With Open Eyes: Neighborhood Aesthetics, Housing Prices and Residential Sorting

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Abstract

There is substantial evidence that visual perception influences consumption preferences, yet it remains unclear how this translates into housing markets. Research in psychology and neuroscience emphasizes that urban aesthetics can shape well-being, suggesting a potential link to demand. We propose a three-pronged approach to measuring urban aesthetics, incorporating low-level information-theoretical concepts such as symmetry and order, mid-level visual stimuli including street greenery, and high-level features reflecting cultural motifs, particularly architectural styles. Combining street view imagery data of houses with precise preservation records, we use these measures to estimate their effect on rental prices. To address endogenous supply, where wealthier neighborhoods have systematically more aesthetically pleasing characteristics, we leverage exogenous variation in the housing stock of East Berlin and Leipzig following the urban transformation after the German reunification. Our findings indicate a significant impact of historic housing features on rental prices. We differentiate between the aesthetics of one's own building and neighboring ones and discuss potential implications for residential sorting and neighborhood change.

JEL Classification: R21, R23, C81, D91

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1 Introduction

When walking through the streets of a city, we are exposed to numerous sensory expressions, both pleasant and unsavory, and a substantial part of our impressions comes from what we see. Each neighborhood or building block offers unique features that we may find more or less appealing. Understanding how these visual elements influence our preferences has long been a subject of interest. One might argue that beauty lies in the eye of the beholder, but research in various fields points to a common perception of aesthetics (Seresinhe et al., 2017, Saiz et al., 2018). While early urban economic theories link agglomeration to disadvantages in consumption through higher rents, noise pollution, and crime rates, there is now broad consensus that urban amenities, especially those found in European cities, positively impact residents' utility, particularly wealthier residents, apart from better income opportunities through more efficient production (Brueckner et al., 1999).

In addition to a larger supply of cultural activities such as theaters, operas and restaurants, the aesthetics of the residential environment, such as historic architecture, could explain part of the premium that people are willing to pay for urban locations (Glaeser et al., 2001). Considering that the outdoor area immediately surrounding the resident's home is perceived most visually, the question arises as to whether and how neighborhood aesthetics influence housing demand and consequently contribute to residential sorting.

Though empirically highly relevant for policymakers and urban dwellers, empirical studies on the influence of aesthetic characteristics on preferences, housing prices, and neighborhood sorting, are sparse (Been et al., 2016, Ahlfeldt and Holman, 2018). The difficulty of appropriately measuring aesthetics is a key challenge, as is its capitalization in the surrounding housing market and its interplay with migration patterns. We address this by making three contributions to the literature:

(i) We propose measuring neighborhood aesthetics by approaching it from a low-level (e.g., symmetry and order), mid-level (i.e., street segmentation), and high-level (i.e., historic architectural elements) visual stimuli perspective, disentangling as the first in the literature the pure direct view and the external view effect.
(ii) We address the endogeneity issue by leveraging the unique historical context of Eastern Germany. Focusing on East Berlin and Leipzig allows us to examine historical buildings that were often upgraded with public expenditure after reunification, attracting a completely new neighborhood composition.
(iii) We assess the price premium of aesthetics in a hedonic pricing model and

develop spatial matching methods by exploiting the heterogeneous architectural urban landscapes, embedding this analysis into a broader framework of residential sorting and neighborhood change (the latter is not yet part of this version).

We attempt to quantify aesthetics using house-level imagery data and historic preservation records to capture various characteristics of visual perception. Neuroscientific research identified that visual awareness and information analysis is made at different stages from detecting basic visual patterns without interpretation to recognition of complex objects and scenes with semantic meaning (Tong, 2003, Jennings and Martinovic, 2014). To measure these aesthetic properties, we draw from concepts not only from urban economics, but also psychology, information theory, urban planning, and cultural studies. Besides appropriately measuring aesthetic characteristics, a second challenge in estimating the impact of neighborhood aesthetics on housing demand is endogeneity: In most cities, buildings perceived as beautiful are often located in more expensive areas, implying that different types of housing supply are not randomly distributed but are produced based on expected returns. In our study, we try to contour this issue by focusing on the historic housing stock of Berlin and Leipzig, the two largest East German cities, after German reunification. In this unique setting, we observe a predominantly exogenous housing supply that lost its original milieu during the GDR period. These pre-war houses, characterized by Wilhelminian style and Art Nouveau architecture (Bernet, 2004), were seen as classicist and unfashionable during the Socialist era and largely fell into disrepair (Richter, 2006). However, they were upgraded and modernized to a high living standard after reunification, thanks to major public expenditure, and attracted better-off groups of inhabitants.
We start with an hedonic price regression, focusing on controlling for variables that might confound with the aesthetics measures, namely air quality, renovation activities and the share of modern buildings in the neighborhood. To better isolate the impact of visual perception on rent prices from functional attributes, we compare rent prices of adjacent houses with similar characteristics but different design elements and control for apartment specific characteristics. In addition, we also compare rents in houses within the same neighborhood and similar aesthetic appeal, to estimate the external effect on other buildings. Our results suggest that detailed historical architecture has a positive influence on rents, while simple architecture of old buildings even has a negative effect. In particular, visual features such as front gardens, opulent facade elements and street greenery come with a premium, while the characteristics of visual order and complexity in the neighborhood may not be capitalized into rental markets.

With our quantification of neighborhood aesthetics and its influence on house prices and residential sorting, we add to several strands of the literature.

First, within the real estate literature, there has long been research on historic district designation or preservation and its effect on house prices. Leichenko et al. (2001), Coulson and Lahr (2005) and Noonan (2007) find that the negative price effects of a preservation status (higher maintenance costs and reduced flexibility) are more than outweighed by the positive positive externalities of historic ambiance, which include the aesthetic appeal of the neighborhood. Asabere et al. (1994) reports a negative effect for small apartments in Philadelphia, where strict regulations may have outweighed the benefits. While studies such as Asabere et al. (1989) incorporate architectural styles into a hedonic pricing regression, this strand of the literature does not try to explicitly measure aesthetics or estimate a causal effect.

Our work is more closely related to recent studies in urban economics that use spatial econometric methods for causal analysis, for example of preservation status (Ahlfeldt et al., 2017) or architectural design (Ahlfeldt and Holman, 2018). Ahlfeldt et al. (2017) and Been et al. (2016) attempt to isolate the external effect of historic ambiance by analyzing house prices in and near landmarked areas, in, respectively, Britain and New York, and finding a price premium of preservation. While these effects can be partially attributed to the visual perception of the neighborhood, the focus of their work is not on isolating the aesthetic appeal. In fact, their price premium also capture spillover effects of unobserved amenities of historic districts (certain types of stores, cafes, or art galleries). Moreover, they cannot consider the effects of the visual perception of the houses where people actually live in isolation. Ahlfeldt and Holman (2018) take a step further towards isolating architectural distinctiveness with survey data. They estimate the price premium of residential buildings in British preservation areas as well as the view of these buildings from the outside using a spatial difference-in-difference variant that controls for differences within and between the boundaries of partially designated neighborhoods. We build upon their insights in various ways, in particular with a novel three-pronged measurement of neighborhood aesthetics and its application to the unique historical context of East Germany. In addition, we are able to distinguish between the aesthetic appeal of an individual building and the visual perception of its immediate surroundings, recognizing that a house may be visually attractive while its surroundings are not, and vice versa.

We expand the incipient sub-strand of the literature that employs big data methods to quantify urban features such as building shapes. For example, Lindenthal (2020) develops a data-driven measure of architectural similarity of building shapes, finding larger property prices on Rotterdam streets with buildings of similar rather than dissimilar shape. We combine such a low-level perspective of aesthetics with mid- and high-level features.

Crucially, our approach lets us distinguish between aesthetic characteristics of the building people live in from the aesthetics of the surrounding buildings, thereby adding to the literature on neighborhood externalities. On the one hand, buildings designed by famous architects have been shown to drive up property values of other buildings in the vicinity (Ahlfeldt and Mastro, 2012), just as the view of a historic city center is related to a higher willingness to pay for adjacent houses (Koster et al., 2016). On the other hand, the price premium of top-floor apartments hinges on the own house being higher than the surrounding ones (Danton and Himbert, 2018), which points to a competition effect between desirable features of neighboring buildings.

We also add to the literature on residential sorting, which cites urban amenities as drivers of social segregation when higher income/educated residents value them more than other population. While Diamond (2016) mainly considers endogenous amenities, to which urban aesthetics in general can be counted, our setting suggests that the historical urban ambiance in East German cities after reunification can be considered exogenous, implying more comparable sorting dynamics caused by factors such as air quality (Bayer et al., 2009) or social amenities (Kasy, 2015). The willingness to pay for viewing historical buildings is estimated by Koster et al. (2016) and Gaigné et al. (2022)' sorting model, which was calibrated with Dutch Micro data and provides further indications of different preferences of income groups. In addition, Garcia-López and Viladecans-Marsal (2024) finds steeper population density gradients in cities with historic centers. Yet to our knowledge, no paper has investigated the effect of aesthetics on residential sorting.

More broadly, we add to the quantification of urban characteristics that contribute to residents' utility, yet are hard to gauge. The growing literature on natural amenities includes sunshine (Fleming et al., 2018), ocean view (Lee and Lin, 2018), hillside location (Ye and Becker, 2021); access to urban greenness is typically captured by residents' distance to the nearest parks or public garden (Bronnmann et al., 2023, Liebelt et al., 2018, Votis, 2017). Measuring cultural amenities often relies on the number of upmarket cafés (Glaeser et al., 2018), density of restaurants (Couture and Handbury, 2020), or their quality inferred from user ratings (Kuang, 2017). Recent studies, such as Saiz et al. (2018) and Salesses et al. (2013) use large amounts of photos to gauge, respectively, people's perception of urban attractiveness and urban inequality. We complement the picture by operationalizing the measurement of neighborhood aesthetics with a multidisciplinary approach combining images with official data. With aesthetics, we unlock a hitherto neglected component of the urban environment that, as we aim to show, significantly adds to residents' willingness to pay and contributes to neighborhood sorting.

The remainder of this paper is organized as follows: Section 2 discusses the concept of aesthetic perception in various scientific disciplines and explores possible approaches to quantifying it. Section 3 lays out the historical setting of the urban transformation in Eastern Germany that we use to plausibly ensure exogeneity of the housing stock. Section 4 explains the construction of our data set, in particular how we try to capture the aesthetics. In Section 5, we present and interpret our main results of our hedonic pricing model estimation including the aesthetic factors, whose implications and limitations we discuss in Section 6. Section 7 concludes.

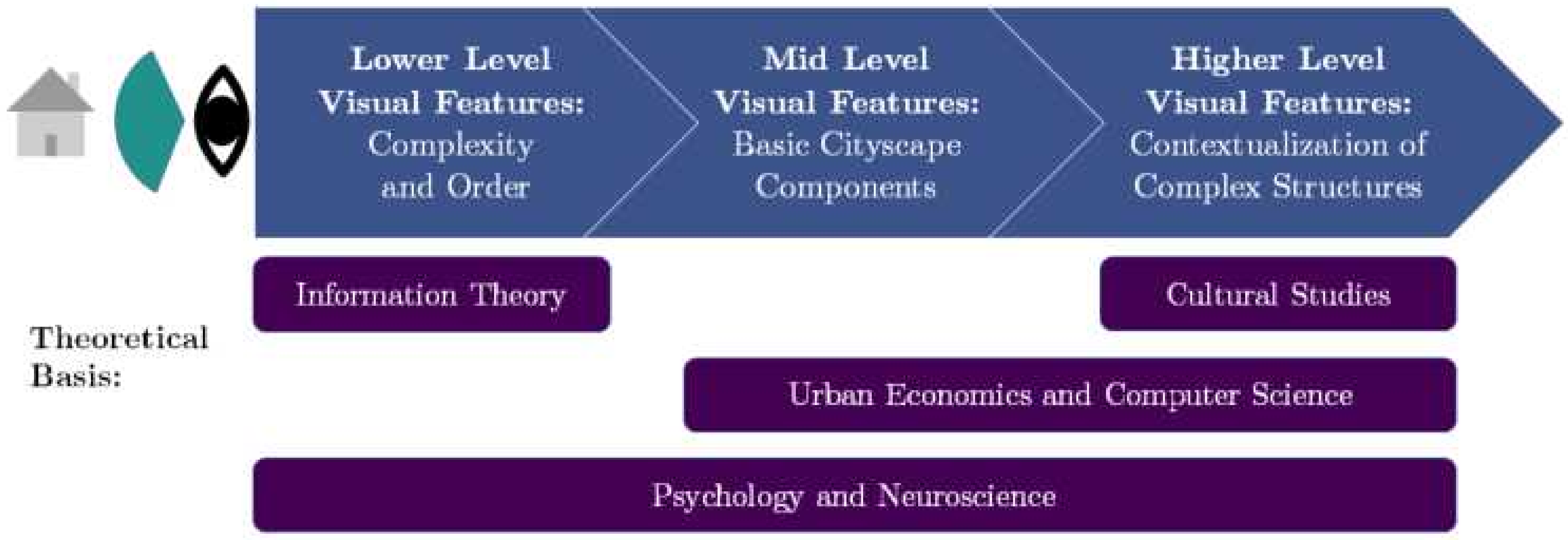
2 Urban Aesthetics and Demand for Housing

A large strand of the economics and marketing research literature finds a strong connection between product design and their demand (Hall and Hanna, 2004, Silayoi and Speece, 2004, Yan et al., 2008, Singh and Sarkar, 2022). In the urban space, Law et al. (2019), Xu et al. (2022), Wang (2023) show that cityscape images are strong predictors of house prices but the perception of the visual environment may vary among individuals, and defining aesthetic appeal remains elusive.

Visual appreciation can be both subjective — shaped by personal experiences and context — and objective, determined by fundamental stimulus properties such as shape and composition (Chamberlain, 2022, Iigaya et al., 2021). To meaningfully quantify urban aesthetic appeal, the search for such measures inherently assumes the existence of universal aesthetic experiences, as proposed by Berlyne (1973). While Stamps and Nasar (1997) finds that certain architectural elements are assessed similarly across different types of individuals, Wang et al. (2016) shows that the aesthetic perception of urban greenery is especially shared by most people. Rapoport (1980) and Chang (2016) argue that design judgments of visual environments are primarily shared among groups with similar socioeconomic characteristics. Positive perceptions, in particular, tend to show greater consensus (Hagerhall, 2001, Kalivoda et al., 2014), a finding that aligns with insights from the economic literature (Diamond, 2016, Koster et al., 2016, Gaigné et al., 2022).

Visual perception relies on a series of interconnected visual areas, each progressively processing stimulus features with increasing complexity at each stage, though the hierarchical structure of these stages remains unclear (Borgomaneri et al., 2023, Arcaro and Livingstone, 2021, Schindler and Bartels, 2016, Manassi et al., 2013, Tong, 2003). We attempt to quantify visual perceptions at three stages, for which different fields have identified—or at least speculated about—common aesthetic judgments (Figure 1): First, we examine low-level features of visual stimulation, applying information-theoretic

Figure 1 – Visual Features at Different Perception Stages



concepts to derive a measure of aesthetics from the fundamental properties of image information—specifically, complexity and order. Next, we segment the immediate surrounding neighborhood into basic visible components, namely Buildings, Green Spaces, Traffic, and Sky, and calculate their proportion in the visible panorama, following an approach in line with visual aesthetic quality research (Kurdoglu and Kurdoglu, 2010, Kalivoda et al., 2014). Finally, we quantify aesthetics based on high-level functional organization by incorporating insights of work from various fields suggesting that certain features of historic architecture appeal to many individuals. A major feature of visible urban surroundings are the buildings themselves, specifically the perception of architecture. Although there is extensive qualitative research on how different buildings are perceived by individuals and their influence on well-being and economic outcomes (Jargowsky, 2015, Abdelmoula and Abdelmoula, 2023), quantitative literature is sparse and relatively new. We measure these features by mapping them to the housing stock, using detailed descriptions from the heritage register, and calculating their share of the visual environment around a dwelling. Subsequently, we analyze whether these measurements are capitalized into the housing market, also differentiating between the house a person lives in and its immediate visual surroundings. This distinction might be crucial: While looking out from one's own apartment, only neighboring houses are visible, but Been et al. (2016) mentions that the exterior of buildings is less visible from inside a building than when viewed from the outside. Furthermore, apart from appreciating the beauty of their surroundings, residents might also value the signaling effect of opulent architecture. From a utilitarian point of view, a household i with the utility function eq. (1) gains utility by consuming a composite good q_i and housing h_{ij} located in its visual surrounding j, which, aside from its amenities x_h, is a function of the house's aesthetic value a_{hj} and the aesthetic perception of neighboring houses a_{-hj}.

$$U_i = U(q_i, h_{ij}(a_{hj}, a_{-hj}, x_h)) \tag{1}$$

While Ahlfeldt and Holman (2018), Been et al. (2016), and Koster et al. (2016) estimate the price premium of a view in a preserved area, they do not isolate the aesthetic effect of the house in which residents live. As we argue below, the perception of low-level visual features should not differ between the two. However, higher-level features in the context of group affiliation and signaling motives might.

3 Unique Historical Setting: Evolution of the Housing Stock in East Berlin and Leipzig

Appropriately measuring urban aesthetics is one challenge plaguing studies on house prices and residential sorting. But another one is the endogeneity of the aesthetic features. Buildings perceived as beautiful are typically located in more expensive areas, implying that different types of housing supply are not randomly distributed but are produced based on expected returns. Through path dependency, the same high social groups might be living in visually attractive neighborhoods over time (see e.g. Lee and Lin, 2018, Heblich et al., 2021), perpetuating the argument.[1]

Our study uses a unique historical setting, in which the typical endogeneity of aesthetics in building supply is broken by historical circumstances. We exploit the situation of Berlin (3.8m inhabitants) and Leipzig (620,000 inhabitants), the largest cities in Eastern Germany. A number of shocks led to an existing historical housing stock that can be considered exogenous to demand from the current residing population.

Both cities expanded considerably at the end of the 19th century and have a historical housing stock from the Wilhelminian, Art Nouveau (Jugendstil) and Reform style periods (1870-1914). In Berlin, these are particularly prevalent in the districts of Prenzlauer Berg and Friedrichshain; the Waldstraßenviertel in Leipzig is even considered the largest district of contiguous Art Nouveau buildings across Europe (Sikora, 2011), with many houses showing figurines and stucco faces in the facades or other art déco elements. Many of the initial residents of these ornate buildings were indeed wealthy or upper middle class (20% of homeowners of the Waldstraßenviertel at that time were Jewish, often merchants Ringel, 2015).

The situation of wealthy upper middle class homeowners living in ornate buildings was completely upended, first by Nazi rule (1933-1945) and the Second World War. Some buildings were damaged or destroyed by bombs; some homeowners were dispossessed, leaving their buildings unoccupied; some had their stucco ornaments removed as part of Nazi urban redesigning strategies (Lübbeke, 2007).

Afterwards, the building policy of the German Democratic Republic (GDR, 1949-1990)

[1] At the same time, even the decision whether historic housing obtains a conservation status is strongly influenced by local homeowners, as shown by Ahlfeldt et al. (2017).

constituted a further shock to historical housing. Socialist ideology strived for a uniform housing stock to reflect its vision of a class-less society, leading to, what Richter (2006, p.53) calls "hostility towards the historical buildings". They constructed mostly pre-fabricated, standardized housing blocks (*Plattenbau*) on the outskirts, which became popular due to the at that time modern interior. The ornate historic buildings fell into disrepair, the removal of stucco elements continued for practical and ideological reasons (Hiller von Gaertringen, 2012), and some houses were demolished to make space for uniform GDP-style buildings. Because of their desolate state, the demolition of entire historic districts had already been decided (Seidel, 2024) - when in 1989 the Berlin Wall fell.

Figure 2 – Derelict houses at the end of the GDR period (1949-1989), Source: Stadt Leipzig (2017)

After re-unification, a lot of money - both public and private - was invested into upgrading the cityscape, including refurbishing and retrofitting historical buildings to bring them to the same living standard as the post-war buildings (Steinführer et al., 2010). Thousands of historic houses became listed as protected buildings, and, if possible, were restored in line with their original looks (Merlino, 2014). Notably, these projects started in the 1990s, when Berlin and Leipzig were losing residents and rents were cheap, so they were not yet driven by increasing demand. It was only after the turn of the millennium - when the most important housing restoration projects were coming to an end - that Berlin and Leipzig started growing again. In an exceptional re-urbinization movement (Steinführer et al., 2010), they attracted new residents from rural areas and other cities (Leipzig grew from 500,000 to 600,000 residents from 2005 to 2021).

The combination of these historical circumstances leads to a situation in which the existing housing stock can be considered exogenous to the demand from the newly attracted population. 35 years after its averted demolition, wealthy and upper-middle class residents have moved again to the Waldstraßenviertel in Leipzig, and it is our goal to extricate the role that aesthetics have played in this residential choice. Moreover, we can leverage the low-scale variation induced by the historical shocks to isolate particular effects: For example, we can look at two neighboring historical houses of protected status, of one which had its stucco removed and one with its stucco still intact (see Figure 3). East Berlin and Leipzig therefore are unique settings to allow us to examine the impact of housing aesthetics - ranging from the low level to the high level - on both rental prices and residential sorting. In the following, we describe our data and methodology in more detail.

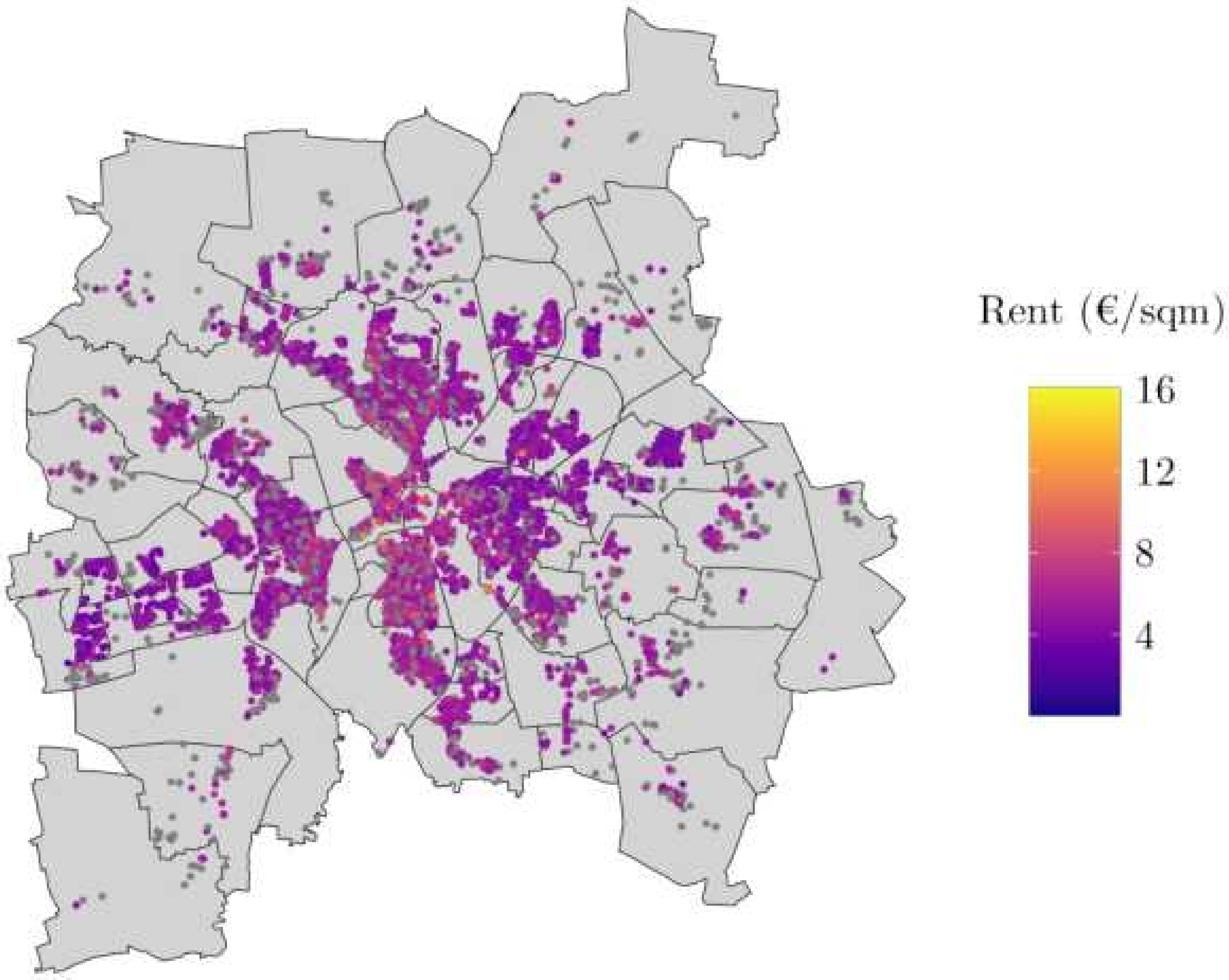
Figure 3 – Example of two historic houses with and without ornamentation due to historical circumstances

4 Data

4.1 Rental Prices and Covariates

We have transaction data on 277,155 new rental agreements of apartments from the years 2007-2023 in the city of Leipzig. Rental apartments are dominant, explained by the low home ownership of only 15% in Leipzig (Amt for Statistik und Wahlen der Stadt Leipzig, 2024). Across Germany, tenant-friendly laws, high real estate transfer taxes, and a large stock of apartments in social housing blocks built after the Second World War contribute to a home ownership rate of 52%, which is low by international comparison (Kaas et al., 2021, Andrews and Caldera Sánchez, 2011). For Leipzig in particular, the big city effect and the historical legacy of the GDR with virtually no home ownership reinforce these factors. Looking at rental rates is therefore highly representative of the overall housing market in Leipzig. Figure 4 shows the spatial distribution of the apartments from our sample. As we can see, they extend across the central districts where most apartments are located, with higher rental prices close to the center.

Figure 4 – Spatial distribution of apartments rented in Leipzig between 2007 and 2023



We are interested in the price-forming effect of aesthetic aspects of the urban environment around an apartment, which are not already captured by the conventionally measured characteristics that we use as control variables. We follow the hedonic pricing literature (Sopranezzi, 2010) and include structural characteristics, comprising the building age, living area (also as a squared term), number of rooms, and various dummies for whether or not the property has a balcony, an elevator, is furnished, has central heating, was renovated in the last 5 years and has a high quality interior. For neighborhood characteristics, we capture the socio-economic composition of the neighborhood by the average income, crimes per resident, migrants and youth ratio,[2] at the district level. Air quality in the neighborhood is measured by the concentration of particulate matter (PM 2.5 level). This control variable allows us to distinguish the positive air quality effect of trees from their aesthetic value in the cityscape of the street. Furthermore, we include locational variables. As predicted by the classical monocentric urban model, distance to the city center is a main pricing determinant in the housing market (Alonso, 1964, Muth, 1969, Mills, 1967). We use the location defined by Angel et al. (2012) as the Central Business District (CBD), which is the centrally-located

[2]The youth ratio is defined is the number of residents under 15 years in relation to the number of residents aged 15 to under 65 years.

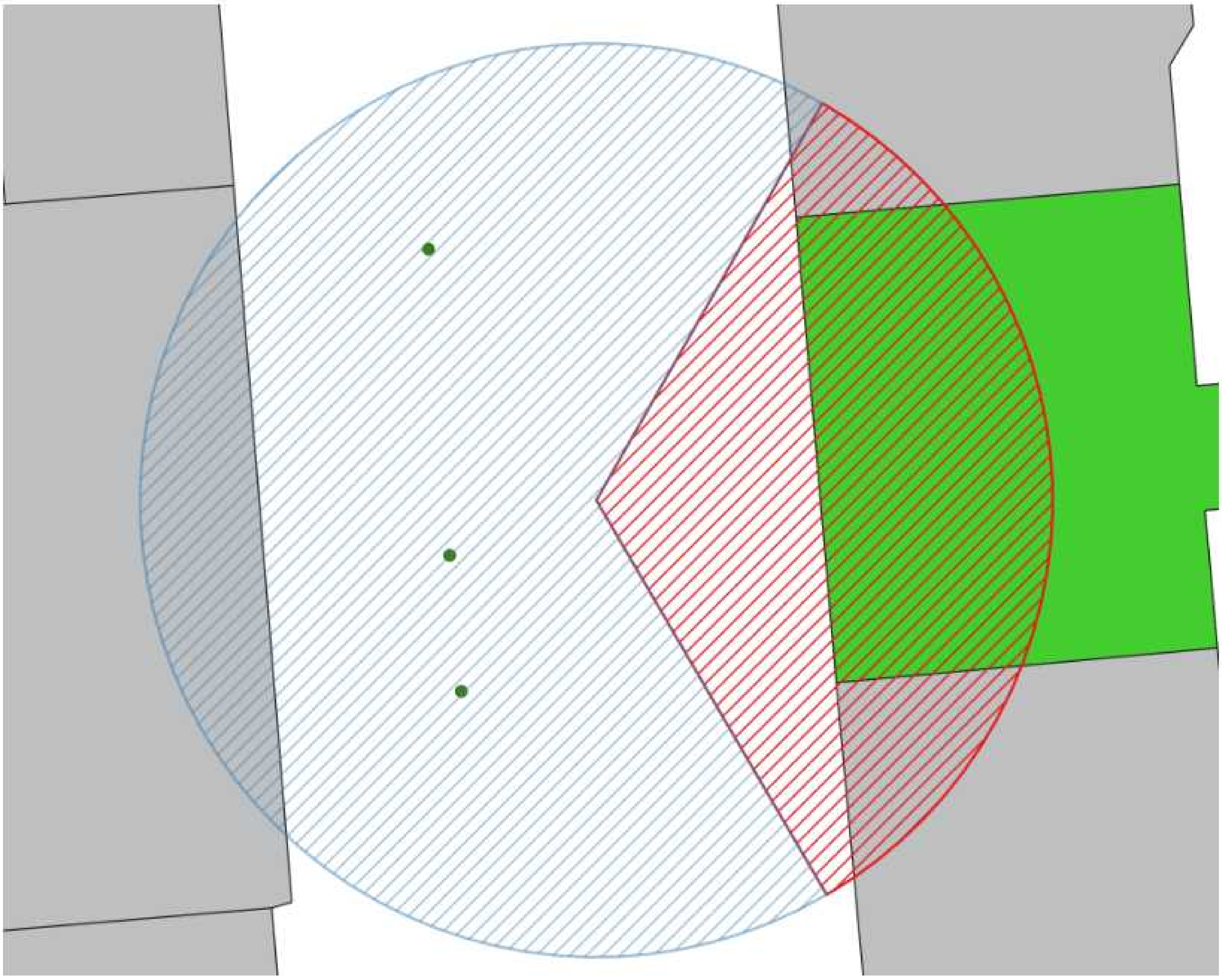
Augustus Square. To capture accessibility and the infrastructure network, we also take into account the distance to the nearest station of the public transport system (train, tram, bus) and highway (also in squared terms). For natural amenities, we control for the distance to the nearest watercourse (e.g., rivers and creeks), standing water body and urban green spaces (UGS) such as parks and urban forests. We also include the distance to the nearest recreational area (e.g., playgrounds and sports), university, schools and medical center (e.g., hospitals).

4.2 Measuring Low-Level Aesthetic Properties

While the rent data is at the apartment level, we identify visual aesthetic features based on the immediate visible surroundings of the building where the apartment is located. To achieve this, we obtain three 120-degree images from the Google Street View API for each apartment, captured from angles closest to the building. The first image shows the building where the apartment is located, while the other two images complete a 360-degree panorama (Figure 5).

Initially, we characterize the aesthetic impression of the built environment based on low-level features of visual perception. In an early effort to define aesthetics through information theory, Birkhoff (1933) introduced a measure based on the interaction between **order** and **complexity**. Contrary to Birkhoff's view that complexity negatively affects beauty judgments, extensive research indicates that the visual complexity of both natural and man-made structures enhances aesthetic preferences (Kaplan et al., 1972, Willis and Dornbush, 1968), while Eysenck (1942) argues that aesthetics arise from the synergy of both elements. This perspective is supported by psychology research, which finds that complexity without order is often perceived as confusion; hence, complexity can be aesthetically pleasing if the observer is capable of organizing the information. Apart from the ambiguity in the functional form of aesthetics, order, and complexity, there is also a wide range of proposed methods for quantifying these concepts (Van Geert and Wagemans, 2020). Order is often associated with visual symmetry and perceptual balance (Gartus and Leder, 2017), while complexity is frequently linked to entropy measures (Eysenck, 1942, Mather, 2018). Rigau et al. (2008) defines aesthetics using low-level visual features as an evolutionary process from initial uncertainty to ultimate order, leveraging concepts of physical entropy (Zurek, 1989). In this preliminary version of our paper, we adopt their measurement methodology and analyze the effect of this aesthetic measure of the visual neighborhood on rent prices, controlling for potential confounders (Section 5). Following this information theory perspective, we calculate the aesthetic quantification for each 360 degree panorama using the method proposed by Rigau et al. (2008). It defines aesthetic perception as the ratio of uncertainty reduction to the initial information content, as captured by LL defined below. Zurek (1989) defines physical entropy as the

Figure 5 – Three Street View Image Angles of an Example House in Leipzig (Green). The First Image (red Angle) Captures the Building Where the Apartment is Located, While the Other two Images (Blue Angle) Complete a 360-Degree View of the Immediate Surroundings. Green Dots are Trees.



process of understanding a system. In our setting, this would correspond to the process of viewing an urban environment, with all its architectural features, (ir)regular structures and design elements. The process starts without any knowledge of the system's state and physical entropy equates to Shannon Entropy. As more measurements are taken - the building is processed in more depth - , if the system exhibits regularity, physical entropy diminishes. This increase in knowledge allows for more efficient data compression. Hence, by exploration, the content of the urban environment is revealed, reducing the missing information (Shannon entropy) and compressing the information that has been uncovered (Kolmogorov complexity). H_{rgb} in eq. (2) defines the Shannon Entropy (Shannon, 1948) of a color image, capturing the sum of the average information (or uncertainty) per pixel based on the intensity distributions in the Red, Green, and Blue channels, respectively. The entropy for each channel is computed separately, using the probability $p(x)^C$ of the x'th intensity level in channel C:

$$H_{rgb} = -\sum_{C\in\{R,G,B\}} \sum_{x} p(x)^C \log_2(p(x)^C) \quad (2)$$

Shannon Entropy H_{rgb} measures the uncertainty in predicting the pixel values X. The sum across the three color channels provides an upper bound on the joint entropy. Higher entropy values indicate greater complexity and variability in pixel values, requiring more information to describe the image in bits. $N \cdot H_{rgb}$ represents the total entropy for an image with N pixels.

On the other hand, K is Kolmogorov Complexity, the amount of information contained in a file as the length of the shortest possible description (Kolmogorov, 1965). Due to the non-computable nature of K, we follow Rigau et al. (2008) by approximating it with the file size of the compressed image.[3]

With these concepts, we define aesthetic perception of the visual neighborhood j as the ratio of uncertainty reduction to the initial information content:

$$LL_j = \frac{N \cdot H_{rgb} - K}{N \cdot H_{rgb}} \quad (3)$$

4.3 Measuring Mid-Level Aesthetic Properties

In addition to measuring direct sensory input to quantify aesthetics, we segment the visual surroundings into basic components: Buildings, Greenery, Traffic, and Sky. These are defined as mid-level visual features, representing a higher level of visual processing where the brain organizes basic low-level inputs into more meaningful structures. Using a similar approach, the visual perception of sky and greenery has been shown to be strongly positively correlated with housing prices (Fu et al., 2019) and mental health (Wang et al., 2019). This goes in line with questionnaire results from (Hur et al., 2010) who show that perceived naturalness and openness of a built environment increases residents' life satisfaction. In fact, an extensive literature supports the aesthetic value of urban greenery for most people, linking it to positive associations with nature beyond its functional utility (Stoltz and Grahn, 2021, Hu et al., 2022, Brady, 2016). We categorize each image into these components using Semantic Segmentation, measure their proportion in the visual field surrounding each apartment, and estimate their impact on rental prices, controlling for confounding factors such as air quality and the presence of a balcony. To quantify how much each component occupies the visual panorama, we use the HRNet-48+OCR semantic segmentation model (Borse et al., 2021), pretrained on the Cityscape Dataset (Cordts et al., 2016), which contains images of German urban areas similar to Google Street View imagery. While the Cityscape Dataset categorizes visual elements into 19

[3] In particular, we use the lossy JEPG real-world compressor, with the compressed size in bits), as it reduces the file size by removing less important information, hence it proxies the ordering capability by the human eye (Roman-Gonzalez, 2013).

classes, we aggregate them into four groups: buildings, greenery (trees, bushes, grass, etc.), sky, and traffic (roads, signs, cars, etc.). Figure 6 illustrates this segmentation process.

Figure 6 – Example of the segmentation process: traffic elements (purple, pink, yellow, and dark blue), sky (light blue), buildings (grey), and greenery (green)

(a) Original Image **(b)** Segmented Image

Following Fu et al. (2019), we calculate the proportion of each component that is visually covered in the observer's panorama (eq. (4)). In this version of the paper, we focus solely on extracting the proportion of greenery architecture, which we refer to as the Green View Index (GVI) and Construction View Index (CVI).

$$VI_{obj} = \frac{\sum_{i=1}^{n} \sum^{m} pixel_{obj}}{pixel_{total}}, \quad obj \in \{\text{building}, \text{greenery}, \text{sky}, \text{traffic}\} \tag{4}$$

4.4 Measuring High-Level Aesthetic Properties

While some subjective aesthetic preferences are unique to an observer or shared by most individuals, others might be shared only by certain groups. In the urban economic literature, historic housing amenities are considered to be more valued from higher educated individuals (Diamond, 2016, Koster et al., 2016, Gaigné et al., 2022). Rapoport (1980) and Chang (2016) argue that educated and higher income groups demand historic aesthetic housing as a way to distinguish themselves as cultured and knowledgeable, hence signaling a certain lifestyle. Moreover, housing appearance may partially act as physical representations of a region's heritage and traditions. These buildings may hold significant emotional value for communities because their unique designs and architectural styles reflect the cultural identity and history of the area (Moro et al., 2013, Chiu, 2004, Jabareen, 2005). Ornate facades, traditional construction techniques, and iconic designs in historic buildings provide a visual connection to the past, fostering a sense of continuity. Notably, complex designs in pre-modern urban architecture not only appeal aesthetically but also promote mental well-being and reduce psychological distress (Lavdas and Schirpke, 2020, Taylor, 2006, Salingaros, 2003). In addition, Seresinhe et al. (2017) analysis of labeled image data find that characterful buildings, in

particular historical ones, are associated with greater scenic attractiveness. We assess the impact of these high-level visual features in urban environments on housing demand by identifying historic architectural elements through text analysis of the preservation register of both cities and extend the estimation model with those variables.
Leipzig has one of the largest continuous districts of historic buildings in Europe (Sikora, 2011). According to the annual Property Market Report of the city of Leipzig, sale prices in historic houses are comparable to, or even higher than, those in newer houses (Weiß, 2023). Cheung and Yiu (2022) take the construction cohort as an identification strategy, estimating a twenty percent price premium for buildings in a neighborhood with historic ambiance in Auckland, New Zealand. We want to extend this concept, given houses from 1900 can have very different aesthetic impressions. Arguably, just being old does not increase the aesthetic appeal of a building, but it is architectural elements such as stucco and other decorative elements in the facade, windows or gateways, which provide a high-level stimulus (Section 2).

In many German cities such as Berlin or Leipzig, the three main architectural styles of historic housing are Wilhelminian (Gründerzeit), Art Nouveau (Jugendstil) and Reform (Figure 7). Wilhelminian style (1870 to 1914) emerged during the period of rapid industrial growth in Germany, known as the Gründerzeit (Founder's Epoch), which corresponds to the reign of Emperor Wilhelm I. Buildings typically feature ornate facades, large windows, high ceilings, and decorative elements like stucco or ornaments. Arguably similarly opulent is Art Nouveau (1890 to 1910), but moves away from historical imitations and towards modernism, which at the time used innovative materials and building techniques and focused on asymmetry and organic forms (Lieb, 2010). In comparison, Reform Style emerged in the early 20th century as a reaction to the ornate styles, representing a shift towards simplicity and functionality (Posener, 1980). Hence, the demand for aesthetics might not be fully understood by simply looking at the construction date of buildings, as there is a large heterogeneity in the visual perception of those different architectural styles.

We rely on the 'Monument register' of Leipzig and Berlin, a database that includes the addresses of buildings with a status of preservation, to identify historic architectural features,[4] including the contiguity of buildings in the Waldstraßenviertel. We apply a semantic analysis of features that are described as relevant for preservation. It should be noted that a preservation status might have economic externalities, as it can attract tourism (Rypkema et al., 2011) and increase social cohesion (Rose, 1980). On the other

[4]One limitation of this data set is that only includes architectural information on buildings with a status of preservation. Yet, most historical buildings in Leipzig built before 1918 have such a status (77 % of houses in total, see Figure 8). Note that most of these buildings have had their preservation status for several decades, which allows us to contour the endogeneity of current residents lobbying for a preservation status outlined by (Ahlfeldt et al., 2017).

Figure 7 – Examples of the three dominant pre-war architectural styles in Leipzig and Berlin (Google Maps, 2024)

(a) Wilhelminian Style **(b)** Art Nouveau (Jugendstil) **(c)** Reform Style

hand, preservation policies restrict the rights of property owners and makes it more expensive and inflexible to create new or adjusted supply, potentially hindering efficient housing provision (Glaeser, 2010).[5] Given that historic buildings arguably do not have any functional advantages, their visual presentation could explain high demand for this type of housing. As Been et al. (2016) argues, "aesthetics are at the heart of historic preservation", we might recover some of the design variation based on descriptions made by experts of the monument protection authority. We extract words that indicate which part of the building was assessed as worthy of protection and categorize building features in facade elements (e.g., stucco, ornaments, paintings or obelisks), front yards, gates or doors and oriels, as those are the main visible features of historic buildings. Furthermore, we track down mentions of the main architectural styles (Wilhelminian, Art Nouveau and Reform). For each apartment (i.e., the immediate urban surrounding as described in Section 4.2), we determine the share of buildings with design features d and architectural styles a_s and include those variables in the hedonic rental price estimation in Section 5.

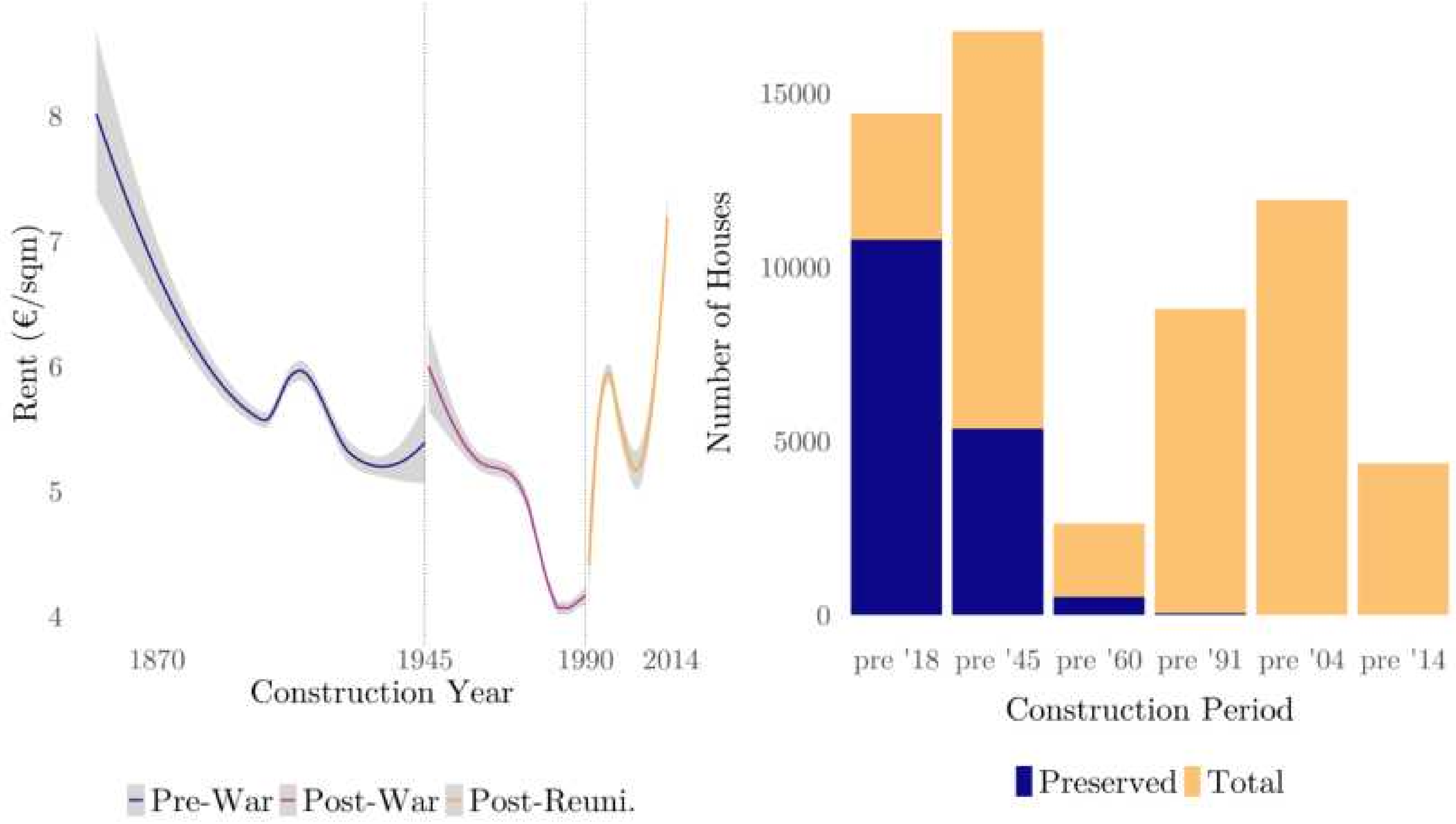
4.5 Descriptive Statistics

About half of all residential buildings in Leipzig were built before 1945, and many of these buildings have been listed as landmarks by the state to protect and preserve these properties, especially those built before 1918. Our data further suggests that rents in historic houses can come at a premium (Figure 8). While buildings constructed before the Second World War often have similar energy efficiency and interior amenities to post-war buildings after the renovation wave of the 1990s and 2000s (see Section 3), rents are highest in the oldest cohorts. Prices are also high in newly constructed buildings in the

[5] Been et al. (2016) theoretically and empirically study the effects of landmarking neighborhoods in New York City on property values. While they recognize the role played by aesthetic amenities, they do not explicitly measure the aesthetical features of the neighborhoods.

2010s, most likely due to improved amenities and a better and more modern building fabric.

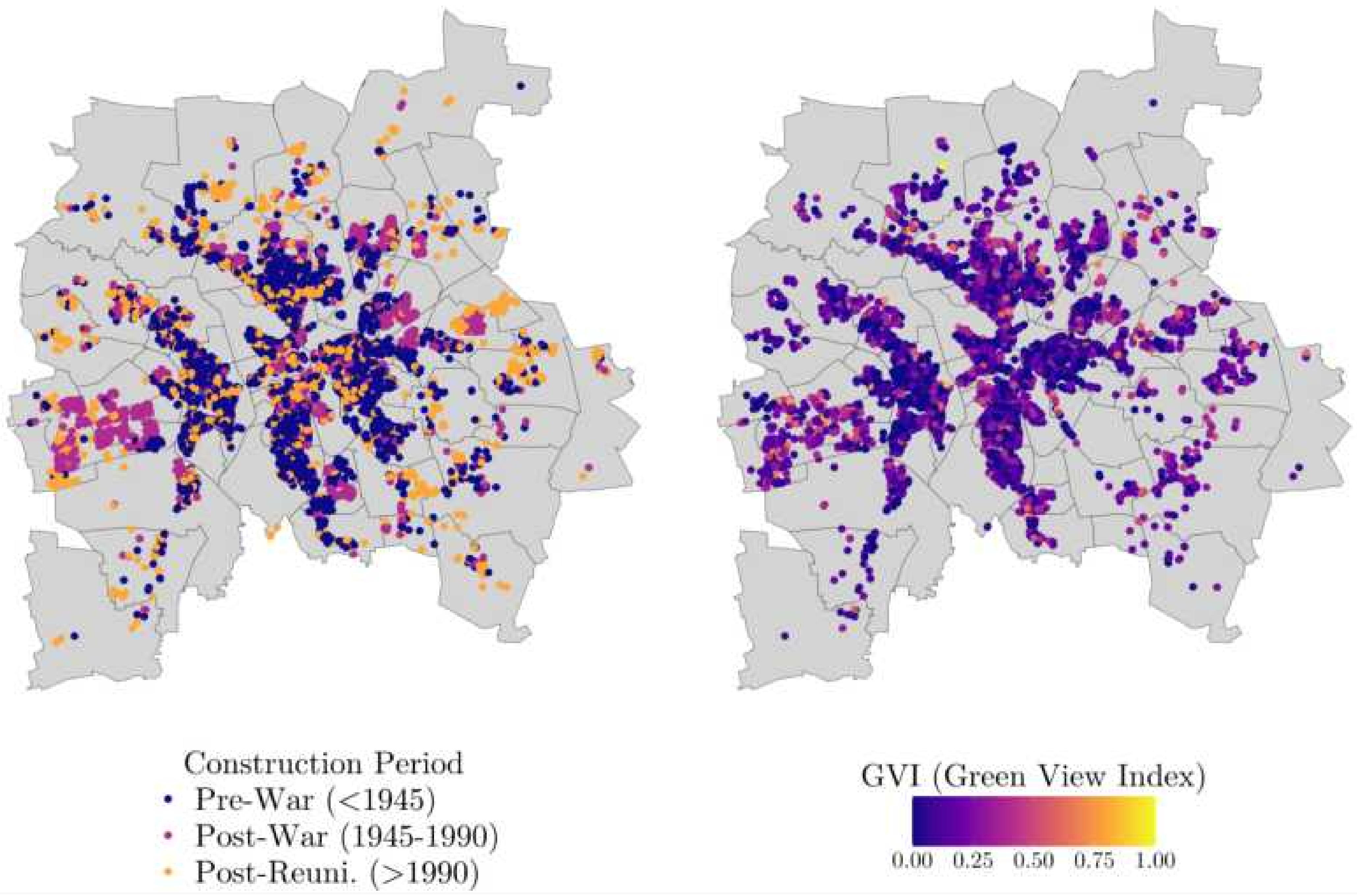
Figure 8 – Left: Local Polynomial Regression of rental prices per year of construction, piecewise for development before and after the Second World War and after Reunification. Right: Residential housing supply per construction cohort and it's share of preserved buildings.



Another factor contributing to the higher rents in historic buildings could be their closer proximity to the city centre compared to post-war buildings, due to the city's expansion over time (Figure 9). As expected, street greening increases with increasing distance from the city centre. Comparing both maps illustrates that the GVI cannot be calculated for all street segment for which we have rental price data, as Google Street View does not provide images of all street segments of the city.

On average, 18.5 % of the view into a street segment of each listing is covered by plants and 39.7 % of buildings have the status of preservation. The mean share of buildings within a street segment highlighted as preserved Art Nouveau is 3 %, while it is 2 % and 5 % for Wilhelminian and Reform Style Architecture, respectively. The mean share of Front Yards in a immidate visual surrounding is 9.1 %, 5.9 % of Oriels, 17 % of Fascade Art and 16.9 % for historic entrances. At 42 %, the mean share of pre-war buildings in the rental data in our sample is lower than the overall share of 49 % for all buildings.

Figure 9 – Map of Leipzig, with the spatial distribution of buildings from different construction periods (left) and the Green View Index of the corresponding street segment (right)



5 Estimating the Impact of Aesthetics

We start with a simple semi-log hedonic price regression to investigate the correlations of neighborhood aesthetics of the immediate visual surrounding of apartment k on rents, with rental price P_{khjt} in house h in vicinity j at year t:

$$\ln(p_{khjt}) = \alpha + \sum_{m=1}^{M}\Big(\beta_m\, a_{hj}^{(m)} + \delta_m\, \underbrace{\Big(\frac{\sum_{l=1}^{n_j} a_{lj}^{(m)} - a_{hj}^{(m)}}{n_j - 1}\Big)}_{a_{-hj}^{(m)}}\Big) + X'_{kjt}\,\gamma + \zeta_{z(j)} + \eta_t + \varepsilon_{hj} \tag{5}$$

In eq. (5), $a_{hj} = (a_{hj}^{(1)}, a_{hj}^{(2)}, ..., a_{hj}^{(M)})$ represents a vector of M aesthetic attributes of h and a_{-hj} the mean of all other houses in its visual vicinity j with n_j houses. X_kj is a vector of standard hedonic characteristics of apartment k, $\zeta_{z(j)}$ district fixed effects, η_t year fixed effect of the transaction, and $\epsilon_{k,t}$ the error term.

We estimate the impact using five different specifications: The baseline (1) hedonic regression, which excludes aesthetic components, serves as a benchmark for comparison with other specifications. In specification (2), we include the low-level aesthetic measure

$a_{hj} = LL_{hj}$ and $a_{-hj} = LL_{-hj}$. In specification (3), we add the mid-level aesthetics, the Green View Index (GVI) and the Construction View Index (CVI), both bounded in the interval $\in [0, 1]$. Specifications (4) and (5) go towards the high-level aesthetics. (4) incorporates the preservation status of unit h and the share of preserved houses in district j. Lastly, in specification (5), we disaggregate the visual feature variables into their architectural elements.

5.1 Capitalization of a Home's Aesthetic Appeal

While we attempt to control for district fixed effects and aesthetic features of the visual surroundings in eq. (5), the estimation is likely biased by unobservable factors such as time-varying neighborhood characteristics and aesthetic features specific to the visual surroundings. To address these concerns, we compare rent prices of adjacent houses that differ in aesthetic measurements, thereby controlling for potential locational confounders. Furthermore, the visual surroundings of two adjacent houses h and h' are arguably very similar, implying $a_{-hj} \approx a_{-h'j}$.

In this version of the paper, we focus on the effect of ornamentation in historically preserved housing, as it can be reasonably treated as a binary variable. However, we plan to extend this analysis to all aesthetic features measured in Section 4 To isolate the price premium, we subset cases where two preserved adjacent houses on the same side of the street are matched—one with facade decoration and one without (Figure 10). In Germany, even-numbered addresses are typically located on one side of the street, while odd-numbered addresses are on the opposite side, which facilitates the identification of adjacent houses.

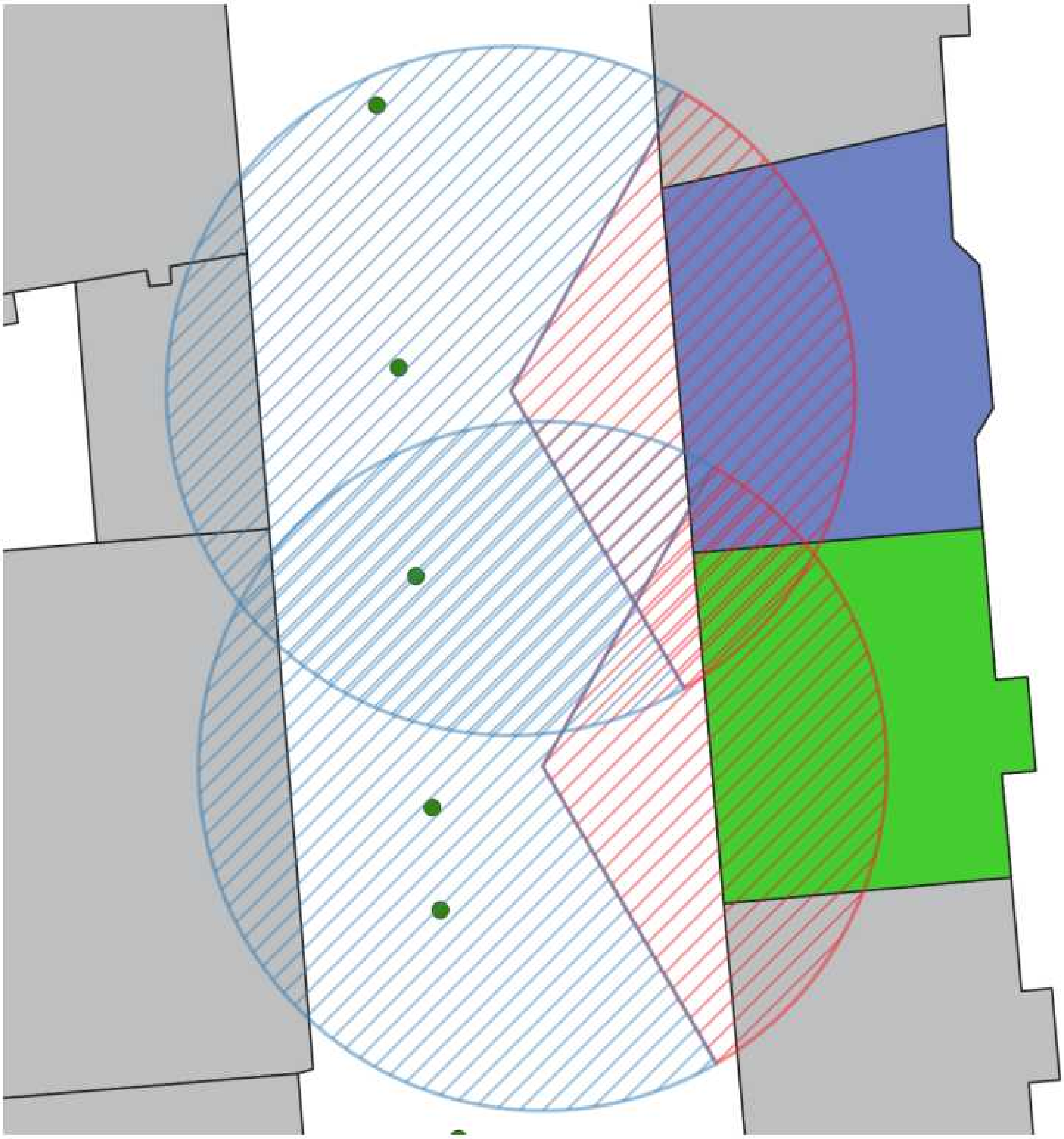
Let us define houses with a preservation status $G_h \in [0, 1]$, located on street S_h, with address number R_h. We denote the prices for houses with and without ornamentation as p_h^{or} and p_h^{no}, respectively. The price difference conditional on covariates X, associated with a decorated facade, is then given by eq. (6):

$$\Delta^{or} = E\Big[p_{h^{or}} - p_{h^{no}} \Big| G_h = 1, S_{h^{or}} = S_{h^{no}}, |R_{h^{or}} - R_{h^{no}}| = 2,\ X\Big]. \tag{6}$$

After geographical matching, we identify 238 pairs of adjacent preserved buildings for which we estimate the price premium for ornamentation using eq. (5).

The results of all specifications are reported in Table 1 (an extended table including all apartment amenity coefficients is provided in Table A-1). In the baseline specification (1), all statistically significant coefficients have the expected signs: positive relationships with structural amenities (e.g., area, balcony) and negative relationships with distances to locational amenities (e.g., CBD, watercourse). The estimation results of the other

Figure 10 – Example of a Preserved House With Ornate Facade (Green) and Adjacent Preserved House Without (Dark Blue). Red Lined-Cone Represents the 120 Degree View of the House, the Blue Fulfills the Visual Surrounding. Green Dots are Trees.



specifications suggest a positive relationship between rental prices and most visual features:

In Specification 2, the Low-Level Aesthetic measurements of the view towards the house where the apartment is situated (LL_{hj}), as well as the immediate urban surroundings (LL_{-hj}), are positive but not significant at any common level. For the picture segmentation variables (Specification 3), a one-percentage-point increase in the street segment's greenness (GVI) is associated with an average 8.1% increase in rental price, significant at the 10% level, c.p., while the share of the panorama covered by construction is associated with a -5.4% change, significant at the 5% level. Unsurprisingly, while the presence of greenery has a positive impact, buildings have a negative one.

In line with the relationship between historic housing and land prices (Asabere and

Table 1 – Main Results

Dependent Variable:	log(Rent €/sqm)				
Model:	(1)	(2)	(3)	(4)	(5)
Low-Level Aesthetics		0.057			
		(0.054)			
Mean Low-Level Aesthetics Nearby Houses		0.057			
		(0.122)			
Construction View Index			-0.054**		
			(0.025)		
Green View Index			0.081*		
			(0.044)		
Preservation Status				0.012***	0.013**
				(0.004)	(0.005)
Share Nearby Houses Preserved				-0.006	-0.007
				(0.005)	(0.006)
Preserved Window					-0.010
					(0.006)
Preserved Entrance					0.001
					(0.005)
Preserved Yard					0.027***
					(0.007)
Preserved Artistic Elements					0.014***
					(0.006)
Share Nearby Houses with Preserved Windows					0.005
					(0.007)
Share Nearby Houses with Preserved Entrances					-0.002
					(0.006)
Share Nearby Houses with Preserved Yards					-0.004
					(0.009)
Share Nearby Houses with Preserved Artistic Elements					0.004
					(0.007)
Fixed Effects					
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
District Fixed Effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Fit statistics					
Adjusted R^2	0.75780	0.76725	0.76733	0.75793	0.75847
Observations	276,155	220,786	220,786	276,155	276,155

Clustered (Visual Surrounding) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Huffman, 1991) or property values (Gilderbloom et al., 2009), preserved housing carries a rent premium, but it is relatively small (1.2%, significant at the 5% level), whereas preserved buildings in the immediate surroundings have no effect (Specification 4). When disaggregating the preserved houses into architectural styles (Specification 5), only the coefficients for facade art and front yards are positive and significant, showing a 1.4% and 2.7% price premium, respectively, both significant at the 5% level. Again, the aesthetics of buildings in the immediate surroundings do not have any effect.

Lastly, when using a matched subset of preserved houses, we estimate a price premium of 8.7% for ornate facades, significant at the 5% level. This model is likely the most unbiased estimation, as it best isolates the impact of aesthetic features. We assume that the regression results from the full dataset suffer from downward bias due to uncontrolled negative factors associated with preserved buildings (e.g., poor insulation).

Table 2 – Results After Geographic Matching

Dependent Variable:	log(Rent €/sqm)
Model:	(1)
Variables	
Ornate House	0.087**
	(0.038)
Controls	Yes
Fit statistics	
Adjusted R^2	0.73726
Observations	476

Clustered (Visual Surrounding) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

6 Discussion and Outlook

Our findings are consistent with qualitative work linking housing preferences with cultural identity as well as information theoretical measurements of aesthetic perception. In a later version of this paper, we plan to explore this relationship in more detail by segmenting the visual surrounding to more categories, investigate spatial spillovers and apply more advanced econometric methods.

This preliminary draft of the paper has some further limitations. For now, we only report our results for the city of Leipzig. In a next step, we want to extend our analysis to East Berlin. As the largest and best-known city of the former German Democratic Republic (GDR), it offers a complementary perspective and has a comparable but more extensive historic housing stock that has been similarly restored with public funds after re-unification. Moreover, East Berlin occupies a unique place in history as it was a focal point of Cold War tensions and the subsequent re-unification process.

Last, we aim to link these findings to residential sorting. As Diamond (2016), Koster et al. (2016), Gaigné et al. (2022) argue, aesthetic amenities might have greater value for higher income groups, which should result in sorting dynamics and implying social segregation. Over the last 20 years, neighborhoods with a high share of historic housing have undergone the most significant gentrification processes — arguably driven, at least in part, by urban aesthetics.

7 Conclusion

An extensive literature has focused on the effects of neighborhood characteristics on housing demand, but little focus has been placed on the visual perception of the immediate surroundings. Qualitative work has suggested that the aesthetic appeal of this environment influences the willingness to pay for different types of housing, but quantitative evidence has been hard to come by. In this paper, we aim to fill this research gap with a novel measurement of aesthetics relying on imagery data and semantic analysis. We leverage the historic event of the reunification of Germany and the subsequent publicly organized and financed restoration of its urban historic housing stock. This unique event provides an opportunity to examine a largely exogenous housing stock, offering deeper insights into the demand for external, non-functional characteristics of individual street segments.

We focus on Leipzig, the largest city in the former GDR after East Berlin, given its substantial historic housing stock and their largely non-market restoration after 1990. We begin with an information-theoretical definition of aesthetics that approximates a visual evolutionary process, moving from initial uncertainty to increasing order. This is described by the ratio of uncertainty reduction to information content.

We extend the analysis to higher level visual perceptions of street greenery and architecture, which are important aspects of the aesthetic cognition of an urban environment. By disentangling its visual features from other price-relevant properties, we measure the extent of greenness and building coverage in street view imagery associated with plants while controlling for potential confounders such as local air quality. For quantifying architectural details, we utilize information from the monument list, a dataset listing properties under preservation orders, including descriptions of architectural design elements. Using semantic analysis to filter and categorize externally perceptible properties of these structures, we label aesthetic characteristics for the historic housing stock to estimate their impact on rent prices of apartments within their visual proximity.

Our preliminary results indicate a significant rent price premium for urban greenery and historic architecture of the building where the apartment is located, but no effect of the immediate visual surroundings. Specifically, opulent architectural styles influence property valuation. Disaggregating the visual features of historic buildings into their components reveals that this effect is driven by facade elements such as ornaments and stucco, as well as front gardens. These findings align with cultural identity theories (Rapoport, 1980, Chang, 2016), which link signaling motives to the demand for historic housing. Additionally, the information theory-based aesthetic measure is positively associated with rental prices but not statistically significant, suggesting that low-level visual stimulus characteristics may have only a minor influence on housing demand.

Our insights have practical relevance not only for real estate professionals seeking to understand housing market dynamics but also for policymakers and urban planners. Neighborhood change and social segregation are particularly pressing issues in cities with a large stock of historic housing. Exploring the impact of hitherto unmeasured aesthetic features on housing demand is an important research agenda, especially as cities worldwide strive to enhance livability and visual appeal. Since historic housing is not reproducible, and assuming that higher-income groups specifically prefer apartments with such architecture, districts — or even entire cities — with a dense stock of historic buildings may struggle to combat social segregation solely by constructing new apartments on the outskirts.

References

Abdelmoula, N. B. and E. Abdelmoula (2023). Architecture and Mental Health Wellbeing versus Architecture Therapy for Mental Disorders. *European Psychiatry 66*(S1), S990–S991.

Ahlfeldt, G. and A. Mastro (2012). Valuing Iconic Design: Frank Lloyd Wright Architecture in Oak Park, Illinoiss. *Housing Studies 27*, 1079–1099.

Ahlfeldt, G. M. and N. Holman (2018). Distinctively different: a new approach to valuing architectural amenities. *The Economic Journal 128*(608), 1–33.

Ahlfeldt, G. M., K. Moeller, S. Waights, and N. Wendland (2017). Game of zones: The political economy of conservation areas. *The Economic Journal 127*, F421–F445.

Alonso, W. (1964). *Location and Land Use: Toward a General Theory of Land Rent.* Harvard University Press.

Amt for Statistik und Wahlen der Stadt Leipzig (2024). Wohnsituation der Haushalte. https://statistik.leipzig.de/statcity.

Andrews, D. and A. Caldera Sánchez (2011). The Evolution of Homeownership Rates in Selected OECD Countries: Demographic and Public Policy Influences. *OECD Journal: Economic Studies 1.*

Angel, S., J. Parent, D. Civco, and A. Blei (2012). Central Business District, Leipzig, Germany, 1990. [Shapefile]. Retrieved from https://hgl.lib.harvard.edu/catalog/stanford-vm589gq4181. Manuscript, Lincoln Institute of Land Policy.

Arcaro, M. J. and M. S. Livingstone (2021). On the relationship between maps and domains in inferotemporal cortex. *Nature Reviews Neuroscience 22*(9), 573–583.

Asabere, P. and F. Huffman (1991). Historic districts and land values. *Journal of Real Estate Research 6*(1), 1–7.

Asabere, P. K., G. Hachey, and S. Grubaugh (1989). Architecture, historic zoning, and the value of homes. *The Journal of Real Estate Finance and Economics 2*, 181–195.

Asabere, P. K., F. E. Huffman, and S. Mehdian (1994). The adverse impacts of local historic designation: the case of small apartment buildings in philadelphia. *The Journal of Real Estate Finance and Economics 8*, 225–234.

Bayer, P., N. Keohane, and C. Timmins (2009). Migration and hedonic valuation: The case of air quality. *Journal of Environmental Economics and Management 58*(1), 1–14.

Been, V., I. G. Ellen, M. Gedal, E. Glaeser, and B. J. McCabe (2016). Preserving history or restricting development? The heterogeneous effects of historic districts on local housing markets in New York City. *Journal of Urban Economics 92*, 16–30.

Berlyne, D. E. (1973). Aesthetics and psychobiology. *Journal of Aesthetics and Art Criticism 31*(4).

Bernet, C. (2004). The 'Hobrecht Plan'(1862) and Berlin's Urban Structure. *Urban History 31*(3), 400–419.

Birkhoff, G. D. (1933). *Aesthetic measure.* Harvard University Press.

Borgomaneri, S., M. Zanon, P. Di Luzio, A. Cataneo, G. Arcara, V. Romei, M. Tamietto, and A. Avenanti (2023). Increasing associative plasticity in temporo-occipital back-projections improves visual perception of emotions. *Nature Communications 14*(1), 5720.

Borse, S., Y. Wang, Y. Zhang, and F. Porikli (2021). Inverseform: A loss function for structured boundary-aware segmentation. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pp. 5901–5911.

Brady, E. (2016). *Aesthetic Value, Nature, and Environment.* Oxford: Oxford University Press.

Bronnmann, J., V. Liebelt, F. Marder, J. Meya, and M. Quaas (2023). The Value of Naturalness of Urban Green Spaces: Evidence from a Discrete Choice Experiment. Land Economics. *Land Economics 99*, 062321–0072R1.

Brueckner, J. K., J.-F. Thisse, and Y. Zenou (1999). Why is central paris rich and downtown detroit poor?: An amenity-based theory. *European economic review 43*(1), 91–107.

Chamberlain, R. (2022). The interplay of objective and subjective factors in empirical aesthetics. *Human Perception of Visual Information: Psychological and Computational Perspectives*, 115–132.

Chang, T. C. (2016). 'New uses need old buildings': Gentrification aesthetics and the arts in Singapore. *Urban studies 53*(3), 524–539.

Cheung, K. S. and C. Y. Yiu (2022). The economics of architectural aesthetics: Identifying price effect of urban ambiences by different house cohorts. *Environment and Planning B: Urban Analytics and City Science 49*(6), 1741–1756.

Chiu, R. L. (2004). Socio-cultural sustainability of housing: a conceptual exploration. *Housing, Theory and Society 21*(2), 65–76.

Cordts, M., M. Omran, S. Ramos, T. Rehfeld, M. Enzweiler, R. Benenson, U. Franke, S. Roth, and B. Schiele (2016). The cityscapes dataset for semantic urban scene understanding. In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 3213–3223.

Coulson, N. E. and M. L. Lahr (2005). Gracing the land of elvis and beale street: historic designation and property values in memphis. *Real Estate Economics 33*(3), 487–507.

Couture, V. and J. Handbury (2020). Urban Revival in America, 2000 to 2010. *Journal of Urban Economics 119*, 103267.

Danton, J. and A. Himbert (2018). Residential Vertical Rent Curves. *Journal of Urban Economics 107*, 89–100.

Diamond, R. (2016). The Determinants and Welfare Implications of US Workers' Diverging Location Choices by Skill: 1980–2000. *American Economic Review 106*(3), 479–524.

Eysenck, H. J. (1942). The Experimental Study of the 'Good Gestalt'—A New Approach. *Psychological Review 49*(4), 344.

Fleming, D., A. Grimes, L. Lebreton, D. Maré, and P. Nunns (2018). Valuing Sunshine. *Regional Science and Urban Economics 68*, 268–276.

Fu, X., T. Jia, X. Zhang, S. Li, and Y. Zhang (2019). Do Street-Level Scene Perceptions Affect Housing Prices in Chinese Megacities? An analysis Using Open Access Datasets and Deep Learning. *PloS one 14*(5), e0217505.

Gaigné, C., H. R. Koster, F. Moizeau, and J.-F. Thisse (2022). Who Lives Where in the City? Amenities, Commuting and Income Sorting. *Journal of Urban Economics 128*, 103394.

Garcia-López, M.-À. and E. Viladecans-Marsal (2024). The Role of Historic Amenities in Shaping Cities. *Regional Science and Urban Economics 109*, 104042.

Gartus, A. and H. Leder (2017). Predicting Perceived Visual Complexity of Abstract Patterns Using Computational Measures: The Influence of Mirror Symmetry on Complexity Perception. *PloS one 12*(11), e0185276.

Gilderbloom, J. I., M. J. Hanka, and J. D. Ambrosius (2009). Historic Preservation's Impact on Job Creation, Property Values, and Environmental Sustainability. *Journal of Urbanism 2*(2), 83–101.

Glaeser, E., H. Kim, and M. Luca (2018). Nowcasting Gentrification: Using Yelp Data to Quantify Neighborhood Change. *American Economic Review Papers & Proceedings 2*, 77–82.

Glaeser, E. L. (2010). Preservation Follies: Excessive Landmarking Threatens to Make Manhattan a Refuge for the Rich. *City Journal, Spring*.

Glaeser, E. L., J. Kolko, and A. Saiz (2001). Consumer City. *Journal of economic geography 1*(1), 27–50.

Hagerhall, C. (2001). Consensus in Landscape Preference Judgements. *Journal of Environmental Psychology 21*(1), 83–92.

Hall, R. H. and P. Hanna (2004). The Impact of Web Page Text-Background Colour Combinations on Readability, Retention, Aesthetics and Behavioural Intention. *Behaviour & information technology 23*(3), 183–195.

Heblich, S., A. Trew, and Y. Zylberberg (2021). East Side Story: Historical Pollution and Persistent Neighborhood Sorting. *Journal of Political Economy 129*, 1508–1552.

Hiller von Gaertringen, H. G. (2012). *Schnörkellos - Die Umgestaltung von Bauten des Historismus im Berlin des 20. Jahrhunderts*. Berlin: Gebr. Mann Verlag.

Hu, T., D. Wei, Y. Su, X. Wang, J. Zhang, X. Sun, Y. Liu, and Q. Guo (2022). Quantifying the Shape of Urban Street Trees and Evaluating its Influence on Their Aesthetic Functions Based on Mobile Lidar Data. *ISPRS Journal of Photogrammetry and Remote Sensing 184*, 203–214.

Hur, M., J. L. Nasar, and B. Chu (2010). Neighborhood Satisfaction, Physical and Perceived Naturalness and Openness. *Journal of Environmental Psychology 30*, 52–59.

Iigaya, K., S. Yi, I. A. Wahle, K. Tanwisuth, and J. P. O'Doherty (2021). Aesthetic preference for art can be predicted from a mixture of low-and high-level visual features. *Nature Human Behaviour 5*(6), 743–755.

Jabareen, Y. (2005). Culture and Housing Preferences in a Developing City. *Environment and Behavior 37*(1), 134–146.

Jargowsky, P. (2015). The Architecture of Segregation. *The Century Foundation 7*.

Jennings, B. J. and J. Martinovic (2014). Luminance and Color Inputs to Mid-Level and Migh-Level Vision. *Journal of Vision 14*(2), 9–9.

Kaas, L., G. Kocharkov, E. Preugschat, and N. Siassi (2021). Low Homeownership in Germany - A Quantitative Exploration. *Journal of the European Economic Association 19.*

Kalivoda, O., J. Vojar, Z. Skřivanová, and D. Zahradník (2014). Consensus in Landscape Preference Judgments: The Effects of Landscape Visual Aesthetic Quality and Respondents' Characteristics. *Journal of Environmental Management 137*, 36–44.

Kaplan, S., R. Kaplan, and J. S. Wendt (1972). Rated Preference and Complexity for Natural and Urban Visual Material. *Perception & Psychophysics 12*(4), 354–356.

Kasy, M. (2015). Identification in a Model of Sorting with Social Externalities and the Causes of Urban Segregation. *Journal of Urban Economics 85*, 16–33.

Kolmogorov, A. N. (1965). Three Approaches to the Quantitative Definition of Information. *Problems of Information Transmission 1*(1), 1–7.

Koster, H. R., J. N. van Ommeren, and P. Rietveld (2016). Historic Amenities, Income and Sorting of households. *Journal of Economic Geography 16*(1), 203–236.

Kuang, C. (2017). Does Quality Matter in Local Consumption Amenities? An Empirical Investigation with Yelp. *Journal of Urban Economics 100*, 1–18.

Kurdoglu, O. and B. C. Kurdoglu (2010). Determining Recreational, Scenic, and Historical–Cultural Potentials of Landscape Features Along a Segment of the Ancient Silk Road Using Factor Analyzing. *Environmental monitoring and assessment 170*, 99–116.

Lavdas, A. A. and U. Schirpke (2020). Aesthetic Preference is Related to Organized complexity. *PLoS One 15*(6), e0235257.

Law, S., B. Paige, and C. Russell (2019). Take a Look Around: Using Street View and Satellite Images to Estimate House Prices. *ACM Transactions on Intelligent Systems and Technology (TIST) 10*(5), 1–19.

Lee, S. and J. Lin (2018). Natural Amenities, Neighbourhood Dynamics, and Persistence in the Spatial Distribution of Income. *Review of Economic Studies 85*, 663–694.

Leichenko, R., N. Coulson, and D. Listokin (2001). Historic Preservation and Residential Property Values: An Analysis of Texas Cities. Urban Studies. *Urban Studies 38*, 1973–1987.

Lieb, S. (2010). *Lieb, Was ist Jugendstil?: Eine Analyse der Jugendstilarchitektur 1890 – 1910.* Wissenschaftliche Buchgesellschaft (wbg).

Liebelt, V., S. Bartke, and N. Schwarz (2018). Hedonic Pricing Analysis of the Influence of Urban Green Spaces onto Residential Prices: The Case of Leipzig, Germany. *European Planning Studies 26.*

Lindenthal, T. (2020). Beauty in the Eye of the Howe Owner - Aesthetic Zoning and Residential Property Values. *Real Estate Economics 48*(2), 530–555.

Lübbeke, W. (2007). Entschandelung - Über einen ästhetisch-städtebaulichen Begriff der Denkmalpflege im Nationalsozialismus. *Die Denkmalpflege 2*, 146–156.

Manassi, M., B. Sayim, and M. H. Herzog (2013). When Crowding of Crowding Leads to Uncrowding. *Journal of Vision 13*(13), 10–10.

Mather, G. (2018). Visual Image Statistics in the History of Western Art. *Art & Perception 6*(2-3), 97–115.

Merlino, K. (2014). [Re]Evaluating Significance: The Environmental and Cultural Value in Older and Historic Buildings. *The Public Historian 36*(3), 70–85.

Mills, E. (1967). An Aggregative Model of Resource Allocation in a Metropolitan Area. *American Economic Review 57*(2), 197–210.

Moro, M., K. Mayor, S. Lyons, and R. S. Tol (2013). Does the housing market reflect cultural heritage? A case study of Greater Dublin. *Environment and Planning A 45*(12), 2884–2903.

Muth, R. (1969). *Cities and Housing: The Spatial Patterns of Urban Residential Land Use.* University of Chicago Press.

Noonan, D. S. (2007). Finding an impact of preservation policies: price effects of historic landmarks on attached homes in chicago, 1990-1999. *Economic development quarterly 21*(1), 17–33.

Posener, J. (1980). Die Architektur der Reform (1900–1924). *arch+ 5.*

Rapoport, A. (1980). *Vernacular Architecture and the Cultural Determinants of Form.* Routledge.

Richter, P. (2006). *Der Plattenbau als Krisengebiet: Die Architektonische und Politische Transformation Industriell Errichteter Wohngebäude aus der DDR am Beispiel der Stadt Leinefelde.* Ph. D. thesis, Staats-und Universitätsbibliothek Hamburg Carl von Ossietzky.

Rigau, J., M. Feixas, and M. Sbert (2008). Informational aesthetics measures. *IEEE computer graphics and applications 28*(2), 24–34.

Ringel, S. (2015). *Leipzig! One Thousand Years of History.* Edition Leipzig.

Roman-Gonzalez, A. (2013). Compression techniques for image processing tasks. *International Journal of Advanced Research in Computer Science and Software Engineering 3*(7), 379–388.

Rose, C. M. (1980). Preservation and Community: New Directions in the Law of Historic Preservation. *Stanford Law Review 33*, 473.

Rypkema, D. D., C. Cheong, and R. Mason (2011). *Measuring Economic Impacts of Historic Preservation.* Advisory Council on Historic Preservation Washington, DC.

Saiz, A., A. Salazar, and J. Bernard (2018). Crowdsourcing Architectural Beauty: Online Photo Frequency Predicts Building Aesthetic Ratings. *PLoS ONE 13*, e0194369.

Salesses, P., K. Schechtner, and C. Hidalgo (2013). The Collaborative Image of The City: Mapping the Inequality of Urban Perception. *PlosOne* (8), e68400.

Salingaros, N. A. (2003). The sensory value of ornament. *Communication and Cognition: An Interdisciplinary Quarterly Journal 36*(3/4), 331–351.

Schindler, A. and A. Bartels (2016). Visual high-level regions respond to high-level stimulus content in the absence of low-level confounds. *NeuroImage 132*, 520–525.

Seidel, M. (2024). Das Waldstraßenviertel in Leipzig – Historismus in seiner schönsten Form. Technical report. https://www.architektur-blicklicht.de/stadtansichten/waldstrassenviertel-leipzig/.

Seresinhe, C., T. Preis, and H. Moat (2017). Using Deep Learning to Quantify the Beauty of Outdoor Places. *Royal Society Open Science 4*, 170170.

Shannon, C. E. (1948). A mathematical theory of communication. *The Bell system technical journal 27*(3), 379–423.

Sikora, B. (2011). *Das Leipziger Waldstraßenviertel – Ein Führer durch Geschichte und Gegenwart.* Miriquidi Media.

Silayoi, P. and M. Speece (2004). Packaging and purchase decisions: An exploratory study on the impact of involvement level and time pressure. *British food journal 106*(8), 607–628.

Singh, J. and P. Sarkar (2022). Visual product assessment by using the eye-tracking equipment to study the effect of product shapes on consumer's thinking. In *International Conference on Advances in Mechanical Engineering and Material Science*, pp. 149–158. Springer.

Sopranezzi, B. (2010). Hedonic Regression Analysis in Real Estate Markets: A Primer. In C.-F. Lee, A. C. Lee, and J. Lee (Eds.), *Handbook of Quantitative Finance and Risk Management*, pp. 1201–1207. Springer.

Stadt Leipzig (2017). *Das Leipziger Waldstraßenund und Bachstraßenviertel - Eine Dokumentation der städtebaulichen Erneuerung im Förderprogramm Städtebaulicher Denkmalschutz".* Stadt Leipzig Dezernat Stadtentwicklung und Bau.

Stamps, A. E. and J. L. Nasar (1997). Design review and public preferences: Effects of geographical location, public consensus, sensation seeking, and architectural styles. *Journal of Environmental Psychology 17*(1), 11–32.

Steinführer, A., A. Haase, and S. Kabisch (2010). Leipzig – Reurbanisierungsprozesse zwischen Planung und Realität. In M. Kühn and H. Liebmann (Eds.), *Regenerierung der Städte*, pp. 176–194. VS Verlag für Sozialwissenschaften.

Stoltz, J. and P. Grahn (2021). Perceived sensory dimensions: An evidence-based approach to greenspace aesthetics. *Urban forestry & urban greening 59*, 126989.

Taylor, R. P. (2006). Reduction of Physiological Stress using Fractal Art and Architecture. *leonardo 39*(3), 245–251.

Tong, F. (2003). Primary visual cortex and visual awareness. *Nature reviews neuroscience 4*(3), 219–229.

Van Geert, E. and J. Wagemans (2020). Order, complexity, and aesthetic appreciation. *Psychology of Aesthetics, Creativity, and the Arts 14*(2), 135.

Votis, A. (2017). Planning for Green Infrastructure: The Spatial Effects of Parks, Forests, and Fields on Helsinki's Apartment Prices. *Ecological Economics 132*, 279–289.

Wang, G.-Y. (2023). The Effect of Environment on Housing prices: Evidence from the Google Street View. *Journal of Forecasting 42*(2), 288–311.

Wang, R., Y. Liu, Y. Lu, J. Zhang, P. Liu, Y. Yao, and G. Grekousis (2019). Perceptions of Built Environment and Health outcomes for Older Chinese in Beijing: A Big Data Approach with Street View Images and Deep Learning Technique. *Computers, Environment and Urban Systems 78*, 101386.

Wang, R., J. Zhao, and Z. Liu (2016). Consensus in visual preferences: The effects of aesthetic quality and landscape types. *Urban Forestry & Urban Greening 20*, 210–217.

Weiß, D.-I. G. (2023). Der Grundstücksmarkt in der Stadt Leipzig Stichtag 01.01.2023.

Willis, E. J. and R. L. Dornbush (1968). Preference for Visual Complexity. *Child development*, 639–646.

Xu, X., W. Qiu, W. Li, X. Liu, Z. Zhang, X. Li, and D. Luo (2022). Associations between Street-View Perceptions and Housing Prices: Subjective vs. Objective Measures Using Computer Vision and Machine Learning Techniques. *Remote Sensing 14*(4), 891.

Yan, H.-B., V.-N. Huynh, T. Murai, and Y. Nakamori (2008). Kansei evaluation based on prioritized multi-attribute fuzzy target-oriented decision analysis. *Information Sciences 178*(21), 4080–4093.

Ye, V. and C. Becker (2021). Moving Mountains: Geography, Neighborhood Sorting, and Spatial Income Segregation. Working paper, Economic Research Initiatives at Duke (ERID) Working Paper No. 304.

Zurek, W. H. (1989). Algorithmic Randomness and Physical Entropy. *Physical Review A 40*(8), 4731.

A Appendix

Table A-1 – Regression Results

Dependent Variable:	log(Rent per sqm)				
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
Construction Year	-0.002	-0.002	-0.002	-0.002	-0.002
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Construction Year Squared	0.000*	0.000*	0.000*	0.000*	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Guest Bathroom	0.057***	0.055***	0.055***	0.057***	0.057***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Fitted Kitchen	0.049***	0.049***	0.049***	0.049***	0.049***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Garden	0.005*	0.003	0.003	0.005*	0.004*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Elevator	0.051***	0.050***	0.050***	0.052***	0.052***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Balcony	0.059***	0.060***	0.060***	0.059***	0.059***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Basement	-0.019***	-0.022***	-0.022***	-0.019***	-0.019***
	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
Parking Space	0.019***	0.020***	0.020***	0.020***	0.020***
	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)
Subsidized Housing	-0.076***	-0.071***	-0.071***	-0.076***	-0.078***
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
Living Area (sqm)	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Living Area Squared	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Number of Rooms	0.018***	0.019***	0.019***	0.019***	0.019***
	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)
Central Heating	0.046	0.062	0.062	0.048	0.045
	(0.036)	(0.044)	(0.044)	(0.036)	(0.036)
Simple Heating	0.039	0.054	0.053	0.041	0.038
	(0.036)	(0.045)	(0.045)	(0.037)	(0.036)
Sophisticated Heating	0.127***	0.133***	0.132***	0.128***	0.125***
	(0.036)	(0.045)	(0.045)	(0.037)	(0.036)
Attic Apartment	0.016***	0.015***	0.015***	0.015***	0.016***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Maisonette Apartment	0.015	0.009	0.008	0.015	0.015
	(0.017)	(0.018)	(0.018)	(0.017)	(0.017)
Penthouse Apartment	0.037***	0.034***	0.034***	0.037***	0.037***
	(0.006)	(0.007)	(0.007)	(0.006)	(0.006)
Floor Level	-0.002***	-0.003***	-0.002***	-0.002**	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Facilities: Normal	-0.017***	-0.017***	-0.017***	-0.017***	-0.017***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Facilities: Sophisticated	0.066***	0.069***	0.069***	0.066***	0.066***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Facilities: Deluxe	0.134***	0.140***	0.141***	0.134***	0.132***
	(0.009)	(0.008)	(0.008)	(0.009)	(0.009)
First Occupancy	0.160***	0.165***	0.164***	0.159***	0.159***
	(0.009)	(0.010)	(0.010)	(0.009)	(0.009)
Modernized	0.061***	0.065***	0.064***	0.060***	0.060***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)
Log Distance to CBD	-0.063***	-0.063***	-0.063***	-0.062***	-0.061***
	(0.022)	(0.023)	(0.023)	(0.022)	(0.022)
Log Distance to Lake	-0.028***	-0.028***	-0.028***	-0.028***	-0.028***
	(0.006)	(0.007)	(0.007)	(0.006)	(0.006)
Log Distance to Medical Center	0.002	0.009	0.009	0.002	0.002
	(0.010)	(0.011)	(0.010)	(0.010)	(0.010)
Log Distance to Recreation	-0.005	-0.004	-0.004	-0.005	-0.005
	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
Log Distance to Restaurant	0.006	0.002	0.002	0.006	0.005
	(0.013)	(0.014)	(0.014)	(0.013)	(0.013)
Log Distance to River	-0.015**	-0.015**	-0.015*	-0.015**	-0.014**
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Log Distance to School	0.005*	0.005	0.004	0.005*	0.005*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Log Distance to Urban Green Spaces	-0.003	-0.003	-0.003	-0.002	-0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Log Distance to University	-0.001	-0.009	-0.008	0.000	-0.002
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)

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Table A-1 – Continued

Dependent Variable:	log(Rent per sqm)				
Model:	(1)	(2)	(3)	(4)	(5)
PM2.5 Air Pollution	-0.036***	-0.027**	-0.028***	-0.036***	-0.036***
	(0.010)	(0.011)	(0.011)	(0.010)	(0.010)
Population Density	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share of Migrants (%)	0.040	0.139	0.139	0.040	0.041
	(0.087)	(0.095)	(0.095)	(0.087)	(0.086)
Crime Rate (%)	-0.029	0.027	0.029	-0.029	-0.031
	(0.056)	(0.032)	(0.033)	(0.056)	(0.056)
Unemployment Rate (%)	-0.515**	-0.757***	-0.755***	-0.525**	-0.515**
	(0.220)	(0.245)	(0.246)	(0.220)	(0.220)
Low-Level Aesthetics (LL)		0.057			
		(0.054)			
Mean Low-Level Aesthetics Nerby Houses		0.057			
		(0.122)			
Construction View Index			-0.054**		
			(0.025)		
Green View Index			0.081*		
			(0.044)		
Preservation Status				0.012***	0.013**
				(0.004)	(0.005)
Share Nearby Houses Preserved				-0.006	-0.007
				(0.005)	(0.006)
Preserved Window					-0.010
					(0.006)
Preserved Entrance					0.001
					(0.005)
Preserved Yard					0.027***
					(0.007)
Preserved Artistic Elements					0.014***
					(0.006)
Share Nearby Houses with Preserved Windows					0.005
					(0.007)
Share Nearby Houses with Preserved Entrances					-0.002
					(0.006)
Share Nearby Houses with Preserved Yards					-0.004
					(0.009)
Share Nearby Houses with Preserved Artistic Elements					0.004
					(0.007)
Fixed-effects					
Year	Yes	Yes	Yes	Yes	Yes
District	Yes	Yes	Yes	Yes	Yes
Fit statistics					
Adjusted R^2	0.75780	0.76725	0.76733	0.75793	0.75847
Observations	276,155	220,786	220,786	276,155	276,155

Clustered (Visual Surrounding) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*