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Using the Hedonic Approach to Value Natural Land Uses in an Urban Area: An Application to Geneva and Zurich

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Summary

We apply the hedonic model to the rental markets of the Geneva and Zurich urban areas, Switzerland, in order to assess the value of natural land uses and land use diversity. In order to construct variables to quantify land uses and patterns in the neighbourhoods of the buildings, we make use of the Zurich and Geneva geographic information system (GIS). Then, by merging these GIS-calculated neighbourhood variables with data on the dwellings' structure and noise exposure levels, we obtain a database of about 3 200 observations for each urban area. We find that proximity

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to various environmental amenities as well as their size in the surrounding areas has a statistically significant impact on rents. In addition, homogeneity in land use commands higher rents. The estimated impacts are relatively similar in the two regions.

Résumé

Dans cet article, nous appliquons la méthode hédoniste aux marchés immobiliers des régions urbaines de Genève et Zurich, Suisse, afin d'évaluer la valeur du paysage naturel et de sa diversité. En utilisant les systèmes d'information géographiques (SIG) de Genève et Zurich, nous construisons des variables permettant de quantifier les différents types de paysage naturel, ainsi que leur configuration, dans chacun des quartiers de ces deux régions. Ensuite, en fusionnant ces nouvelles variables SIG avec des données sur la structure des appartements et sur leurs niveaux d'exposition au bruit, nous obtenons une base de données d'environ 3 200 appartements pour chacune des régions urbaines étudiées. Nos résultats montrent que la proximité ainsi que la taille des différents types de paysage naturel ont un impact statistiquement significatif sur les loyers des appartements environnants. De plus, l'homogénéité du paysage dans les quartiers est valorisée par des loyers plus élevés. Les coefficients estimés sont relativement similaires dans les deux régions.

Keywords: Hedonic Model; Rental Market; Housing Market; Landscape Value; Geographic Information System (GIS).

Mots clés : Modèle hédoniste ; marché immobilier ; marché du logement ; valeur du paysage; Système d'Information Géographique (SIG).

J.E.L. : R14, R52, R31, D62

1. Introduction

Cities are growing almost everywhere and they are seen as powerful engines of economic growth. Yet, their sprawl is increasingly challenged, the emphasis now being placed on densification. However, city densification puts pressure on open urban spaces such as parks and forests. Those green areas are essential for the beauty of the urban landscape and for air and water quality in the city. They provide opportunities for recreation and relief from urban stress and congestion to city dwellers. Thus, green areas are just as vital for their well-being as the density of built amenities. Reason enough for the Smart Growth Network to defend urban greens and mixed land uses (see Congress of New Urbanism, 2002). In the trade-off between preserving open urban spaces and developing housing and business surfaces, economic arguments play a central role. To give green areas a chance, it is essential to assess their value. This research aims at supporting policies preserving or improving the quality of the urban natural and built environment in order to meet economic, environmental and social needs of current and future generations.

The economic literature proposes various methods for assessing the value of non-marketed goods such as environmental quality (for a survey, see e.g. Mäler and Vincent, 2006). Among the methods based on revealed preferences, the hedonic approach is a very popular one (see Boyle and Kiel, 2001; Navrud, 2002). The seminal work of Rosen (1974) provides the theoretical foundation of the property-hedonic model, by assuming that heterogeneous goods are valued for their utility-bearing characteristics. Given the key assumption that the housing market is competitive (see Freeman, 1993), the equilibrium hedonic price schedule P results from the market interaction between households' willingness to pay for the housing characteristics and landlords' costs for providing them, and is given by the vector of the house characteristics, z, $P = P(z)$ (see Palmquist, 1999). The vector of characteristics z is often decomposed in a vector of structural (for example the number of rooms), accessibility (such as the proximity to an urban park), neighbourhood (for example proportion of green areas) and environmental quality (such as quietness) variables. Hence, even if there is a missing market for environmental quality (such as open spaces), by unbundling the housing product it is possible to assess the (implicit) value that individuals are revealing by their (explicit) choice in the housing market. Surveys of the hedonic approach literature applied to housing markets are provided by e.g. Bateman *et al.* (2001), Day (2001), Palmquist (2005) and Sheppard (1999).

The economic valuation of land uses is a relatively recent development in the hedonic literature. A recent survey on this topic by McConnell and Walls (2005) shows that the early studies on the value of urban open spaces focused generally on the presence of urban parks and simply used dummy variables indicating a nearby location. In contrast, latest studies characterise more precisely the open spaces, by differentiating them by land use types and by accounting for their size (see e.g. Lutzenhiser and Netusil, 2001; Anderson and West, 2006). In addition, starting with the contribution of Geoghegan *et al.* (1997), a few papers in the literature focus on the impact of land use patterns on housing prices. Referring to the ecology domain, this literature uses various spatial land use indices measuring e.g. land use diversity, fragmentation and contagion (see also Dumas *et al.*, 2006). The expected impact of land use patterns on house prices is *a priori* not known, since a higher diversity may imply in some cases potential proximity to various desirable activities (such as recreation, shopping, workplaces), whereas in other cases it might lower housing prices, if it is associated with undesirable activities or chaotic land use. Geoghegan *et al.* (1997) show that land use diversity and fragmentation in the immediate neighbourhood of the properties have generally a negative impact on their prices, while the impact is reversed for the highly developed suburbs (of Washington DC) of their sample. Using the same diversity index and an additional one measuring "richness" of land use, Acharya and Bennet (2001) confirm that the presence of open spaces increases property prices, while diversity and richness decrease them. On the same topic, Song and Knaap (2004) analyse the impact of the land use diversity on the property value of single-family houses in Washington County, Oregon. They account for the proximity of the different land uses, their percentage in the neighbourhood, as well as a diversity index. They find that the proximity to public parks and to commercial area increases property value of single-family houses, while property prices are higher in neighbourhoods dominated by single-family residential land use, in which non-residential land uses are evenly distributed. Therefore, despite the premium associated with accessibility to parks and to commercial uses, they find that property owners still value homogeneous single-family residential neighbourhoods.

In Switzerland, there are numbers of studies applying the hedonic approach to the Swiss rental or real estate markets. While Rieder (2005) and Fahrländer (2006) specify nation-wide hedonic models, most of these studies are region specific and focus on the valuation of a particular environmental amenity. For instance, the impact of road traffic or airport noise on the rental/housing market, is studied in Baranzini and Ramirez (2005) and Baranzini *et al.* (2006) using data from Geneva; Grosclaude and Soguel (1992) from Neuchâtel; Pommerehne (1987) from Basle; Iten and Maibach (1992), Sommer *et al.* (2000), Salvi (2003) and Banfi *et al.* (2006) from Zurich. Salvi *et al.* (2004) and Baranzini and Schaerer (2007) assess the value of view on the Zurich property prices and Geneva rents, respectively, whereas Tangerini and Soguel (2004) analyse the value of the landscape in the Alps for both residents and tourists. However, in spite of the relatively important international literature on the impact of the land uses on the housing market, there exists no study that addresses this question explicitly in Switzerland. Consequently, in this paper we apply the hedonic model to assess the value of land uses in the Geneva and Zurich rental markets. While considering these two major Swiss urban areas will allow inter-regional comparisons, the choice of Geneva and Zurich is also dictated by their similar morphology (end of lake location), their world-top ranking in terms of quality of life [1], the relatively large rental market, and by the fact that for both we can access several rich databases, including Geographical Information System (GIS) data. After merging datasets from different sources, and by adding GIS data, we obtain a relatively large sample of about 3 200 dwellings in each of the two urban areas.

The paper is organised as follows. In Section 2, we discuss how we constructed the land use and diversity variables and we present the datasets. The results are discussed in Section 3, while we conclude in Section 4.

2. Land Use Variables and Datasets Description

Since in this paper we concentrate on an urban context, we focus the analysis on the municipality of Zurich and on the Greater Geneva area [2]. The two urban areas are of relatively comparable sizes of about 64 square kilometres for Geneva and 92 square kilometres for Zurich, contained in a radius of about 6 kilometres. We divide the urban areas into different districts, by using administrative sub-areas boundaries of the municipalities. As a result, the Greater Geneva is divided into 14 districts, which have a mean surface of 4.56 square kilometres, and Zurich is divided into 12 districts, with a mean surface of 7.6 square kilometres. Differences of relevance between the two regions are that the Canton of Zurich is larger (1 729 square kilometres) than the Canton of Geneva (282 square kilometres), but population density is much higher in Geneva (1 525 persons per square kilometre) compared to Zurich (736). Moreover, in the Zurich Canton, in addition to the main Lake of Zurich, there are two small lakes (one of which is in the region under consideration), whereas there is only one lake in Geneva. Finally, in the areas considered for this study, the agricultural surface in Zurich is relatively small, representing 1 percent maximum of the district surface, while in Geneva the district with the maximum surface devoted to agricultural land use amounts to about 30 percent.

1. See http://www.citymayors.com/features/quality_survey.html
2. We use the Greater Geneva area instead of the municipality of Geneva alone, because this latter has a relatively small size (about 16 square kilometres) and is divided in four district divisions only.

2.1. Land Use Variables

The analysis of the impact of land uses in the two urban regions is performed by accessing GIS data and defining land use variables at the district level in which the building is located. The Information System of the Geneva Territory (SITG) and the GIS-centre of the Zurich office of land use regulation and measurement (ARV) [3] provide two very rich and well-developed GIS databases, from which we are able to differentiate various land uses in each region. Therefore, we are working with real land uses and not with planned areas. However, although the two regional land use maps are relatively similar, they do not present the same aggregation level for the different land uses. Consequently, for comparison purposes, and also to limit multicolinearity issues, we reduce the number of variables in both regions by grouping similar land uses. For both regions we define seven categories:

1. Forest area, which includes the delimited wood and forest areas in the land use maps of the two regions. For Geneva it also includes scattered trees.
2. Agricultural area.
3. Water area, which includes the water-covered surfaces (lakes and rivers).
4. Built area, which includes all the constructed areas (mixed and residential areas). In the case of Geneva, it includes scattered housing outside of the built areas.
5. Urban parks: natural parks, recreation parks, cemeteries as well as sport courts.
6. Transportation area, which include all area devoted to transport facilities, like roads, railways and airport. Note that in the Zurich region, the transportation surface cannot always be distinguished from the general built area.
7. Industrial area.

Figure 1 represents the seven above-defined land uses in the Geneva region (left) and Zurich region (right), at the district level.

Using these seven land uses categories, we compute two different types of variables.

Firstly, we calculate accessibility variables, which measure precisely the proximity to environmental amenities. We calculate the distance from each building to each one of the seven above-mentioned land uses, e.g. the distance from the building to the nearest urban park.

Secondly, based on landscape ecology, we compute neighbourhood variables and use them to characterise the pattern of land uses surrounding the buildings.

3. In German: GIS-Zentrum des Amtes für Raumordung und Vermessung des Kantons Zürich.

Those variables are computed as the percentage of each land use type in the neighbourhood of the building. We delimit the building's neighbourhood by the district boundaries in which it is located[4]. Then, referring to Geoghegan *et al.* (1997), we calculate a "land use diversity index", which measures the variety of the land uses in the vicinity of the buildings of our two samples:

$$H = -\sum_{k=1}^{K} (P_k) ln(P_k) \tag{1}$$

where P_k is the proportion of the area dedicated to land use k in the neighbourhood of the building, relatively to the total neighbourhood area. A larger value for H, indicates a more diverse landscape.

To be able to analyse the impact of the land uses on the housing markets of the two regions, these GIS-calculated variables are combined with data on the dwellings' characteristics.

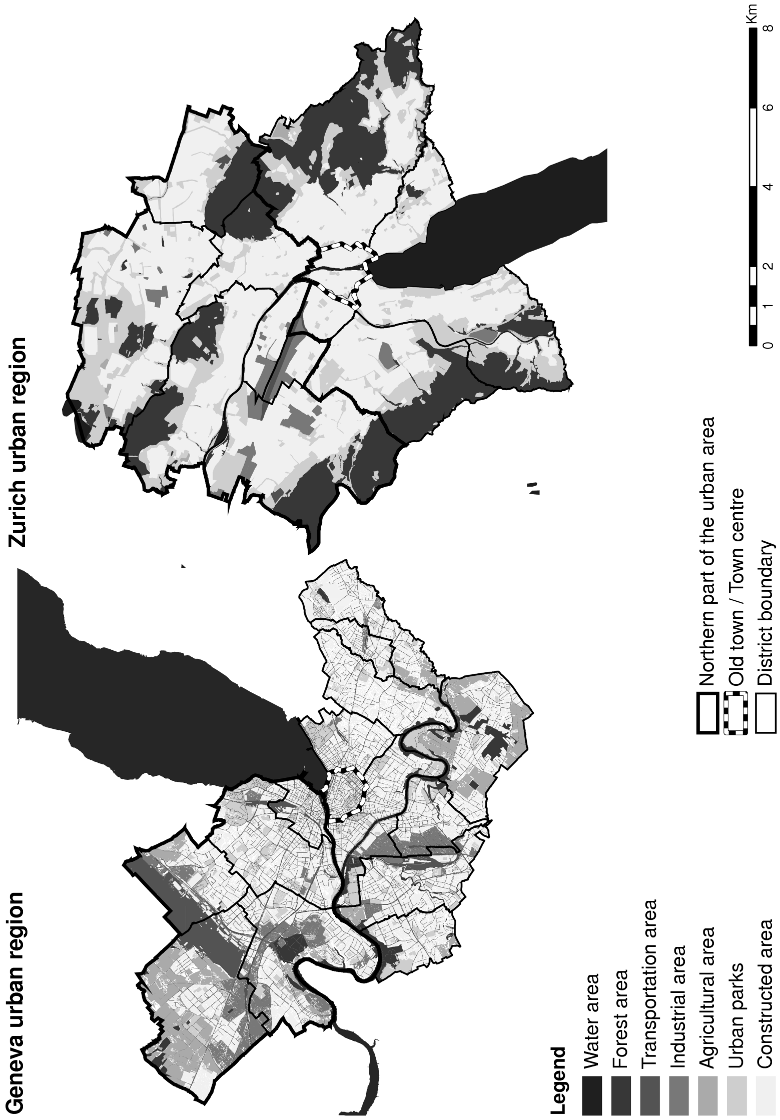
2.2. Dataset Description

The main source of data is the 2003 Statistical Information Survey on Rent Structure from the Swiss Federal Statistical Office. This dataset is based on a survey of 320 000 randomly selected households, in all regions of Switzerland (12 900 for the Zurich municipality and 15 001 for the Greater Geneva area) and contains detailed information on the rents, quality and quantity characteristics of the dwellings. In our analysis, we keep only the dwellings located in the municipality of Zurich, and those located in Greater Geneva area. From the original samples, we exclude the home-owners (who account for only about 10% of all households in the areas examined) and the recipients of special rent discounts, such as caretakers, relatives of the property owner, beneficiaries of housing subsidies and members of real estate cooperatives, in order to have comparable rents. Note that the dataset does not include single-family houses.

From the Cantonal offices of protection against noise of Geneva and Zurich, we obtained the yearly averaged daytime and night-time road traffic noises, expressed in the A-weighted decibel scale (dB(A)). The daytime noise level represents the equivalent continuous noise level averaged over 15 hours and averaged over 9 hours for the night-time noise level. The data refer to the level of noise caused by road traffic, measured at some fixed points, and then extrapolated for each facade of the buildings, using noise level curves.

4. Different definitions of "neighbourhood" have been used in the literature. Most commonly, the neighbourhood is delimited by the predefined administrative boundary in which the building is located (such as census blocks, postal codes or municipalities' boundaries). Other studies used a radius of different distances around each building (see Baranzini and Schaerer, 2007).

Figure 1 : *Illustration of land uses in the Geneva and Zurich urban regions.*



After merging all the information on the dwellings and noise levels with our GIS-calculated variables, dropping observations for which noise exposure is unreliable[5], as well as a few outliers using the Welsch distance criteria, we obtain two final samples of 3 327 observations for Geneva and of 3 194 observations for Zurich. Our samples are representative of the full Statistical Information Survey on Rent Structure, e.g. in terms of number of rooms and construction period. The descriptive statistics are reported in Table 1.

The mean gross monthly rent[6] in 2003 is somewhat lower in Geneva (about CHF 1 355) than in Zurich (about CHF 1 517), while the rent distribution is broader in Geneva[7]. The Zurich sample contains slightly older buildings than the Geneva sample: about 50 per cent of the buildings were constructed before 1946 in Zurich, while only about 38 per cent in Geneva. Conversely, the share of buildings constructed between 1960 and 1980 is higher in Geneva than in Zurich. The percentage of dwellings that have been totally renovated is comparable.

The percentage of buildings owned by a public entity (municipality, canton or confederation) is about the same in the two cities, while the share of privately owned buildings appears to be higher in Zurich (54 per cent against 23 per cent in Geneva). However, this difference might result from the higher share of "unknown ownership" reported in the survey in the Geneva region (41 per cent), a share which amounts only to 10 per cent in Zurich.

With a mean number of rooms of about 3, for a mean surface per room of 27 square metres, the size of the dwellings are about the same in the two urban areas.[8] Interestingly, the mean duration of residence in the same dwelling is quite long: about 13 years in Zurich and about 15 years in Geneva, with a very large distribution. Note that long-tenure dwellings are not concentrated in specific districts.

The accessibility variables to the different land uses have all a low mean, which illustrates that the studied regions are relatively small and dense. About 2 percent of the dwellings are located in the old part of each city. Concerning noise levels, the mean exposure to the daily road traffic noise amounts to 66 dB(A) in Geneva and to 67.5 dB(A) in Zurich, which exceed the legal limit of 60 dB(A) set in the

5. Observations for which the noise exposure lies above 75 dB(A) are dropped because noise measures at those levels are unreliable (see acoustic literature, e.g. Miedema et al., 1998; 2001). In the same vein, we restricted our samples to the observations for which the noise levels exceeded, or equalled, 55 dB(A) during the day, or 45 dB(A) during the night. These thresholds correspond to the planning regulations for housing areas in Swiss law (see Swiss Noise Abatement Ordinance, 1986, art. 43). See Baranzini et al. (2006) for a discussion about low exposure to noise levels and the use of scientific vs. subjective noise measures in hedonic models.

6. The gross rent includes the monthly charges for electricity and hot water, but excludes any extra charges for e.g. the use of a parking car.

7. Currently, CHF 1 = USD 0.83 or EURO 0.61.

8. The number of rooms includes living room and bedrooms, but excludes the kitchen and bathrooms.

Table 1 : *Descriptive statistics.*

	Geneva				Zurich			
	(N = 3 327)				(N = 3 194)			
Variables	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Structural Variables								
Gross monthly rent	1 355	615	200	9 396	1 517	644	236	6 600
Building was built before 1920	0,22	0,41	0	1	0,26	0,44	0	1
Building was built between 1920 & 1945	0,16	0,37	0	1	0,26	0,44	0	1
Building was built between 1946 & 1960	0,18	0,39	0	1	0,2	0,4	0	1
Built between 1960 & 1970	0,2	0,4	0	1	0,09	0,29	0	1
Built between 1970 & 1980	0,12	0,33	0	1	0,07	0,26	0	1
Built between 1980 & 1990	0,05	0,23	0	1	0,04	0,21	0	1
Built between 1990 & 2000	0,06	0,24	0	1	0,07	0,26	0	1
Totally renovated building	0,16	0,37	0	1	0,18	0,38	0	1
Elevator in the building	0,78	0,41	0	1	0,29	0,46	0	1
Floor level	3,58	2,51	0	19	2	1,97	0	46
Privately owned building	0,23	0,42	0	1	0,54	0,5	0	1
Publically owned building	0,03	0,17	0	1	0,05	0,23	0	1
Building belongs to a insurance or a pension fund	0,37	0,48	0	1	0,28	0,45	0	1
Ownership is unknown	0,41	0,49	0	1	0,1	0,31	0	1
Number of rooms	3,02	1,16	1	6	3,02	1,06	1	10
Surface per room (m2)	26,75	7,16	7	60	26,55	7,25	7	100
Dwelling with terrasse/garden	0,1	0,3	0	1	0,19	0,39	0	1
Penthouse dwelling	0,07	0,25	0	1	0,1	0,3	0	1
Balcony	0,62	0,49	0	1	0,7	0,46	0	1
Separated toilet	0,22	0,42	0	1	0,15	0,36	0	1
Duration of residence (years)	15,47	13,36	0	92	12,77	12,56	0	95
Aesthetic variables								
View on the lake	0,07	0,25	0	1	0,07	0,26	0	1
View on the mountains	0,46	0,5	0	1	0,23	0,42	0	1
Environmental variables								
Road traffic daytime noise (dB(A))	65,7	4,73	50	75	67,53	3,55	55	77
Accessibility variables								
Old town (dummy)	0,03	0,16	0	1	0,02	0,14	0	1
Northen part of the urban area	0,37	0,48	0	1	0,36	0,48	0	1
Distance to the lake (km)	1,7	1,26	0,05	5,98	1,84	1,15	0,05	5,68
Distance to nearest forest (km)	0,45	0,27	0,01	1,3	0,62	0,42	0,01	1,92
Distance to nearest park (km)	0,16	0,12	0	1,24	0,14	0,09	0	0,47
Neighbourhood variables								
Percent of water area	2,61	2,39	0	6	6,15	10,93	0	36
Percent of forest area	24,15	7,19	11	47	22,39	14,16	0	44
Percent of agricultural area	1,98	5,92	0	30	0,2	0,31	0	1
Percent of urban parks	12,89	5,39	4	21	19,12	6,75	4	31
Land-use diversity index	1,43	0,14	1,18	1,67	1,14	0,14	0,71	1,41

Swiss noise regulation for residential areas (Swiss Noise Abatement Ordinance, art. 43). However, the average noise level in our sample may overestimate the effective average noise exposure in the regions, because noise is often measured where the road traffic noise is suspected to be high.

The Statistical Information Survey on Rent Structure contains two questions asking whether or not the dwellers enjoy a view on the lake and on the mountains. Table 1 shows that the share of dwellings enjoying a view on the lake is about the same in the two regions, reflecting the fact that the morphology of both cities is similar. By contrast, the share of dwellings in the Geneva region benefiting from a view on the mountains (46 percent) is twice the one of Zurich. This is not surprising given that Geneva is wedged between two mountains (the Jura chain and the Mont Blanc Massif).

Concerning the neighbourhood variables, the percentages of forest area and urban parks land uses in the proximity of the sample buildings are almost the same in the two urban areas. As already mentioned, the major difference between them in terms of land uses is the share of agricultural surface, which is ten times greater in Geneva than in Zurich (2.0 percent vs 0.2 percent) and the percentage of water, which is smaller in Geneva. Indeed, the municipality of Zurich includes a small lake in its North. Finally, the mean and the distribution of the land use diversity index are slightly greater for Geneva, which implies that in our samples land use is more homogeneous in the Zurich area.

3. Results

In this section, we examine whether the Geneva and Zurich regions rental markets award a premium to those dwellings that are located in the vicinity of environmental amenities, and compare the results obtained for the two different regions.

The literature does not dictate any functional form for the hedonic equation, which has to be determined empirically. Box-Cox transformations of the dependent and independent variables were jointly and alternatively tested. The semi-logarithmic functional form appears to be the most adequate form. In fact, we allowed for a more flexible functional form by introducing the square of the duration of residence, in order to account for the non-linearity of the impact of the duration of residence on the rent[9]. More specifically, we estimate the following

9. As suggested by a reviewer, we (roughly) tested for the possible non linear impact of distances by considering the square of all the distances. However, all the square terms were not statistically significant and introduced problems of multicolinearity.

hedonic equation:

$$lnY_i = \alpha + \sum_{m=1}^{M} \beta_{im} S_{im} + \sum_{x=1}^{X} \delta_{ix} V_{ix} + \sum_{k=1}^{K} \gamma_{jk} A_{jk} + \sum_{z=1}^{Z} \lambda_{jz} E_{jz} + \sum_{k=1}^{K} \phi_{jk} N_{jk} + \mu_i \qquad (2)$$

where $ln\ Y_i$ is the natural logarithm of the 2003 monthly rent of dwelling i, S_{im} corresponds to structural or ownership characteristic m of dwelling i, V_{ix} stands for view indicator x from dwelling i, A_{jk} represents the accessibility to land use k from building j sheltering dwelling E_{jz} stands for the environmental characteristic z at building j, N_{jk} refers to the land use indicator k in the neighbourhood of building j, and μ_i is an error term reflecting all the unobservable.

For each of the two regions, we fit a hedonic equation and estimate two different models in order to determine for which environmental amenities households pay a premium or get compensation on the housing market. Model 1 is the base model, which in addition to the "classic" hedonic variables contains the accessibility variables and the road traffic noise exposure levels. In Model 2 we add the neighbourhood land use variables [10]. Note that, in order to account for unobservable at the district level, we divided the regions in two higher spatial level areas (North and South) and introduced one dummy accordingly [11]. The results are reported in Table 2.

The analysis of Pearson's correlations indicates that there are no significant dependencies between the explanatory variables. Moreover, the variance inflation factor (vif) tests confirm that there are no problems of multicolinearity in the models (e.g. the mean vif is 2.13 for Zurich and 2.56 for Geneva). In order to minimise heteroskedasticity, the White's consistent estimators of variances are used. The two models for the Geneva region explain about 65 per cent of the variance of rents in that region, while the model for the Zurich regions explains about 60 per cent of the rents' variance. We checked for the robustness of the results in two ways. Firstly, we estimated the models with other neighbourhood boundaries (the postal code division) and found that the coefficients are not statistically different from those used here (the administrative sub-areas boundaries). [12] Secondly, we performed a bootstrap estimation with 1 000 replications in order to check for the significance of the coefficients. Results, available upon request, show that our estimations are robust.

10. As expected, the F and LR tests rejected at the 0.01 level pooled models with the two regions together.

11. We thank one reviewer for suggesting this.

12. As pointed out by a referee, we acknowledge that this is not a proof that our results are not affected by the so-called modifiable areal unit problem (MAUP). In addition, in order to test whether a specific district drives the result on land use variables, we run our model alternatively by suppressing the observations from each sector in turn and tested whether the coefficients of the land use variables change significantly due to the exclusion of a particular sector. The results (available upon request) show that all the land use coefficients remain statistically the same as those in Model 2.

The comparison of the coefficients for the models within each of the two regions shows that the coefficients are remarkably stable across the two models and very similar between the two urban areas. Almost all the coefficients are statistically significant with the expected signs. Given the semi-logarithmic functional form of the estimated hedonic equation (2), the coefficients of the continuous variables represent semi-elasticities, i.e. the percentage change in the rent for a small change in the independent variables, all the other characteristics remaining the same. For instance, the results show that, all else equal, the surface per room has a positive impact on the rents amounting to 1.1 per cent per additional square metre per room in Geneva and to 0.8 per cent in Zurich. All the other coefficients can be interpreted in the same fashion, except the duration of residence. Since the duration of residence enters with a quadratic effect, the decreasing impact on rent amounts to –3 per cent in Geneva after 2 years of tenancy and to – 20.2 per cent by the mean duration of residence of 15 years. For Zurich, these rent discounts amount to –2.4 per cent after 2 years, and to –14.4 per cent after 13 years of residence in the same dwelling. This result confirms the suspicion that the rent is usually raised at changes in tenancy (see Thalmann, 1987).

For the dummy and the discrete variables, the coefficients are not directly interpretable. Indeed, as shown by Halvorsen and Palmquist (1980), those coefficients must be transformed using the formula ($e^{\beta} - 1$) to obtain the percent change in the dependent variable. Therefore, for instance, a dwelling with a terrace or garden will be rented 8.9 per cent higher in Geneva, respectively 5 per cent higher in Zurich, while the rent differential for a balcony amounts to 2.9 per cent in Geneva and to 5.3 per cent in Zurich. Professionals in the Swiss urban rental markets consider that the existence of a second toilet in the dwelling or a separated one traduces generally a higher "standard living" of the dwelling. Our results confirm that dwellings with a separated toilet are, *ceteris paribus*, rented 8.6% higher in Geneva and 20.6% in Zürich.

Except for the floor level, which is not statistically significant in any of the two regions, the coefficients obtained for the structural variables are very similar to results obtained in other studies focusing on these two Swiss rental markets (see e.g. Baranzini *et al.*, 2006, for Geneva; and Banfi *et al.*, 2006, for Zurich). Although the floor level is not significant, it is interesting to note that the interaction between the floor level at which the dwelling is located and the presence of an elevator in the building is statistically significant with the expected sign in Zurich. Note that Swiss building managers often charge a constant premium per floor level, when there is an elevator. Younger buildings generally command higher rents, although there is a small discount in buildings built in the last ten years. This reflects the supply side, as construction and particularly land prices declined after the boom of the 1980s.

Concerning the impact of noise on rents, an increase by 1 dB(A) reduces the rent by 0.2 per cent on average in the Geneva region and by 0.38 per cent in the Zurich region, although the coefficients are not statistically different at the 5 per cent level. The impact of noise on rents is slightly reduced once the neighbourhood variables are introduced in Model 2. Those results are comparable, although in the lower range of impacts, with those obtained by Iten and Maibach (1992), Sommer *et al.* (2000), and Banfi *et al.* (2006) for the Zurich rental/housing market, and by Baranzini and Ramirez (2005), Baranzini el al. (2006) and Baranzini and Schaerer (2007) for Geneva.

Table 2 : *Results of the estimations*

	Geneva		Zurich	
	Model 1	Model 2	Model 1	Model 2
Dependent variable: ln(gross monthly rent)	Coefficient	Coefficient	Coefficient	Coefficient
Structural Variables				
Built between 1960 & 1970	0,023* (0,013)	0,023* (0,013)	−0,008 (0,014)	−0,010 (0,014)
Built between 1970 & 1980	0,049*** (0,013)	0,053*** (0,013)	0,036** (0,017)	0,038** (0,017)
Built between 1980 & 1990	0,157*** (0,017)	0,159*** (0,017)	0,174*** (0,018)	0,175*** (0,018)
Built between 1990 & 2000	0,091*** (0,018)	0,095*** (0,018)	0,116*** (0,017)	0,118*** (0,017)
Totally renovated building	0,036*** (0,012)	0,037*** (0,012)	0,108*** (0,012)	0,106*** (0,012)
Elevator in the building	0,056*** (0,018)	0,049*** (0,018)	0,038** (0,016)	0,037** (0,016)
Floor level	−0,000 (0,004)	−0,001 (0,004)	−0,003 (0,004)	−0,003 (0,004)
Floor level x Elevator	0,001 (0,005)	0,002 (0,005)	0,012** (0,006)	0,012** (0,006)
Privately owned building	0,056*** (0,011)	0,055*** (0,011)	0,084*** (0,009)	0,082*** (0,009)
Number of rooms	0,253*** (0,005)	0,253*** (0,005)	0,209*** (0,006)	0,208*** (0,006)
Surface per room (m^2)	0,011*** (0,001)	0,011*** (0,001)	0,008*** (0,001)	0,008*** (0,001)
Dwelling with terrasse/garden	0,085*** (0,015)	0,084*** (0,015)	0,049*** (0,013)	0,049*** (0,013)
Penthouse dwelling	0,094*** (0,020)	0,093*** (0,020)	0,057*** (0,019)	0,054*** (0,019)
Balcony	0,026*** (0,010)	0,025** (0,010)	0,052*** (0,011)	0,054*** (0,011)
Separated toilet	0,083*** (0,011)	0,080*** (0,011)	0,187*** (0,015)	0,187*** (0,015)
Duration of residence (years)	−0,015*** (0,001)	−0,015*** (0,001)	−0,013*** (0,001)	−0,013*** (0,001)
Square of the duration of residence (x 100)	0,013*** (0,002)	0,013*** (0,002)	0,012*** (0,002)	0,012*** (0,002)

Table 2 : *Results of the estimations (continued)*

		View Variables		
View on the lake	0,065*** (0,019)	0,063*** (0,019)	0,081*** (0,019)	0,068*** (0,019)
View on the mountains	0,010 (0,010)	0,012 (0,010)	0,004 (0,013)	0,004 (0,013)
		Environmental Variables		
Road traffic daytime noise (dB(A)) (x 100)	–0,204** (0,095)	–0,166* (0,096)	–0,381*** (0,119)	–0,369*** (0,121)
		Accessibility Variables		
Old town (dummy)	0,096*** (0,034)	0,079** (0,037)	0,088** (0,038)	0,078* (0,044)
Northen part of the urban area	0,022** (0,010)	–0,015 (0,014)	–0,014 (0,011)	0,004 (0,012)
Distance to the lake (km)	–0,027*** (0,004)	–0,014** (0,001)	–0,020*** (0,004)	–0,016*** (0,005)
Distance to nearest forest (km)	–0,081*** (0,019)	–0,052** (0,002)	–0,055*** (0,011)	–0,042*** (0,015)
Distance to nearest park (km)	–0,056 (0,039)	–0,069* (0,004)	0,130*** (0,049)	0,107** (0,050)
		Neighbourhood Variables		
Percent of water area (x 100)		–0,023 (0,273)		0,223*** (0,073)
Percent of forest area (x 100)		–0,135 (0,098)		0,149*** (0,049)
Percent of agricultural area (x 100)		0,231* (0,119)		4,394** (1,995)
Percent of urban parks (x 100)		0,560*** (0,108)		–0,165 (0,109)
Land-use diversity index		–0,120** (0,050)		–0,053 (0,053)
R^2	0,649	0,651	0,601	0,604
N	3327	3327	3194	3194

Notes: *** significant at the 0.01 level; ** significant at the 0.05 level; * significant at the 0.10 level; standard errors in brackets. The reference for the period of construction is a building built before 1960. The reference for the privately owned buildings is all the other buildings (publicly owned, owned by an insurance or pension fund, owner unknown).

In Model 1, the premium associated with a view on the lake is on average higher in Zurich than in Geneva. However, after the land use characteristics of the neighbourhood are added in Model 2, the coefficients of the lake view are almost the same in the two regions. The positive impact of view on residential values has been found in the majority of the studies focusing on the aesthetic benefits of landscapes (see e.g. Bourassa *et al.*, 2004). By contrast, we note that the coefficients associated with the view on the mountains are not statistically significant. This latter result is quite surprising and in contradiction with previous studies by Rieder (2005) and Baranzini *et al.* (2006), which both found that the view on the mountain implies an increase in rents by respectively 0.7 per cent and 2.6 per cent on average. However, the results of those studies are not directly comparable. Indeed, Rieder (2005) considers Switzerland as a unique housing market, applying spatial econometric techniques in order to account for rent differentials at the regional level, while Baranzini *et al.* (2006) use data for the whole Canton of Geneva. In addition, Salvi *et al.* (2004) for Zurich and Baranzini and Schaerer (2007) for Geneva analyse the impact of the view on the housing market. Both studies find a statistically significant impact of the lake view, while Baranzini and Schaerer (2007) find also a significant impact for the view on the mountains. However, the results of those papers are again not comparable since the view variables were calculated using the functionalities of GIS rather than based on survey data.

Concerning the GIS-constructed accessibility and the neighbourhood land use variables, added in Model 2, note that some accessibility and neighbourhood variables (e.g. distance to the nearest agricultural area, percentage of land devoted to transportation and to constructions) are dropped due to correlation with another variable. However, the seven different types of land uses were accounted for in the calculation of the land use diversity index. To account for the accessibility to city centre, but in order to avoid correlation problems, we do not introduced a variable for the distance to the centre, but instead a dummy indicating whether the dwelling is located in the old town (or city centre) [13]. On average, being in the city centre commands a premium of 10.5 per cent in Geneva and to 9.1 per cent in Zurich.

Dwellers of both regions are willing to pay a premium to live close to the large lake bordering the city, but the percentage of water area in the neighbourhood has a statistically significant impact on rents only in Zurich, where there is another small lake. Similar results can be found in the literature, see e.g. Mahan *et al.*, 2000. The proximity and extent of forest area influence also positively the rents in Zurich. For Geneva however, although the proximity to a forest has a positive impact on rents, the percentage of forest area has a negative, albeit not significant coefficient. This kind of ambiguous results can also be found in the literature concerning the impact of forest area on rents or property prices. For example, Tyrväinen (1997) showed that although the size of forest area increases apartment prices in Joensuu, Finland, proximity to a forest lowers them. She explained that result by the possible shading effect of dense forests on nearby houses. This

13. Since the distance to the lake and distance to city centre are highly correlated, which introduces multicolinearity problems, we decided to keep only the distance to the lake in our estimations and to introduce a dummy "old town" to account for the proximity to the urban centre. Nevertheless, it is possible that the coefficient of distance to the lake still captures some impacts related to the distance to the city centre.

interpretation seems to be confirmed by Garrod and Willis (2002), who found that deciduous trees increase house prices located near them, while spruce conifers decrease them.

From Table 2, we observe that the impact of the share of agricultural area in the neighbourhood is positive and statistically significant in both regions. The relatively high coefficient for Zurich is probably due to the higher scarcity of agricultural land, as the maximum surface percentage of agricultural areas among the districts amounts to 1 per cent only (see Table 1).

Concerning the proximity and percentage of land devoted to urban parks, they have a positive impact on rents in the Geneva region, while in Zurich the reverse is observed, although the associated coefficients are not significant. In fact, Lutzenhiser and Netusil (2001) distinguished between three categories of parks, namely the "urban" parks (devoted mainly to non-natural recreation activities, such as sport courts), "natural area" park (consisting above all of natural vegetation), and "specialty" parks (dedicated primarily to a special activity, e.g. a boat ramp facility). The authors show that, in Portland, Oregon, while the proximity and size of natural or speciality parks induce higher property prices, the proximity to an urban park decreases them, although the size of the urban park has a positive impact on prices. Other studies have confirmed that urban parks may command a lower housing price given the negative externalities resulting from busy recreation activities in those parks (e.g. see Schultz and King, 2001). Remembering that our "urban parks" include natural parks, recreational parks, cemeteries as well as sport courts, a more stable result could be obtained by differentiating between those types. Unfortunately, the data do not allow us to perform this distinction.

Finally, we find that the coefficients of the land use diversity indices are negative in both urban areas, but statistically significant only in Geneva. These results are in line with what was found by Geoghegan (1997), Acharya and Bennet (2001), and Baranzini and Schaerer (2007) for the Canton of Geneva. Homogeneity in land use thus commands somewhat higher rents.

4. Conclusion

Using a hedonic approach, the aim of this paper was to develop, test and compare the impact of land uses on the two Swiss urban rental markets of Geneva and Zurich. To our knowledge, this paper is the first empirical comparison of land use valuation performed on the Swiss urban rental market using the hedonic model. After calculating precise measures of land uses in the neighbourhoods of each building, we estimated two different hedonic models for each region: to a relatively classic hedonic model, we added type-specific land uses variables as well as a land use diversity index.

Our results show that land use variables significantly affect Geneva and Zurich regions’ rents, in addition to the mere proximity of the different land use types. The estimated impacts are relatively similar in the two regions. More precisely, we find that proximity, size and view on water amenities increase rents in Zurich. Similar results are obtained for Geneva, except that the size of water area in the neighbourhood is not significant. The proximity to forest as well as its size in the neighbourhood implies a higher rent in Zurich, while only the proximity of forest (and not its size) is rewarded on the Geneva rental market. The size of the agricultural area in the neighbourhood increases rents unambiguously in Geneva and Zurich, while there are some differences concerning the urban parks. In Geneva, the proximity and the size of urban parks in the neighbourhoods act positively and significantly on the rents, whereas they are not significant in Zurich. Finally, we find that diversity in land uses in the building neighbourhood has a negative impact on rents in the Geneva region.

We are currently working to expand this paper by including socio-economic characteristics of the households in order to test for the presence of spatial concentration (socio-economic segregation), and in that event to determine whether this socio-economic pattern has an impact on rents, in addition to land uses patterns. This will also allow us to analyse if some categories of households in Geneva or Zurich are more exposed to environmental nuisances than others, without adequate compensation through lower rents. This future research will open the doors to discussing the existence of a household effect (cf. price discrimination) and/or a neighbourhood effect (cf. prejudice) on the Geneva and Zurich rental market.

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