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A Sight for Sore Eyes:
Assessing the Value of View and Land Use in the Housing Market

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Abstract

We apply a hedonic model to the Geneva-Switzerland rental market to assess the value of view from dwellings and of land uses around buildings. Using a geographic information system, we calculate three-dimensional view variables, accessibility and land use variables. To our knowledge, this is the first paper to develop precise view measures at the dwelling level, considering surrounding land uses, in an urban context and with a large sample of 13,000 observations. The results show that view of various environmental amenities and its size has a significant impact on rents. The estimated rent premium for a dwelling located in a neighbourhood with an extended surface of water can be as high as 3 percent, and a view of water-covered area can raise rent up to 57 percent.

JEL classification: Q5, R14, R52, R31, D62

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1 Introduction

Urban parks and forests, water resorts, lake shores, farmlands, and land use are residential amenities that contribute to the wellbeing of urban households. These amenities provide opportunities for recreation, relief from urban stresses and congestion, as well as view amenities to the residents of surrounding buildings. A number of studies have found that tenants and owners are willing to pay a premium for apartments or houses with a scenic view (e.g., Bond et al. 2002; Seiler et al. 2002) located in proximity to particular land use features (see McConnel and Walls 2005; Lutzenhiser and Netusil 2001).

Valuing natural land uses, especially in an urban context, can be useful for policy planning and decisions. Given cities development, there is growing pressure on natural land uses to satisfy the need for additional housing and commercial spaces. As urban sprawl is increasingly challenged, emphasis is now placed on city densification. Several movements have stimulated the debate over reorienting development practices to support neighbourhood diversity, accessibility of public spaces, and urban design accounting for pedestrians (e.g., Congress of New Urbanism 2002). Those often competing demands need to be balanced by city planners, and effective land use regulation policies should integrate the benefits of preserved open spaces.

The economic literature proposes various valuation methods to assess the value of urban features. One of the most widespread approaches refers to the hedonic method, which disentangles market information on house prices or apartment rents in order to obtain the implicit price of each characteristic of the housing bundle, including environmental amenities and landscape features. In other words, the hedonic method quantifies the premium residents are willing to pay to live in a dwelling that offers a comparatively better view and is located in an area possessing some particular urban features. However, using the hedonic model to quantify the value of environmental amenities requires data on the views from the dwellings and on the different land uses in the vicinity of the buildings. These variables are not particularly easy to characterise and measure. Traditionally, they are measured by subjective assessments either from direct site inspection or from household surveys, the disadvantage being that the resulting samples are relatively small (see Bourassa et al. 2004 for a survey). The extensive functionalities of geographical information systems (GIS) have only recently started to be used to quantify the size of the land uses and to assess more precisely view variables (see Bateman et al. 2001; Cavailhès 2008; Lake et al. 1998).

Using GIS capabilities, we develop three-dimensional quantitative measures of view at the dwelling level. Then, we introduce land use and view measures in a hedonic model of the Geneva rental market and quantify the premium residents are willing to pay for those characteristics. We focus on the Canton of Geneva, Switzerland, because it possesses a large rental market (about 85 percent of the dwellings are rental) with a relatively dense city and a more dispersed rural area. Moreover, several rich databases are accessible, including GIS data. In addition, evaluating the impact of view in the Geneva rental market is of particular interest since a new law that allows raising the height of the buildings in the city centre has very recently been accepted by popular vote. Therefore, the impact of the view obstructions on rents and the impact of view from high-rise buildings is of particular concern.

The paper is organised as follows. In Section 2, we briefly present the hedonic approach and review the literature focusing on open space and land use valuation in an urban context. Section 3 explains how we define the variables concerning view, land use, and diversity. Section 4 presents the dataset, Section 5 details the study's results, and Section 6 offers conclusions.

2 Assessing view and land use in the hedonics literature

Rosen's (1974) seminal work provides the theoretical foundations of the property-hedonic model by assuming that heterogeneous goods are valued for their utility-bearing characteristics. Therefore, the implicit prices of house attributes can be revealed from the observed prices of differentiated products and the quantities of characteristics associated with them. Given the key assumption that the housing market is competitive, rent, P, is determined by the implicit vector prices of the dwelling's characteristics, z, $P = P(z)$, which is the general form of the hedonic price model. These characteristics are often decomposed in a vector of structural (e.g., the number of rooms), accessibility (e.g., proximity to public transportation), environmental quality (such as noise), and neighbourhood (e.g., proportion of green areas) variables. Hence, the hedonic model is particularly useful for estimating the (implicit) value of a given landscape characteristic (such as proximity to or view of an urban park) for which there is no explicit market. Literature surveys of the hedonic approach applied to housing markets are provided by, for example, Bateman et al. (2001), Day (2001), Palmquist (2005) and Baranzini et al. (2008).

A relatively recent but fast-growing part of the hedonic literature concentrates on the value of preserved urban landscape, analysing the recreation use of urban open spaces or their aesthetic benefits. McConnell and Walls (2005) survey studies on the value of urban open spaces. Earlier studies often focused on urban parks by using dummy variables to indicate whether a house is located near them. Other studies characterise open spaces more precisely, differentiating by types and size. For instance, Lutzenhiser and Netusil (2001) consider three categories of parks in Portland, Oregon. They show that houses near natural or speciality parks (the primarily use of which is linked to a peculiar facility, for example boat ramp facilities) are more expensive, with price increasing based on park size. In contrast, proximity to an urban park decreases house prices, although the size of the urban park has a positive impact on prices (for forest areas, see Tyrväinen 1997; Tyrväinen and Miettinen 2000). In addition to distance, type and size, open space value may also depend on its status and ownership (on this topic, see Geoghegan 2002; Irwin 2002).

A quite separated strand of the hedonic literature focuses on the view amenity. A survey by Bourassa et al. (2004) shows that emphasis is placed on the valuation of water view (river, lake, sea and ocean), while other types of view, such as mountain or forest, have been analysed less frequently. This survey also indicates that dummy variables are frequently used to characterise the view from a property or an apartment. Those variables can illuminate whether or not a particular feature is visible from the property (see Bond et al. 2002; Seiler et al. 2002) or may include (see Benson et al. 1998) dwellers' subjective assessments of the quality of the view (full-quality view, poor partial view, and so on. Given that the view may also be interpreted as a proxy for access to a particular feature, distances are also included in the estimation. Therefore, in their studies of the impact of a lake view and on land on property values, Bourassa et al. (2004) and Samarshinghe and Sharp (2006) include indicators for the quality of the view (narrow, medium, and wide) as well as the distance to the coast for the properties that enjoy a water view. The majority of existing studies conclude that view has a positive impact on residential values; however, the more distant the view, the smaller the view premium.

Since most traditional studies on visual amenities generally rely on surveys, they are often characterised by relatively small samples. More recent literature overcomes this problem by exploiting the functionalities of GIS to develop sophisticated view indices. The papers using GIS data are thus not based on individual assessments; rather, they are based on quantitative measures of view and neighbourhood characteristics.[1] For example, Lake et al. (1998) and Bateman et al. (2001) use the functionalities of GIS to assess the impact of road development (noise and visual intrusion) on property prices. Bin et al. (2006) and Yu et al. (2007) used a similar methodology to measure view on the sea and estimate its impact on real estate prices. Interestingly, Cavailhès et al. (2008) do not only consider the landscape seen from the house, but also the view that others have of this house. They find that individuals are willing to pay a premium for a house with a view, but that being exposed to the view from other houses lowers its price. Moreover, they conclude that view has a greater influence on real-estate than the mere land use around the property. Paterson and Boyle (2002) calculate the percentage of visible land of each land use category within a radius of one kilometre around each property using GIS technology. However, their visibility measures are based exclusively on topographic data, i.e. they do not account for the objects that can impede the view. They find that visibility is an important environmental variable, omission of which could produce bias in the coefficient of other environmental attributes.

To our knowledge, there are only two studies focusing on the value of view characteristics on the Swiss housing market. Rieder (2005) considers Switzerland a single housing market and introduces dummy variables for lake view, river view and mountain view. He finds that having a view of a lake increases rents by 2.9 percent on average. Salvi et al. (2004) focus on the Zurich real estate market. They use the

[1] The problem of using perceived vs. measured variables is often encountered when using hedonics to assess environmental impacts. See Baranzini et al. (2010) for an analysis of the relationship between subjective and scientific noise measures and their use in a hedonic framework.

functionalities of GIS to calculate lake view and a general clear view at the hectare level. Their GIS-based view variables are defined using exclusively topographic data and are calculated at the hectare level, i.e. the same view value is associated to all buildings in a given hectare. They find that both general view and lake view have a significant positive impact on property prices, with the lake view proving to have a greater impact. In the following Section, we develop original measures of view amenities at the dwelling level and quantify the scope of different types of view by accounting for view impediments.

3 Constructing GIS-based landscape use and view variables

We calculate multiple variables characterising land uses surrounding each building by drawing on a very rich and well-developed GIS database – the Information System of the Geneva Territory (SITG). The SITG provides information on the types of land uses, topographic data, and height of the surrounding buildings and trees. In order to limit multicolinearity issues and to reduce the number of variables, we gather similar land uses into seven categories, sorted into two groups. The first group is called "natural environment" and is composed of tree-covered areas (trees and forests), agricultural areas, and water-covered areas (Geneva Lake and Rhone River). The second group refers to the "built environment" and contains buildings and built areas, urban parks (including sport courts), transportation areas (roads, railways and airport), and industrial areas.

Using the previous seven land use categories, we define the following two types of variables: neighbourhood and view. The neighbourhood variables are computed as the surface area of each land use type in a radius of one kilometre around each building. Then, using these surfaces, we refer to Geoghegan et al. (1997) and calculate land use diversity indices in order to define the land use pattern, i.e. the variety of the land uses in the vicinity of the buildings. The diversity index is calculated as follows:

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

where R_k is the proportion of the area dedicated to land use k in the neighbourhood of the building, relative to the total neighbourhood area, and s is the number of different land use types considered. The value of H varies between 0 and 1, a larger value for H

indicating more diverse landscape use. The expected impact of landscape pattern on house prices is *a priori* not known. For instance, increasing diversity may be preferred since it could imply proximity to various activities, such as recreation, shopping, and workplaces; on the contrary, high diversity can lower housing prices, if it is associated with chaotic land use planning. Geoghegan et al. (1997) and Acharya and Bennet (2001) find that landscape diversity in the immediate neighbourhood of the properties generally has a negative impact on their prices. We have constructed two different diversity indices, one considering only the natural land uses, i.e. water covered areas, tree-covered areas, and agricultural land, and another that refers only to the built environment (built areas, urban parks, transportation and industrial areas).

The calculations of the view variables are complex and time-intensive, since they have to account for a very large number of factors. We calculate them in accordance with Lake et al. (1998) and Bateman et al. (2001), but unlike existing literature, we define our view variables at the dwelling level. We combine a numerical terrain model that includes the topographic land profile with a surface numerical model, which accounts for the height of all the objects (e.g., buildings, trees). This allows us to construct a three-dimensional layer[2] that accounts for all the objects that can impede the view. Then, using complex queries, we are able to calculate the view in a radius of one kilometre[3] around the central point of each building. To be as precise as possible, the visible surface (the "viewshed")[4] is calculated for three different observer heights – from the ground floor level (1.8 metres above terrain height), from the middle of the building (half the difference between the building surface height and the terrain height), and at the attic level (1 metre less than the building height). By summing up all the visible cells, we obtain the total number of visible hectares in a radius of one kilometre around the building at the three different height levels. In Figure 1, we draw the viewshed for a given building from two different standpoints. The observer, who is symbolized by the

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[2] The pixel size is 1 m^2.

[3] Given the enormous amount of information that has to be taken into account in an urban context and the resulting heavy calculation time, we limited the view variable to the same scale as the land use variables, i.e. a radius of one kilometre around the building.

[4] The viewsheds are calculated using ArcGIS 9.2. For more information on the calculations, see http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Performing_a_viewshed_analysis.

blue line in the middle of the invisible building, is able to see the entire surface in green. Then, to determine which and how much of each land use type is visible, we overlay the visible surface with the seven land use covers. This allows us to calculate natural and built view diversity indices by applying equation (1). Finally, by using the viewshed methodology, we determine whether the dwelling has a view of the famous Geneva *Jet d'eau* (water fountain) and of the ancient cathedral. Since measuring the visible surface precisely does not make sense in this case, we define two dummy variables, taking the value of one if the measured view is positive.

The resulting ground, middle, or attic views are subsequently associated with each dwelling of a building according to the floor level at which it is located. This is done by assuming that each floor has a height of 3 metres and then associating the closest view (ground, middle, or attic).

[Insert Figure 1 about here]

Our view variables are the most precise measures that can be calculated using the available data. Indeed, our source databases provide information about the floor level at which the dwellings are located inside the buildings, but they do not indicate the exact position of the dwelling on each floor level (i.e. we know that the dwelling is situated on the third floor, but we do not know if it is, for example, on the left or right of the floor level) or the position of the dwelling's windows (e.g., backyard or front yard). Therefore, since our methodology reports all the visible hectares on a 360 degree base, it could well be that our calculations report a very nice lakefront view, while the dwelling only has a backyard view. Nevertheless, we have been able to cross-check our GIS-calculated view variables with a dummy-type view variable, available in the 2003 Survey on the rent structure from the Federal Statistical Office. In this survey, the respondents were asked to indicate whether or not they had a view of the lake, river, and/or mountains from their dwellings. Thus, to make sure that our GIS-calculated view variables are relevant, we transformed our variables, expressed as the number of hectares visible, into dummy variables to obtain two variables in comparable dimensions. We found that our GIS-calculated view variable is only inexact for 10 percent of the 7,395 dwellings in our database and surveyed by the Federal Statistical Office.

4 Dataset and descriptive statistics

Our main data source is the "Statistics on Rents in the Geneva Canton" for the year 2005, issued by the Geneva Cantonal Statistical Office. The sample of this annual survey covers more than 18,000 apartments in about 7,700 buildings, which represents almost 1/8 of the total number of dwellings rented out in the canton. It includes data on rents, year of construction, number of rooms, floor level, status of the apartment (private rental sector or public rental sector), and it specifies if there was at least one change of tenant in the last year. The database does not cover owners, individual homes, and buildings with less than three apartments. Moreover, the dataset does not include single-family houses. From the original statistics sample, the dwellings that belong to the public rental sector or to a housing cooperative were excluded, since the rents in those two sectors are often based on construction costs rather than on market conditions and therefore evolve in a quite different market segment. After merging all the information from this dataset with our GIS-calculated variables, we obtain a final sample of 12,932 complete observations. Our sample is representative of the full sample of the "Statistics on Rents in the Canton of Geneva", e.g., in terms of rents, number of rooms and construction period. The descriptive statistics are reported in Table 1.

The mean monthly rent in 2005 is about CHF 1,122[5] for the whole sample with a large variance. Most of the buildings in our sample were constructed between 1946 and 1970. Note that construction year takes major renovations into account. The mean number of rooms is about 3.6, which includes the living room, bedrooms and the kitchen.

We calculate accessibility variables to account for the precise location of the buildings in the Canton of Geneva. These variables represent the most popular and the relatively easiest application of GIS. Thus, as in Baranzini and Ramirez (2005), we calculate the distance from each building to the major public infrastructures, such as primary schools, public transport stops and the distance to city centre, which approximates the location of major economic activities. The small means of the accessibility variables illustrate that the Canton of Geneva is small and dense.

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[5] In June 2005, CHF 1 = USD 0.80 or EURO 0.65.

[Insert Table 1 about here]

The top of Figure 2 shows the mean value of the variable measuring the overall view of the land use surface in the neighbourhood (which amounts to about 1.5 ha, see the picture at the top left) and for its maximum value in the sample (about 131 ha, see the picture at the top right). The bottom of Figure 2 provides a two- and three-dimensional representation of the view calculated from the ground level (in blue) and from the attic level (in yellow).

[Insert Figure 2 about here]

From Table 1, we note that only 2 percent of the dwellings have a view of the Geneva *Jet d'eau* and 1.4 percent of the ancient cathedral. In addition, there are large differences between the land use surfaces and the corresponding neighbourhood view variables. For instance, the mean surface of lake and rivers within one kilometre around the building is equal to 20 hectares, while the mean view from the dwelling on the lake is 0.09 hectares. Similarly, the mean surface covered by urban parks within this distance is equal to 17 hectares, while the mean view on them is 0.04 hectares. Given those differences, in the next section, we will be able to assess whether it is the presence of an environmental amenity or the view of it that is rewarded in the housing market.

5 Empirical application and results

Since the theoretical literature does not dictate any functional form for the hedonic equation, it has to be determined empirically. Linear, semi-logarithmic, log-linear, as well as linear Box-Cox transformations are commonly used functional forms. Box-Cox transformations of the dependent and independent variables were jointly and alternatively tested, and the semi-logarithmic functional form appears to be the most adequate.[6] More specifically, we estimate the following hedonic equation:

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[6] Malpezzi (2002) highlighted the following five major advantages of the semi-logarithmic functional form: (i) the implicit price of a housing attribute is related to the quantity of the other housing attributes; (ii) the coefficients are easily interpretable in terms of semi-elasticity; (iii) it mitigates heteroskedasticity problems; (iv) it can be computed easily; and (v) some flexibility in the specification of the independent variables can be easily introduced.

$$\ln P_i = \alpha + \sum_{m=1}^{M} \beta_{im} S_{im} + \sum_{k=1}^{K} \gamma_{jx} A_{jx} + \sum_{k=1}^{K} \phi_{jk} N_{jk} + \sum_{z=1}^{Z} \delta_{iz} V_{iz} + \mu_i \quad (2)$$

where $\ln P_i$ is the natural logarithm of the 2005 monthly rent of dwelling *i*; S_{im} the structural characteristic *m* of dwelling *i*; A_{jx} the accessibility characteristics for building *j* to the public infrastructures *x;* N_{jk} the neighbourhood characteristics *k;* V_{iz} the view attributes *z* from dwelling *i*; and μ_i is an error term.

To determine which environmental amenities are rewarded in the housing market, we estimate three different models. The first model, Model 1, is the traditional model, which contains only the "classic" hedonic variables, i.e. the structural and accessibility variables. In Model 2, we add the overall neighbourhood and view variables on the natural and built environments as well as the diversity measures. In Model 3, we distinguish the different types of land uses. The results of the estimations of these models are reported in Table 2. There is no significant dependency between the variables, and the variance inflation factor (vif) test confirms that there are no problems of multicollinearity. The four models explain about 65 percent of the variance of rents in the Canton of Geneva.

The comparison of Model 1 coefficients with the two alternative models shows that the coefficients are remarkably stable across the models.[7] Indeed, based on statistical t-tests, the equality of the coefficients between the three models cannot be rejected. Therefore, in terms of prediction, we do not expect Models 2 and 3 to be globally more powerful than Model 1. To test the predictive power of our models, we perform 50 out-of-sample estimations, each containing 25 percent of the whole sample. We find a mean absolute value percent error of 21.67 percent with Model 1 and 21.46 with Model 3. These are error values comparable to those obtained in the literature using OLS (see Case et al. 2004). In the same vein, based on Bourassa et al. 2010, the percentage of prediction within 15 percent of the actual price is on average 44.56 with Model 1 and 44.94 with Model 3. However, Models 2 and 3 are better than Model 1 when

[7] Note that although the null hypothesis of the absence of spatial correlation is not rejected, the estimation of the three models using the spatial GMM estimator (Kelejian and Prucha, 1999) gives similar results as with OLS.

predicting rents for the apartments possessing view variables. Indeed, for the latter, the mean absolute value percent error is 24.14 with Model 1 and 20.19 with Model 3, while the percentages of prediction within 15 percent of the actual price are 38.12 and 48.62, respectively.

Almost all the variables are statistically significant and have the expected sign. 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 given unit change in the independent variables. For example, everything else being equal, an increase of 10 metres in the height of the building leads on average to a 3 percent decrease in the rent. 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^{β} – 1) to obtain the percent change in the dependent variable. Therefore, the rent of an attic dwelling is, for instance, on average about 7.2 percent higher than a dwelling located on lower floor levels. The impact of the building's year of construction behaves peculiarly, since on average, the rents of buildings built between 1946 and 1970 are lower than those built before 1946, while the rents of more recent buildings (since 1971) are higher. This result might arise from the fact that pre-war buildings were more massive with better sound and thermal insulation and more generous room dimensions than those that were rapidly built during the post-war housing boom.

[Insert Table 2 about here]

Note also that in case of a change in tenancy between 2004 and 2005, the 2005 rent is on average about 22 percent higher, which confirms the suspicion that landlords generally seize the opportunity to raise the rent at changes in tenancy (Thalmann 1987). Concerning the accessibility variables, proximity to primary school and public transport stops acts negatively on rent, while proximity to the city centre has a positive influence.

In Model 2, we add the general neighbourhood and view variables on natural and built environments and the corresponding diversity indices. The results reported in

Table 2 show that the surface and view of an additional hectare of natural landscape increases the rent. The magnitude of these coefficients indicates that the view of natural environment has a greater impact on rents than the mere presence of natural land use in the neighbourhood. A possible economic explanation could be that the view on natural environments is scarcer, as reported in Table 1. While the surface of the built area in the neighbourhood does not dictate a statistical impact on rents, the view on built land uses has a negative effect. Moreover, in general, the results of Model 2 show that the residents do not only value the presence of natural environmental amenities in their neighbourhood, but also their view of them. In this model, we also introduce diversity indices related to natural and built land uses. Table 2 reports that the surface and view diversity indices of the built environment have negative statistically significant coefficients. This means that, everything else being equal, a greater heterogeneity in the built environment decreases rent, which is in line with the results by Geoghegan et al. (1997) and Acharya and Bennet (2001). The diversity indices related to natural land uses have no significant impact on rents.

In Model 3, we more precisely investigate which type of neighbourhood and views have an impact on rents. We thus differentiate for the type of land use and view according to the various land use covers. Note that built and transportation areas are dropped from the estimation of Model 3, since these variables are highly correlated with other types of land uses. As expected, both the surface and the view on the water-covered areas have a positive impact on rents of 0.02 percent and 0.645 percent per additional hectare of lake/river, respectively. Interestingly, we can observe that while the coefficient of the view on agricultural land is not statistically significant, the size of this land use in the neighbourhood adds a premium to rents of 0.043 percent on average by additional hectare. This suggests that the presence of agricultural land in the neighbourhood has a positive influence on rents, whether visible or not.

The size of urban parks in the neighbourhood has positive impact on rents, while the view of these parks acts negatively. Lutzenhiser et al. (2001) and Schultz and King (2001) obtained the same results and they suggest that busy urban parks might generate negative externalities. As expected, the impact of industrial areas on rents is clearly negative, since the coefficients of their surface and view possess statistically negative coefficients.

Table 3 reports the impact on rents of the surface of, and view on, different land use types. The first column shows the impact on rents at the mean values of land use surfaces in the neighbourhood and at mean values of view of the different land uses. The second column indicates the maximum impact on rents of surface and view for the different types of landscapes. We observe, for instance, that the impact on rents of the surface of water-covered areas can be as high as 3.15 percent of the rent for the dwelling with the highest water-covered surface in its neighbourhood (i.e. about 165 ha as reported in Table 1), while the impact for the mean value of water-covered area (20 ha, see Table 1) is about 0.38 percent. The surfaces of agricultural area can increase the rent up to about 10 percent.

[Insert Table 3 about here]

From Table 3, we observe that a dwelling with the maximal view of a water area (88 ha) can generate a rent up to 57 percent higher than a dwelling without a view on water. Therefore, the view of water-covered areas has a much greater impact on the rents than the mere presence of surface water in the neighbourhood. However, we note that the relationship between the impact of the view and the land use surface depends on the variable; for instance, the maximum impact of the surface of, and view on, industrial areas are similar (for both it is approximately –19 percent), while the surface of and the view of urban parks has an opposite impact on rents.

In Model 3, we also introduce two GIS-calculated dummies to indicate the view of the famous Geneva *Jet d'eau* and of the ancient cathedral. The results show that the *Jet d'eau* implies a 3.6 percent rent premium, while the ancient cathedral commands a 7.4 percent premium.

6 Conclusions

The aim of this paper is to develop and incorporate original neighbourhood and aesthetic environmental variables in a hedonic model and to test their impact on Geneva's rental market. We compute precise measures of the view and land uses at the dwelling level in a radius of one kilometre around each building and test three different hedonic models. To the first "traditional" model, we add in model 2 overall neighbourhood and view variables as well as the corresponding diversity indices, and finally, model 3 includes type-specific neighbourhood and view variables. Our results show that both land use and aesthetic variables significantly affect Geneva rents. In particular, the size and the view of the natural environment increase rents, while the view of built environments lowers them. We also find that diversity indices of built environment land uses and of their views have a negative impact on rents. Looking at the various land uses more precisely, we find that size and view of water amenities increase rents. More precisely, the rent premium for a dwelling located in a neighbourhood with an extended water surface can be as high as 3 percent, while it can reach up to 57 percent for a view of water-covered areas. In comparison, the surface of agricultural areas in the neighbourhood of the building can increase rents up to about 10 percent, but a view of them does not have a significant impact. On the contrary, a view of urban parks affects rents negatively, as does a view of industrial areas. Finally, dwellings with a view of the famous Geneva *Jet d'eau* (water fountain) and of the ancient cathedral generate on average 3.6 and 7.4 percent higher rents, respectively.

This paper highlights the possibility to evaluate the increase of buildings' value resulting from an environmental improvement. Moreover, environmental quality, such as neighbourhood land use composition, their proximity and view, can be precisely measured at the dwelling and building levels. Therefore, accurate information about environmental quality would increase market transparency and would reward efforts to improve natural and built environments. Finally, our results can be of particular relevance in the context of urban densification, since they can be used to assess the impact of the view obstructions on rents and the impact of view from high-rise buildings.

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Table 1 Descriptive statistics (N = 12 932)

Variables	Mean	Std. Dev.	Min	Max
Mean annual net rent	13,462	6,307	2,760	96,000
Structural Variables				
Built between 1946 & 1960	0.238	0.426	0	1
Built between 1961 & 1970	0.254	0.436	0	1
Built between 1971 & 1980	0.198	0.398	0	1
Built between 1981 & 1990	0.129	0.336	0	1
Built after 1990	0.074	0.261	0	1
Number of rooms	3.602	1.271	2	12
Floor level	3.433	2.568	0	30
Height of the building (x10) *[meters]*	21.957	8.558	0	91
Attic dwelling	0.028	0.166	0	1
Tenancy change (in the past year)	0.075	0.264	0	1
Accessibility variables				
Distance to city centre *[km]*	2.529	1.906	0	13
Distance to nearest primary school *[km]*	0.213	0.111	0	1
Distance to nearest public transport stops *[km]*	0.128	0.065	0	0
Neighbourhood variables				
Surface of natural environment *[ha]*	120.382	39.132	15	284
Surface of built environment *[ha]*	173.203	42.204	16	250
Surface of water-covered area *[ha]*	19.836	30.330	0	165
Surface of agricultural area *[ha]*	14.912	38.980	0	239
Surface of urban parks *[ha]*	17.478	7.730	0	50
Surface of industrial area *[ha]*	7.508	12.034	0	105
Natural land use diversity index	0.476	0.114	0	1
Built land use diversity index	0.569	0.080	0	1
View variables				
View of natural environment *[ha]*	0.674	2.873	0	88
View of built environment *[ha]*	0.797	1.951	0	43
View of water-covered area *[ha]*	0.087	1.735	0	88
View of agricultural area *[ha]*	0.198	1.572	0	38
View of urban parks *[ha]*	0.043	0.223	0	6
View of industrial area *[ha]*	0.012	0.104	0	4
Natural view diversity index	0.297	0.103	0	1
Built view diversity index	0.366	0.116	0	1
View on *Jet d'eau* (dummy)	0.020	0.139	0	1
View on ancient cathedral (dummy)	0.014	0.119	0	1

Data source: Calculated using data from the Statistics on Rents 2005 and from SITG.

Table 2 Estimation results (N = 12 932)

	Model 1			Model 2			Model 3		
Dependent variable: ln(net annual rent)	Coeff.		(Std.err.)	Coeff.		(Std.err.)	Coeff.		(Std.err.)
Structural Variables									
Built between 1946 & 1960	-0.035	***	(0.008)	-0.035	***	(0.008)	-0.032	***	(0.008)
Built between 1961 & 1970	-0.065	***	(0.009)	-0.057	***	(0.009)	-0.053	***	(0.009)
Built between 1971 & 1980	0.063	***	(0.009)	0.065	***	(0.010)	0.069	***	(0.009)
Built between 1981 & 1990	0.186	***	(0.010)	0.185	***	(0.010)	0.190	***	(0.010)
Built after 1990	0.272	***	(0.011)	0.273	***	(0.011)	0.277	***	(0.011)
Number of rooms	0.238	***	(0.002)	0.238	***	(0.002)	0.238	***	(0.002)
Floor level	0.013	***	(0.001)	0.014	***	(0.001)	0.013	***	(0.001)
Height of the building (x10) *[meters]*	-0.003	***	(0.000)	-0.004	***	(0.000)	-0.003	***	(0.000)
Attic	0.056	***	(0.014)	0.058	***	(0.014)	0.059	***	(0.014)
Tenancy change (in the past year)	0.202	***	(0.009)	0.203	***	(0.008)	0.201	***	(0.008)
Accessibility variables [in km]									
Distance to nearest primary school	0.155	***	(0.000)	0.103	***	(0.000)	0.120	***	(0.000)
Distance to city centre	-0.018	***	(0.000)	-0.031	***	(0.000)	-0.020	***	(0.000)
Distance to nearest public transport stops	0.144	***	(0.000)	0.176	***	(0.000)	0.195	***	(0.000)
Neighbourhood variables [ha]									
Surface of natural land use (x 100)				0.065	***	(0.000)			
Surface of built land use (x 100)				-0.013		(0.000)			
Natural land use diversity index				-0.041		(0.029)			
Built land use diversity index				-0.197	***	(0.037)			
Surface of water-covered area (x 100)							0.019	**	(0.000)
Surface of agricultural area (x 100)							0.043	***	(0.000)
Surface of urban parks (x 100)							0.062	**	(0.000)
Surface of industrial area (x 100)							-0.177	***	(0.000)
View variables [ha]									
View of natural environment (x 100)				0.194	**	(0.001)			
View of built environment (x 100)				-0.380	**	(0.002)			
Natural view diversity index				0.022		(0.026)			
Built view diversity index				-0.074	***	(0.020)			
View of water-covered areas (x 100)							0.645	***	(0.001)
View of agricultural areas (x 100)							0.041		(0.002)
View of urban parks (x 100)							-2.911	**	(0.012)
View of industrial areas (x 100)							-5.214	**	(0.023)
View of *Jet d'eau* (dummy)							0.035	**	(0.017)
View of ancient cathedral (dummy)							0.071	***	(0.019)
Adjusted-R^2	0.6345			0.6412			0.6405		
F	1101			1003			1003		
Mean VIF	1.7			2.2			1.6		
Max VIF	2.9			6.9			3.0		

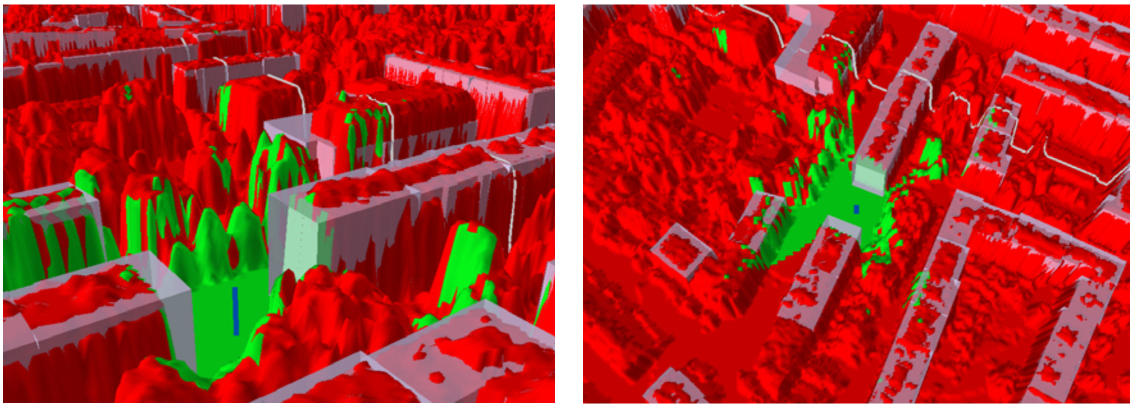
Notes: *** significant at the 0.01 level; ** significant at the 0.05 level; * significant at the 0.10 level. The reference for the period of construction is before 1946. Data sources: Statistics on Rents 2005 and SITG.

Table 3 Magnitudes of the impact on rents of different land use surfaces and views

Variables	Mean	Max
Surface of water-covered area [ha]	0.38%	3.15%
Surface of agricultural area [ha]	0.64%	10.34%
Surface of urban parks [ha]	1.08%	3.07%
Surface of industrial area [ha]	-1.33%	-18.57%
View of water-covered area [ha]	0.06%	56.67%
View of urban parks [ha]	-0.13%	-17.70%
View of industrial area [ha]	-0.06%	-19.31%

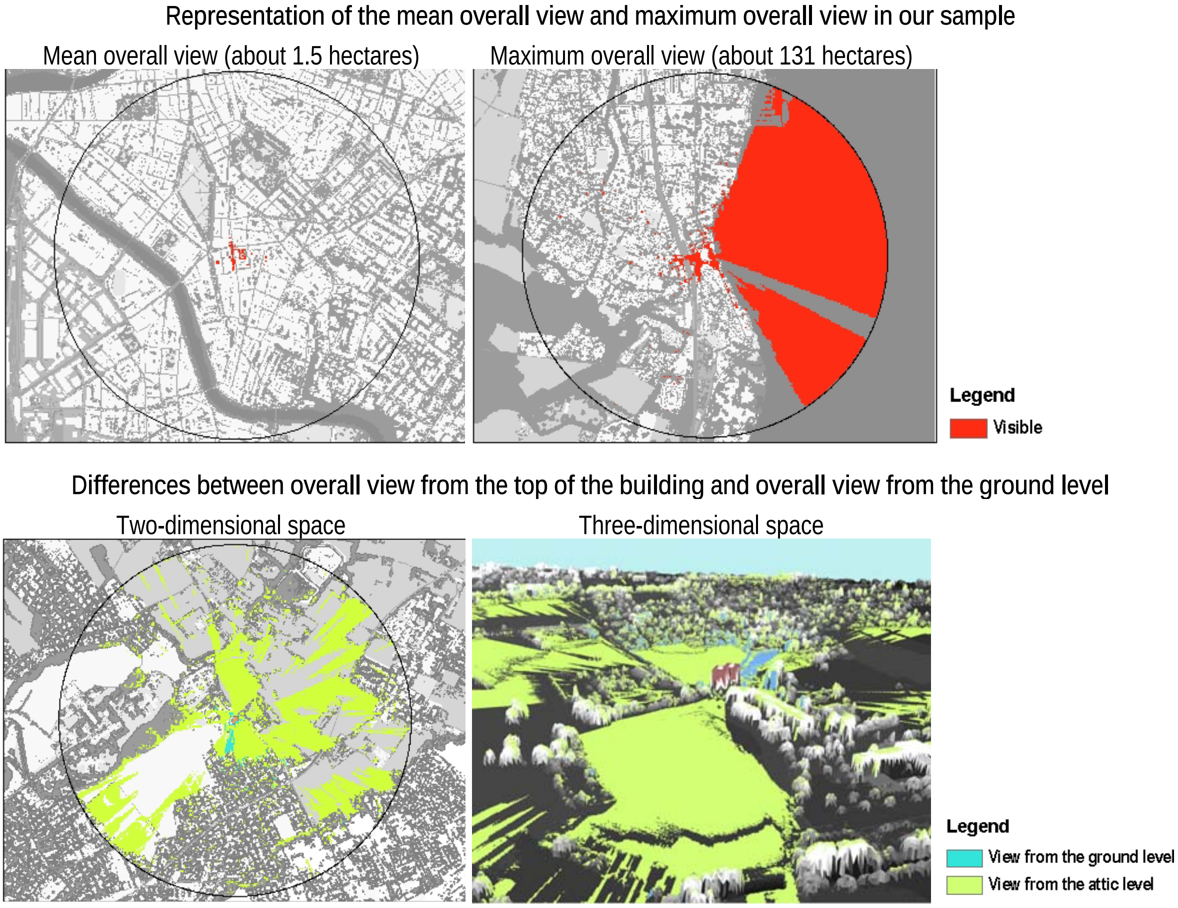
Note : The magnitude of the view of agricultural area is not reported, since the estimated impact on rent is not statistically significant.

Figure 1 Illustration of the view measure for a given apartment in our database



Source: Built using data from SITG.

Figure 2 Representation of the mean and maximum overall view in a one-kilometre radius around the building (top), and views from ground and attic levels (bottom)



Source: Built using data from SITG.