance variables are computed by road networks using Geographic Information System (GIS) software.

2.2.2 Forest areas

We used two databases to define our forest areas: the Paris region land-use land-cover (IAURIF, 2008) and the National Forestry Office (ONF, 2012). We ended up with 406 forest areas. To account for a potential "border effect", we used a buffer zone tool to analyze forest areas close but outside the departement. Result shows there is no major interest forest at less than 30km from the border. This distance is higher than the maximum impact distance usually found in hedonic forest studies (i.e. 10km; Chau et al., 2005).

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Our forest amenities were based on a survey of forest visits in the Paris region (Maresca, 2000), which included questions on individuals' recreational practices in the forest. We created three variables corresponding to the top responses. We added the surface area of the forests as a main proxy for the supply of recreational amenities. Finally, our four explanatory forest amenities (forest statistics in Appendix I.a) were as follows:

- Forest surface area variable in km²;
- Protection index variable, which is the number of French biodiversity protection statuses (e.g., Natura 2000 or Biological Reserves);
- Biking and hiking path in km;
- Leisure area dummy variable (leisure areas correspond to sports and recreation complexes).

The forest is a multi-site amenity characterized by spatial heterogeneity in recreational quality (Tuffery, 2017). Thus, our study accounts for both the nearest forest and all other forest areas in our territory. Equation (7) shows the introduction of distance decay between dwellings and forests to account for the decreasing effect of the variable as distance increases. We used exponential distance decay as recommended by Baerenklau (2010).

$$N_{i,k} = \sum_{j=1}^{406} (e^{-D_{i,j}}) * n_{j,k} \text{, with } j = 1, \ldots, 406 \text{ and } k = 1, \ldots, 4 \quad (7)$$

where $D_{i,j}$ is the distance (based on the road network) between dwelling i and forest area j (the forest area location is the closest intersection between the road and the forest outline), and $n_{j,k}$ is the set of k recreational amenities (see Appendix I.b for the spatial distribution of forest amenities).

2.2.3 Purchaser categories

To create sub-groups of purchasers, we used the two variables of the BIEN database linked to the purchaser profile: socio-professional category (SPC, i.e. social group) and the age of the reference person of the household purchaser (usually the oldest employed household member). These variables are proxies of income level, employment and family status.

Four SPCs are represented in our dataset: high managerial, administrative or professional workers; intermediate managerial, administrative or professional workers; office workers; and skilled and unskilled manual workers. In addition, three age groups were defined: under 30 years, between 30 and 45 years, and over 45 years. We then created 12 categories of agents (see table 1).

Table 1. Distribution of housing transactions for each category

Socio-professional Categories	Age (years)	Freq.	%
High managerial, administrative or professional workers	< 30	1126	3%
	30 to 45	2994	8%
	> 45	3283	8%
Intermediate managerial, administrative or professional workers	< 30	3869	10%
	30 to 45	6229	16%
	> 45	5039	13%
	< 30	3039	8%

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	30 to 45	4143	11%
Office workers	> 45	3507	9%
	< 30	1672	4%
Skilled and unskilled manual	30 to 45	2388	6%
workers	> 45	2065	5%
Total		39354	100%

3. Results

The results of the estimation are presented in Table 2 (results on controlled variables are detailed in Appendix II). The results of the Chow test (Chow, 1960) show significant differences for each of the 12 sub-categories and across age groups in all SPCs with one exception: manual workers in the 30-45 age group (see Appendix III.a and III.b). These results allow us to consider all but one purchaser category. Interactions between forest surface area, protection status, leisure area, hiking paths and urban parks were tested and the results are globally non-significant.

Table 2. Results of the RBM estimation

	High managerial			Intermediate managerial		
	< 30 years	30 to 45 years	> 45 years	< 30 years	30 to 45 years	> 45 years
Surface area						
coeff.	0.0008*	0.0015***	0.0023***	-0.0001	0.0005*	0.0010***
Std. error	0.000	0.000	0.000	0.000	0.000	0.000
Protection status						
coeff.	0.001	0.005*	0.003	-0.006**	-0.002	-0.001
Std. error	*0.004*	*0.003*	*0.003*	*0.003*	*0.002*	*0.002*
Leisure areas						
coeff.	0.033	0.049**	0.085***	-0.006	0.008	0.049***
Std. error	*0.031*	*0.023*	*0.022*	*0.021*	*0.018*	*0.019*
Hiking & biking						
coeff.	0.009	0.006	-0.010**	0.021***	0.020***	0.006*
Std. error	*0.006*	*0.004*	*0.004*	*0.004*	*0.003*	*0.004*
	Office workers			**Manual workers**		
	< 30 years	**30 to 45 years**	**> 45 years**	**< 30 years**	**30 to 45 years**	**> 45 years**
Surface area						
coeff.	-0.0008	-0.0007**	0.0004	-0.0007*	-0.0004	-0.0007*
Std. error	0.000	0.000	0.000	0.000	0.000	0.000
Protection status						
coeff.	-0.005*	-0.002	-0.003	-0.013***	-0.015***	-0.009***
Std. error	*0.003*	*0.002*	*0.002*	*0.003*	*0.003*	*0.003*
Leisure areas						
coeff.	-0.039*	0.0001	0.026	0.022	0.013	0.062**
Std. error	0.023	0.02	0.021	0.028	0.024	0.025
Hiking & biking						
coeff.	0.022***	0.025***	0.009**	0.019***	0.016***	0.011**
Std. error	*0.004*	*0.004*	*0.004*	*0.005*	*0.005*	*0.005*

** p < 0.10; ** p < 0.05; *** p < 0.01*

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The results of the estimation of the control variables are consistent with previous studies on hedonic analyses (Tyrväinen & Miettinen, 2000; Irwin, 2002).

The surface area variable of the overall forest environment is globally significant in our sample and across the sub-groups, although the impact on WTP varies. Since the sub-groups are based on the age and SPC groups, a two-dimension analysis is required. As expected, for the wealthier SPCs (*i.e.*, high and intermediate managerial), forests appear to be an amenity with a positive WTP. Moreover, we observe that older households present higher and more significant coefficients. This finding is consistent with studies based on revealed preferences (Martínez-Espiñeira & Amoako-Tuffour, 2008; Abildtrup *et al.*, 2013), which show that the demand for natural areas increases with income. Conversely, when the estimated effect is significant, it is negative for the less affluent SPCs (*i.e.*, office and manual workers). The effect of age on the surface area variable estimation is not significant for the less affluent SPCs. The literature defines age as one of the key explanatory variables of the WTP (along with gender, income and education), although because of the unavailability of information, few studies are based on the hedonic approach. For instance, age positively affects the WTP for green space proximity in the case of the city of Brest, France (Flachaire *et al*., 2007).

Regarding the estimated effect of leisure areas, households over 45 years old generally positively value the proximity to forest leisure areas regardless of the SCP except for office workers. This impact is globally not significant for other groups.

In the literature, recreational amenities, such as biking and hiking paths, positively affect the WTP for most categories (Sander & Polasky, 2009; Sander *et al*., 2010). We observe the same global results in our case study, although the WTP remains heterogeneous in terms of coefficient magnitude with an opposite trend observed for age and SCP. Older and wealthier households correspond to a lower valuation of hiking and biking paths. Age negatively affects the WTP since the positive effect decreases when age increases. The coefficients for groups under 30 years of age are twice those of purchasers aged 45 years or older. Hence, hiking and biking paths appear to be the most important recreational amenity for young and less affluent households.

The effect of protection status index in forests is globally negative, especially for the office and manual worker SPCs, which is inconsistent with our initial intuition and literature findings. However, we found some support in the literature (Shultz & King, 2001; Terrasson, 2007; Lévêque, 2008; Tuffery, 2017), and this finding could be explained by the biodiversity protection status, which may restrict access to forests, or by the fact that urban and peri-urban populations fear undomesticated nature (Terrasson, 2007). Previous studies on revealed preferences have not explained the impact of socio-economic profiles on the WTP for forest biodiversity. Nevertheless, several studies based on surveys and qualitative approaches have demonstrated that there is a positive correlation among income, SPC, education level or age and concern for biodiversity conservation (Kinzig *et al*., 2005; Strohbach *et al.*, 2009; Shwartz *et al*., 2012).

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4. Conclusions

Our conclusions are centered on the following four major original findings:

(i) The WTP for proximity to urban parks is globally non-significant compared with that for forests, which appear to be the most important recreational areas;

(ii) When forests are recreational green spaces (defined by surface area), the WTP is positive for the wealthiest SCPs and higher for the oldest households but negative for the less affluent social groups;

(iii) When forests are natural protected areas, the WTP is globally negative, especially for the less affluent groups;

(iv) Finally, forest areas and amenities, such as hiking and biking paths, positively affect the WTP for almost all SPCs, especially for the youngest households.

The distinction of purchasers according to their preferences is important for putting the results to practical use in order to provide guidance for environmental planning that considers forest non-market value. First, identifying groups with preferences for different recreational attributes of forest areas can indicate who will move to an area if we change the access to green areas. Furthermore, these results feed into the political guidelines for greening cities and show that urban parks make very limited contributions to housing quality compared with forests areas.

However, some limitations should be mentioned. From an econometric point of view, the RBM estimation has constraints. There is less flexibility in econometric estimations based on parametric formulations, and it is more difficult to address spatial correlations. Finally, with regard to our results and contributions, the applicability of our work is limited to our extraction of the BIEN database, which does not contain information on the retired population, the tenant households or social housing market (which represent more than 50% of our territory inhabitants).

Based on this work, several research perspectives could be investigated. Here, we evaluate the state of the art of recreational services in a positive (*i.e.,* objective) approach. An interesting extension would be to adopt a normative analysis and thus to optimally allocate different services with spatial optimization modeling.

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References

Abildtrup, J., Garcia, S., Olsen, S., & Stenger, A. (2013). Spatial preference heterogeneity in forest recreation. *Ecological Economics*, 92(C), 67-77. doi - 10.1016/j.ecolecon.2013.01.001

Aissaoui H., Bouzouina L., Bonnel P. (2015). Choix de localisation résidentielle, entre contraintes du marché et préférences individuelles : application à l'aire urbaine de Lyon (1999). *Revue d'Économie Régionale & Urbaine*, vol.4, 629-656. DOI : 10.3917/reru.154.0629.

Baerenklau, K.A. (2010). A latent class approach to modeling endogenous spatial sorting in zonal recreation demand models. *Land Economics*, 86(4), 800-816. Doi - 10.3368/le.86.4.800

Bayer, P., Mc Millan, L., & Rueben, K. (2005). An Equilibrium Model of Sorting in an Urban Housing Market, NBER, Working Paper 10865, National Bureau of Economic Research, Inc.

[dataset] Base Immobilière et Economiques Notariales, Chambre des notaires de Paris, 2001-2008, 2008.

Chattopadhyay, S. (1998). An empirical investigation into the performance of Ellickson's random bidding model, with an application to air quality valuation. *Journal of Urban Economics*, 43(2), 292-314. Doi - 10.1006/juec.1997.2046

Chau, K., Yiu, C., Wong, S., & Lawrence, W. (2005). Hedonic Price Modelling of Environmental. Attributes: A Review of the Literature and a Hong Kong Case Study. Encyclopedia of Life Support Systems.

Chow, G.C. (1960). Tests of Equality between Sets of Coefficients in Two Linear Regressions, *Econometrica*, 28, 591-605. Doi - 0012-9682(196007)28:3<591:TOEBSO>2.0.CO;2-H

Ellickson, B. (1981). An alternative test of the hedonic theory of housing markets. *Journal of Urban Economics*, 9, 56-79. Doi - 10.1016/0094-1190(81)90048-6

Filoche, S., Perriat, F., Moret, J., & Hendoux, F. (2010). Atlas de la flore sauvage de Seine-et-Marne. Publication du Conseil Général de Seine-et-Marne.

Flachaire, E., Jayet, H., Ragot, L., & Tropeano, J-P. (2007). *Économie urbaine et espaces verts publics*. Rapport pour le compte du Ministère de l'Écologie et du Développement Durable.

Geneletti, D. (2016). Handbook on biodiversity and ecosystem services in impact assessment. Edward Elgar Publishing Limited, Cheltenham.

Gin, A., & Sonstelie, J. (1992). The Streetcar and Residential Location in Nineteenth Century Philadelphia. *Journal of Urban Economics*, vol.32, 92-107. Doi - 10.1016/0094-1190(92)90016-E

Gross, DJ. (1988). Estimating willingness to pay for housing characteristics: an application of the Ellickson bid-rent model. *Journal of Urban Economics*, 24(1), 95-112. Doi - 10.1016/0094-1190(88)90049-6

Gross, DJ., Sirmans, C., & Benjamin, JD. (1990). An empirical evaluation of the probabilistic bid-rent model: The case of homogenous households. *Regional Science of Urban Economics,* 20(1), 103-110. Doi - 10.1016/0166-0462(90)90027-Z

Horowitz, J.L. (1986). Bidding models of housing markets. *Journal of Urban Economics*, 20(2), 168-190. Doi - 10.1016/0094-1190(86)90005-7

Hurtubia, R., & Bierlaire, M. (2014). Estimation of Bid Functions for Location Choice and Price Modeling with a Latent Variable Approach. *Networks and Spatial Economics*, 14(1), 47-65. Doi - 10.1007/s11067-013-9200-z

Institut d'Aménagement Urbain de la région Ile-de-France –IAURIF (2015). Ile-de-France 2030 - mise en œuvre du sdrif - bilan 2014. 76p.

[dataset] Institut d'Aménagement Urbain de la région Ile-de-France -IAURIF, Mode d'Occupation du Sol (MOS) & MOS Ecologique (ECOMOS), 2008.

[dataset] INSEE, Revenus fiscaux localisés des ménages, 2007.

[dataset] INSEE, La base permanente des équipements, 2010a.

[dataset] INSEE, La base mobilité, Recensement de la Population, 2010b.

[dataset] INSEE, Les zones d'emploi, Recensement de la Population, 2010c.

Irwin, E.G. (2002). The effects of open space on residential property values. *Land Economics*, 78, 465-480. Doi - 10.2307/3146847

Kazmierczack-Cousin, S. (1999). Thèse de doctorat en Économie Appliquée « L'Évaluation des fonctions d'enchères des ménages : les agglomérations Lilloise et Brestoise », Université des sciences et technologies de Lille.

Kinzig, A.P., Warren, P., Martin, C., Hope, D., & Katti, M. (2005). The effects of human socioeconomic status and cultural characteristics on urban patterns of biodiversity. *Ecology and Society*, 10(1), 23pp. doi - 10.5751/ES-01264-100123

Lerman, S.R., & Kern, C.R. (1983). Hedonic theory, bid rents, and willingness-to-pay: Some extensions of Ellickson's results. *Journal of Urban Economics*, 13(3), 358-363. Doi - 10.1016/0094-1190(83)90039-6

Lévêque, C. (2008). La Biodiversité au Quotidien: le développement Durable à l'épreuve des Faits, Quae/IRD, Paris.

Maresca, B. (2000). La fréquentation des forêts publiques en Île-de-France, Habitudes, représentations et flux de visites des franciliens, publication du Crédoc N° S1271.

Martínez-Espiñeira, R., & Amoako-Tuffour, J. (2008). Recreation demand analysis under truncation, overdispersion, and endogenous stratification: an application to Gros Morne National Park. *Journal of Environmental Management,* 88(4), 1320-1332. Doi - 10.1016/j.jenvman.2007.07.006

Mendelsohn, R. (1987). A review of identification of hedonic supply and demand functions. *Growth and Change*, 18, 82-92. Doi - 10.1111/j.1468-2257.1987.tb00075.x

[dataset] Office National des Forêts - ONF, Cartographie des forêts publiques françaises, 2012.

Rosen, S. (1974). Hedonic prices and implicit markets: product differentiation in pure competition. *Journal of Political Economy*, vol.82, 34-55. Doi - 10.1086/260169

Salbitano, F., Borelli, S., Conigliaro, M. & Chen, Y. (2017). Directives sur la foresterie urbaine et périurbaine. Études FAO: Forêts no. 178. Rome, FAO.

Sander, H.A., & Polasky, S. (2009). The value of views and open space: estimates from a hedonic pricing model for Ramsey County, Minnesota, USA. *Land Use Policy*, 26(3), 837-845. Doi - 10.1016/j.landusepol.2008.10.009

Sander, H.A., Polasky, S., & Haight, R.G. (2010). The value of urban tree cover: A hedonic property price model in Ramsey and Dakota Counties, Minnesota, USA. *Ecological Economics*, vol.69, 1646–1656. Doi - 10.1016/j.ecolecon.2010.03.011

Shultz S.D., & King D.A., 2001. The use of census data for hedonic price estimates of open-space amenities and land use. *Journal of Real Estate Finance and Economics*, 22, 239–252. Doi - 10.1023/A:1007895631071

Shwartz, A., Cosquer, A., Jaillon, A., Piron, A., Julliard, R., Raymond, R., Simon L., & Prévot-Julliard, A.C. (2012). Urban biodiversity, city-dwellers and conservation: How does an outdoor activity day affect the human-nature relationship. *PLoS ONE*, 7(6), 8pp. doi - 10.1371/journal.pone.0038642

Strohbach, M.W., Haase, D., & Kabisch, N. (2009). Birds and the city: urban biodiversity, land use, and socioeconomics. *Ecology and Society*, 14(2). Doi - 10.5751/ES-03141-140231

Terrasson, F. (2007). La Peur de la nature, Sang de la Terre, 1991, 2e éd., 192pp.

Tuffery, L. (2017). The value of recreational services of the nearby periurban forest versus the regional forest environment. *Journal of Forest Economics*, vol.28, 33–41. Doi - 10.1016/j.jfe.2017.04.004

Tyrväinen L., & Miettinen, A. (2000). Property prices and urban forest amenities. *Journal of Environmental and Economic Management*, vol.39, 205-223. Doi - 10.1006/jeem.1999.1097

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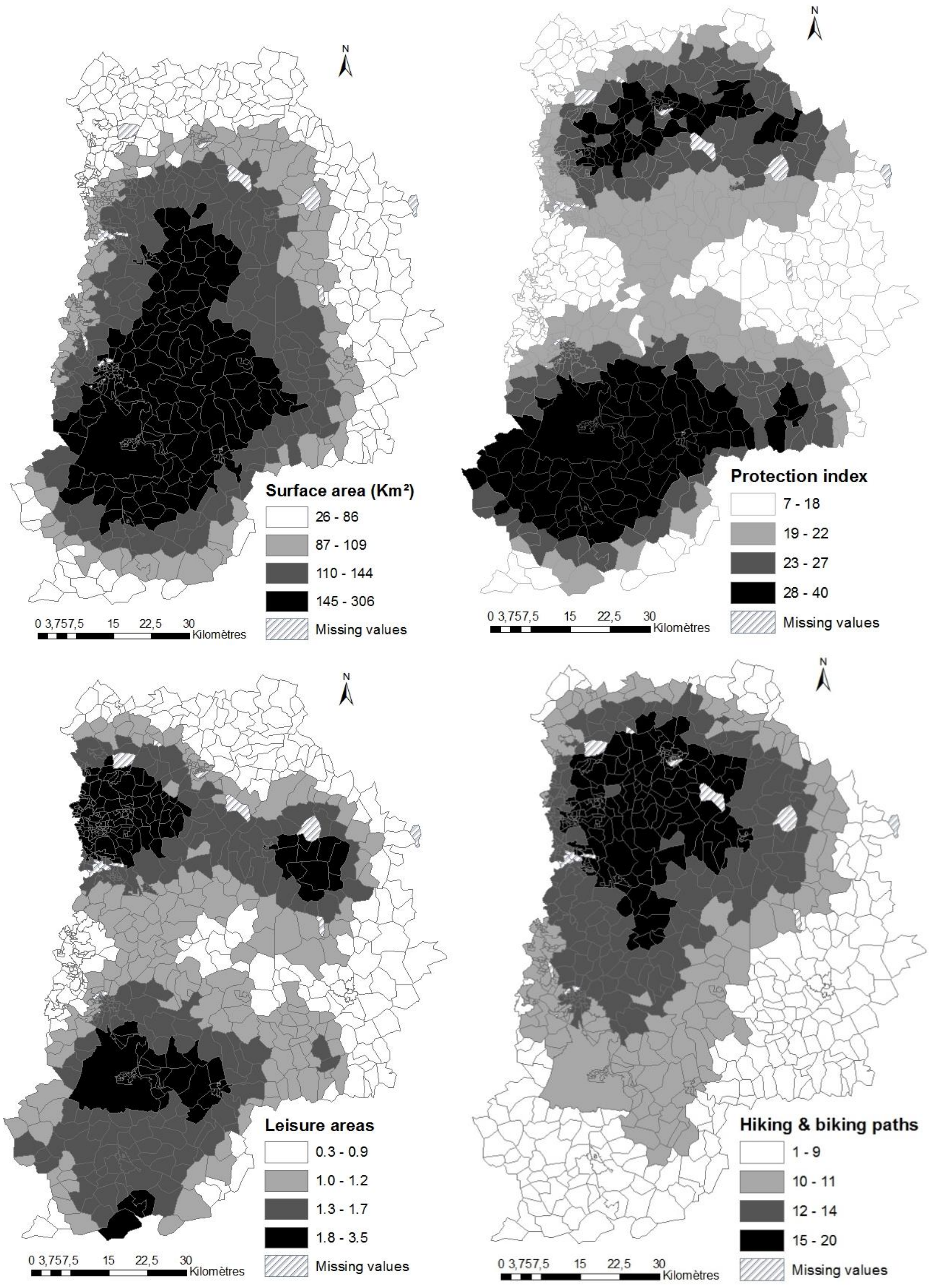
Appendix I. Statistics and mapping on forest variables

I.a Statistics of forest variables

	Surface (Km²)	Protection index	Hiking paths (Km)	Leisure area
[min; max]	[0.1 ; 59]	[0 ; 6]	[0 ; 182]	[0 ; 1]
mean	3	0.9	11	0.04
median	1.3	0	7	0
Quartile				
1st	0	0	0	0
3rd	3	1	16	0

I.b Spatial distribution of forest variables



Sources: MOS, 2008; IAURIF and ONF, 2012

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Note on the interpretation: Forest amenities are based on equation 7 (forest amenities weighted by distance from housing transactions). Transaction-weighted forest variables have different spatial distributions: high values for the surface variable are concentrated in the center and the south of the study area; high values for the protection index are located in two clusters: one in the north and one in the south of the study area; and hiking and biking paths are concentrated in the northern part.

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Appendix II: Results of the random bidding function estimations for the control variables

SPC	High managerial			Intermediate managerial			Office workers			Manual workers		
Age (year)	**< 30**	**30 to 45**	**> 45**	**< 30**	**30 to 45**	**> 45**	**< 30**	**30 to 45**	**> 45**	**< 30**	**30 to 45**	**> 45**
Constant												
coeff.	1.545*	-0.970	-0.024*	4.885***	2.719***	3.831***	7.315***	4.221***	5.511***	8.260***	7.160***	8.759***
Std. error	*0.944*	*0.662*	*0.635*	*0.640*	*0.534*	*0.561*	*0.707*	*0.600*	*0.629*	*0.868*	*0.733*	*0.760*
2001 (ref)	-	-	-	-	-	-	-	-	-	-	-	-
2002												
coeff.	0.022	0.102**	0.087**	0.036	0.075**	0.084**	0.045	0.058	0.053	-0.012	0.086**	0.072
Std. error	*0.057*	*0.042*	*0.041*	*0.039*	*0.033*	*0.035*	*0.043*	*0.037*	*0.038*	*0.050*	*0.042*	*0.046*
2003												
coeff.	0.092	0.177***	0.158***	0.161***	0.175***	0.141***	0.130***	0.172***	0.100***	0.058	0.118***	0.103**
Std. error	*0.056*	*0.041*	*0.040*	*0.038*	*0.033*	*0.034*	*0.042*	*0.036*	*0.038*	*0.049*	*0.042*	*0.046*
2004												
coeff.	0.225***	0.330***	0.315***	0.220***	0.282***	0.215***	0.245***	0.278***	0.198***	0.127***	0.182***	0.204***
Std. error	*0.053*	*0.039*	*0.038*	*0.037*	*0.031*	*0.033*	*0.040*	*0.035*	*0.036*	*0.048*	*0.041*	*0.044*
2005												
coeff.	0.304***	0.427***	0.382***	0.391***	0.467***	0.384***	0.417***	0.409***	0.276***	0.294***	0.282***	0.349***
Std. error	*0.055*	*0.039*	*0.039*	*0.036*	*0.031*	*0.033*	*0.040*	*0.035*	*0.037*	*0.047*	*0.042*	*0.044*
2006												
coeff.	0.498***	0.571***	0.510***	0.501***	0.579***	0.503***	0.504***	0.480***	0.410***	0.433***	0.424***	0.466***
Std. error	*0.055*	*0.041*	*0.040*	*0.038*	*0.032*	*0.034*	*0.041*	*0.036*	*0.038*	*0.048*	*0.043*	*0.045*
2007												
coeff.	0.566***	0.593***	0.584***	0.566***	0.611***	0.575***	0.534***	0.554***	0.522***	0.481***	0.490***	0.577***
Std. error	*0.054*	*0.041*	*0.039*	*0.037*	*0.032*	*0.034*	*0.041*	*0.036*	*0.037*	*0.048*	*0.043*	*0.044*
2008												
coeff.	0.558***	0.563***	0.582***	0.502***	0.558***	0.598***	0.494***	0.493***	0.482***	0.534***	0.419***	0.507***
Std. error	*0.057*	*0.044*	*0.042*	*0.040*	*0.035*	*0.036*	*0.044*	*0.039*	*0.040*	*0.051*	*0.047*	*0.048*

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SPC	High managerial			Intermediate managerial			Office workers			Manual workers		
Age (year)	< 30	30 to 45	> 45	< 30	30 to 45	> 45	< 30	30 to 45	> 45	< 30	30 to 45	> 45
Surface area (log)												
coeff.	-0.331***	0.098***	0.039	-0.644***	-0.226***	-0.196***	-0.770***	-0.347***	-0.403***	-0.721***	-0.487***	-0.536***
Std. error	*0.041*	*0.033*	*0.030*	*0.028*	*0.025*	*0.026*	*0.030*	*0.028*	*0.029*	*0.036*	*0.034*	*0.034*
Garage (log)												
coeff.	0.125***	0.138***	0.261***	0.085***	0.134***	0.171***	0.086***	0.147***	0.232***	0.044	0.155***	0.168***
Std. error	*0.043*	*0.031*	*0.030*	*0.029*	*0.025*	*0.026*	*0.031*	*0.028*	*0.029*	*0.037*	*0.033*	*0.035*
Bathroom (log)												
coeff.	-0.068	0.298***	0.640***	-0.224***	0.123***	0.400***	-0.106	0.073	0.193***	-0.336***	-0.125**	0.020
Std. error	*0.083*	*0.053*	*0.052*	*0.060*	*0.045*	*0.047*	*0.067*	*0.052*	*0.054*	*0.079*	*0.062*	*0.065*
Construc. age (> 5 years)												
coeff.	-0.241***	-0.387***	-0.484***	-0.084**	-0.195***	-0.232***	-0.061***	-0.169***	-0.122***	0.053	-0.011	-0.066
Std. error	*0.046*	*0.035*	*0.032*	*0.034*	*0.029*	*0.030*	*0.037*	*0.033*	*0.035*	*0.052*	*0.046*	*0.046*
House												
coeff.	-0.090*	0.266***	0.043	-0.053**	0.311***	0.148***	-0.080***	0.268***	0.201***	0.143***	0.552***	0.500***
Std. error	*0.039*	*0.030*	*0.029*	*0.026*	*0.023*	*0.025*	*0.028*	*0.026*	*0.027*	*0.035*	*0.033*	*0.034*
Bakery (log)												
coeff.	-0.045	-0.022	-0.044***	0.000	-0.016	-0.030**	-0.001	-0.009	0.005	0.004	0.002	-0.041**
Std. error	*0.023*	*0.017*	*0.016*	*0.014*	*0.013*	*0.013*	*0.015*	*0.014*	*0.014*	*0.019*	*0.017*	*0.019*
Shops (log)												
coeff.	0.011	0.026***	0.047***	0.003	0.020***	0.028***	-0.008	0.002	0.021***	-0.013	-0.007	0.014*
Std. error	*0.010*	*0.007*	*0.006*	*0.006*	*0.006*	*0.006*	*0.007*	*0.006*	*0.006*	*0.009*	*0.008*	*0.008*
Cinema (log)												
coeff.	-0.037	0.114	0.157**	0.126**	0.078	0.019	0.082	0.043	-0.076	-0.003	-0.049	-0.082
Std. error	*0.109*	*0.077*	*0.072*	*0.064*	*0.059*	*0.064*	*0.069*	*0.066*	*0.075*	*0.087*	*0.084*	*0.087*
Median income (log)												
coeff.	0.588***	0.632***	0.536***	0.425***	0.423***	0.263***	0.204***	0.311***	0.178***	0.026	0.029	-0.149*
Std. error	*0.099*	*0.070*	*0.067*	*0.067*	*0.056*	*0.059*	*0.074*	*0.063*	*0.066*	*0.091*	*0.077*	*0.080*

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SPC	High managerial			Intermediate managerial			Office workers			Manual workers		
Age (year)	**< 30**	**30 to 45**	**> 45**	**< 30**	**30 to 45**	**> 45**	**< 30**	**30 to 45**	**> 45**	**< 30**	**30 to 45**	**> 45**
Dist. to Train station												
coeff.	-0.007	-0.011***	0.003	0.002	-0.003	-0.004	-0.004	-0.003	-0.006*	-0.004	-0.001	-0.004
Std. error	*0.005*	*0.004*	*0.003*	*0.003*	*0.003*	*0.003*	*0.004*	*0.003*	*0.003*	*0.004*	*0.004*	*0.004*
Time to -Paris by train												
coeff.	-0.007***	-0.006***	-0.001	-0.004***	-0.005***	-0.002**	-0.004***	-0.004***	-0.001	0.000	0.000	0.000
Std. error	*0.002*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*
Dist. to Employment area												
coeff.	0.002	0.003**	0.000	0.003**	0.004***	0.002**	0.002	0.001	0.003*	0.007***	0.005***	0.004*
Std. error	*0.002*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.002*	*0.001*	*0.001*	*0.002*	*0.002*	*0.002*
Dist. to High school												
coeff.	-0.008	-0.008**	-0.015***	-0.007**	-0.003	-0.004	0.005	0.004	-0.002	0.002	-0.003	0.001
Std. error	*0.005*	*0.004*	*0.004*	*0.003*	*0.003*	*0.003*	*0.003*	*0.003*	*0.003*	*0.004*	*0.004*	*0.004*
Dist. to Hospital												
coeff.	0.012	-0.010	-0.024***	0.012*	0.008	-0.008	0.010	-0.004	-0.014**	0.021***	0.008	0.001
Std. error	*0.010*	*0.007*	*0.007*	*0.006*	*0.005*	*0.006*	*0.007*	*0.006*	*0.006*	*0.008*	*0.007*	*0.007*
Dist. to Mall												
coeff.	-0.004	-0.014***	0.002	-0.004	-0.003	-0.006	-0.007*	-0.008*	0.001	-0.005	-0.008**	-0.010***
Std. error	*0.006*	*0.004*	*0.004*	*0.004*	*0.003*	*0.003*	*0.004*	*0.003*	*0.004*	*0.004*	*0.004*	*0.004*
Dist. to Urban park												
coeff.	-0.002	-0.004	-0.002	-0.005*	-0.007***	-0.001	0.001	-0.001	-0.006**	0.001	-0.002	0.001
Std. error	*0.004*	*0.003*	*0.003*	*0.002*	*0.002*	*0.002*	*0.003*	*0.002*	*0.002*	*0.003*	*0.003*	*0.003*

** if p < 0.10; ** if p < 0.05; *** if p < 0.01*

Appendix III. Chow test

We test, Ho: coefficients are *stable* (i.e. not significantly different) across groups.

a. Chow test across all groups

Purchaser categories	F(21, 39312)	Prob > F
1	2.83	0.00
2	9.93	0.00
3	29.51	0.00
4	8.09	0.00
5	4.45	0.00
6	4.71	0.00
7	9.22	0.00
8	4.20	0.00
9	4.14	0.00
10	10.46	0.00
11	11.61	0.00
12	6.04	0.00

b. Chow test across age groups for each SPC

	Purchaser categories	F(k, n-2k)	Prob > F
High managerial		F(21, 7361)	
	< 30	5.87	0.00
	30 to 45	3.48	0.00
	> 45	6.55	0.00
Intermediate managerial		F(21, 15095)	
	< 30	9.62	0.00
	30 to 45	3.34	0.00
	> 45	7.03	0.00
Office workers		F(21, 10647)	
	< 30	4.84	0.00
	30 to 45	2.36	0.00
	> 45	4.69	0.00
Manual workers		F(21, 6083)	
	< 30	3.52	0.00
	30 to 45	1.22	0.00
	> 45	2.79	0.00