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"Estimating building prices in Vienna: A hedonic pricing model analysis incorporating energy efficiency factors "

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Abstract

The master thesis investigates several research questions, mainly estimating the transaction price for buildings in Vienna, using unique dataset obtained from europa.data database published by Stadt Wien. It is a collection of transaction data, including the date of purchase, location of each building, transaction price, and more. The dataset with two added variables, rental and electricity prices, is sufficient for constructing a hedonic pricing model incorporating explanatory variables linked to energy efficiency. The essential concern represents independent variable construction class of the building, considering that it is strongly associated with the energy efficiency of the properties. Therefore, another research question focuses on the influence of energy efficiency through construction class rather than the other variable's impact. In other words, considering the effect of construction materials on energy efficiency determines whether there is a connection between the construction class and the building's transaction price. The period is set at the beginning of the corona pandemic, followed by the Russian invasion of Ukraine. Time dummies are used to eliminate any time effect. In the last 20 years, there has been a preference to build more efficient buildings under energy efficiency goals in Austria, making Austria one of the leading countries in this sector. Applying advanced technologies in building construction presents a substantial opportunity for energy savings.

Key words: hedonic pricing model, energy efficiency, construction class, real estate, property

Zusammenfassung

Die Masterarbeit untersucht mehrere Forschungsfragen, hauptsächlich die Schätzung des Transaktionspreises für Gebäude in Wien, mit einem einzigartigen Datensatz aus der europa.data Datenbank der Stadt Wien. Es handelt sich um eine Sammlung von Transaktionsdaten, einschließlich Kaufdatum, Standort jedes Gebäudes, Transaktionspreis und mehr. Der Datensatz, ergänzt um zwei Variablen, Miet- und Strompreise, reicht aus, um ein hedonistisches Preisbildungsmodell zu konstruieren, das erklärende Variablen in Bezug auf die Energieeffizienz berücksichtigt. Die Hauptüberlegung stellt die unabhängige Variable Bauklasse des Gebäudes dar, da sie stark mit der Energieeffizienz der Immobilien verbunden ist. Daher konzentriert sich eine weitere Forschungsfrage auf den Einfluss der Energieeffizienz durch die Bauklasse, eher als auf die Auswirkungen anderer Variablen. Mit anderen Worten, unter Berücksichtigung der Auswirkungen von Baumaterialien auf die Energieeffizienz wird ermittelt, ob es eine Verbindung zwischen der Bauklasse und dem Transaktionspreis des Gebäudes gibt. Der Zeitraum ist auf den Beginn der Corona-Pandemie festgelegt, gefolgt von der russischen Invasion in die Ukraine. Zeitdummies werden verwendet, um jeglichen Zeiteffekt zu beseitigen. In den letzten 20 Jahren gab es in Österreich unter den Zielen der Energieeffizienz eine Präferenz, energieeffizientere Gebäude zu bauen, was Österreich zu einem der führenden Länder in diesem Sektor macht. Der Einsatz fortschrittlicher Technologien im Bauwesen bietet erhebliche Möglichkeiten zur Energieeinsparung.

Schlüsselwörter: hedonistisches Preisbildungsmodell, Energieeffizienz, Bauklasse, Immobilien, Eigentum

1. Introduction

As the corona pandemic hit the world, a construction sector in Austria emerged with substantial growth. This sector is generally resilient to economic fluctuations and crises. In fact, it is in a persistent crisis, residential property prices decreased by 2.3% from the 4th quartal in 2022, and the prediction is to decline by 10% in 2024. (Eder, 2023) In 2021 construction activity slightly decreased and continued falling. In other words, count of housing permits to construct the dwellings. On the other hand, transactions of homes rose. (Delmendo, 2022) There is also a growing trend of reconstruction of older buildings in Austria, largely due to the political framework and Austria's goals towards energy efficiency. (Federal Ministry for Sustainability and Tourism, Federal Ministry for Transport, Innovation and Technology, 2018)

Nowadays, one of the most popular topics worldwide is global warming, which brings attention to the building sector, the main interest of this thesis. The building sector represents a huge role in emission production, creating a great opportunity for emission savings.

This thesis clarifies whether there is a link between building sector energy efficiency policies and the real estate market. More importantly, according to available sources, there is no study in Austria examining the influence of construction classes on transaction prices, which makes this study unique. Is there a link between construction class and energy efficiency? There are several reasons why construction class is linked to energy efficiency. Construction classes have different insulation and thermal mass levels, which can affect the building's ability to maintain heat and, thus its energy efficiency. Moreover, the higher construction class uses more advanced and efficient construction technologies. The construction classes of the building have been developing over time, as it is visible from the dataset, where the majority of the construction class is 1. More about the characteristics of all classes is described in Data chapter. Expected impact is that the better the construction class, the higher the transaction price of the building. In addition, it is anticipated that every district will have a different impact on the transaction price due to location characteristics. In addition, electricity prices and rental prices are expected to impact transaction prices negatively.

The core methodology in the thesis is a hedonic pricing model, widely used to estimate the prices of properties. (Kolbe, J., Schulz, R., Wersing, M. et al. , 2020) The sustainable urban development and real estate valuation sectors have increasingly recognized the importance of energy efficiency in building construction. (Federal Ministry for Sustainability and Tourism, Federal Ministry for Transport, Innovation and Technology, 2018) It is directly connected with construction classes of buildings which play a significant role in emission production. Hence, understanding the effect of building characteristics and its impact on the prices of buildings, with an emphasis on energy efficiency, is crucial in shaping urban development, energy efficiency policies, and real estate investment strategies. (Federal Ministry Republic of Austria Climate Action, n.d.)

Each construction class has its characteristics, mainly materials used in their construction. The variation in materials inevitably leads to different energy consumption levels, ultimately impacting their energy efficiency. Given that property's energy efficiency significantly contributes to its overall value, the essential question investigates whether it substantially influences the transaction price. Considering the growing importance of sustainability and energy conservation in the modern world, it is plausible that buildings with superior energy efficiency will probably attract higher prices in the real estate market. In addition, thanks to less energy consumption, energy efficient buildings usually have lower utility bills. (Evangelista, R., Ramalho, E. A., Silva, J. A., 2020) Moreover, as the real estate market is not homogenous, the district is another intriguing variable that could shed light on how the location differs across properties, especially in Vienna, where some districts are generally more popular than others. With this in mind, property purpose and the type of the building could also impact the transaction price however, it is more demanding to capture this effect.

This study contributes to the existing literature by examining the relationship between property prices and characteristics included in the hedonic pricing model. These characteristics could be any closer information about the property describing the price development. Furthermore, in energy efficiency impact studies on real estate prices, one of the explanatory variables is the energy certificate of the building. (Evangelista, R., Ramalho, E. A., Silva, J. A., 2020) In this thesis, the author decided to exchange this variable for the construction class of the building, as mentioned before. The essential goal of the thesis is to enhance our understanding of how key variables, district, construction class, size indicator, and other key variables affect building transaction prices. Such an insight could enrich sustainable construction practices, contributing to urban plans and shaping future energy policies in Austria and EU.

2. Economic outlook

Austria aims to raise its share of renewable energy sources in the electricity mix resulting in a transition to a low-carbon energy system. Several policies have been implemented to achieve this target, such as wind, solar, biomass, and hydropower. Base for the renewable energy support is set by the "Green Electricity Act" which was first introduced in 2002 and had its latest update in 2017. It is closely related to the feed-in-tariff system that registers which renewable sources electricity comes from. The idea is to support small-scale producers of solar panels on homes or other buildings by restricting changes in prices for renewable energy. In other words, renewable energy has fixed prices for these producers. (International Energy Agency, 2017) Moreover, every four year larger businesses must undergo audits, while small companies are not obligated to. (Eurofond, 2021)

Plenty of policies have been implemented regarding the energy efficiency of building construction. "Building of Tomorrow" and "City of Tomorrow" are the most relevant to this thesis. (Federal Ministry Republic of Austria Climate Action, bmk.gv.at, n.d.) "Building of Tomorrow" is one of the research and technology initiatives, initiating from the foundations of "*low-energy solar buildings*" (Federal Ministry Republic of Austria Climate Action, nachhaltigwirtschaften.at, 2023) and passive building designs while integrating environmentally friendly and renewable construction materials. The aim is to invent modern and efficient technology for the construction. Moreover, other aims are to rebuild the office and factory buildings and to share knowledge about technologies and methodologies beyond Austria. The long-term goal of this project is to boost the building's energy efficiency by improving construction and usage, aiming to decrease greenhouse gas emissions to a net-zero level. (Federal Ministry Republic of Austria Climate Action, nachhaltigwirtschaften.at, 2023)

"City of Tomorrow" is more focused on residential buildings thus its primary goal is to reduce emissions in scope of residential real estate while increasing its attractiveness in the real estate market. (Federal Ministry Republic of Austria Climate Action, nachhaltigwirtschaften.at, 2023) It is not surprising that the better characteristics of the building, the less energy is needed, therefore less additional electricity. (Federal Ministry Republic of Austria Climate Action, bmk.gv.at, n.d.) This could impress potential buyers or tenants.

Implementing energy certificates on each building represents a huge step towards energy efficiency goals in European Union. According to Directive 2010/30/EU of the European Parliament, all EU countries must implement Energy Performance Certificate (EPC) (The

European Parliament, 2010). EPC's main target is to offer information about the energy efficiency of property for all interested agents and buyers or tenants. The certificates should also reveal owner's or tenant's cost-effective way of energy realization of properties. (European Commission, n.d.)

Time period in the research is focused on the years 2019 to 2022. Several aspects have been affecting the real estate market prices. (Statistics Austria, 2022) According to a paper from Ernst & Young (2020), the housing market in Austria is less vulnerable to the economic crisis than markets with other properties. In 2020, interest rates were expected to stay the same, and rents would decrease. (Young, 2020) Due to a significant rise in the prices in the following years, the trend in construction activity has declined, with a 6.1% decrease in the total count of residences authorized for construction in 2021, compared to the previous year. Demand did not decline, on the contrary, it continued to rise. (Delmendo, 2022) As reported by OeNB, as the covid-19 restrictions were lifted, Austria's economy expanded. (Nationalbank, 2023)

3. Literature overview

The hedonic pricing model allows for decomposition of detailed property characteristics. Therefore, it is suitable for real estate price estimation. According to Sirmans et al. (2005), the real estate market is not homogenous since several house characteristics vary across locations and buyers. Hedonic regressions usually show contribution to overall price of each characteristic separately. (Sirmans, G., S., Macpherson, D., A., Macpherson, Zietz, N., E., 2005) Hedonic pricing model presents certain features, for example heteroscedasticity and non-linear relationships. Study from Stevenson (2004) addressed the presence of heteroscedasticity in the hedonic pricing models when using OLS. A possible cause of heteroscedasticity are the inhomogeneous properties of real estate mentioned above. On the other hand, in some cases, when the sample is smaller and less variable, issues do not appear. (Stevenson, 2004)

Kolbe et al. (2020) focused on various types of data, focusing on identifying different use for economists. They claim that in hedonic pricing applications, the estimates can be used for estimation of transaction prices as well as sale prices. They distinguished between ask and sale data and found that they are noticeably different, and both are suitable for estimating different characteristics. For instance, ask data are not suited to predict prices of individual properties. Both sale and ask data belong to listing data although, in case of this study, transaction data are used, which have proved to be efficient estimates. (Kolbe, J., Schulz, R., Wersing, M. et al. , 2020) Potrawa and Tetereva (2022) claimed that hedonic models are sufficient and successful for using to estimate prices and that they are easy to interpret. Several assumptions must be fulfilled to have credible estimates. They also showed that machine learning models are undeniably more fitting than basic hedonic OLS regressions. (Potrawa, T., Tetereva, A., 2022)

Moreover, a study by Brounen and Kok (2011) investigated the impact of policy implications in EU establishing energy certificates on the transaction price of the properties. They demonstrated that better energy labelling increases property prices. (Brounen, D., Kok, N., 2011) Another study by Kahn and Kok (2013) using hedonic analysis claimed that offering customers to see energy or sustainability information about the property can indeed change their decisions. (Kahn, M. E., Kok, N., 2014)

Similarly, as the other studies, main objective of the thesis is to estimate the transaction prices with characteristics that could likely contribute to the building's energy efficiency and other property's characteristics. Based on Asdrubali and Desideri (2019), the main goal concerning climate crisis production in course of policy has become to mitigate the huge environmental effects across numerous countries, including Austria. (Asdrubali, F., Desideri, U., 2019) "*Building sectors become key targets of energy policies in various countries, to be matched by means of strategies aimed at enhancing energy efficiency, integration of renewable energy technologies in buildings, mitigation of environmental impacts, and use of "low-carbon" materials and technologies*." (Asdrubali, F., Desideri, U., 2019) Thus an essential intention is to build a higher energy efficient building that produces less environmental corruption while not decreasing comfort. (Asdrubali, F., Desideri, U., 2019)

Along the way towards energy efficient buildings, one of the major steps emerged in 2003 when the European Union established the Energy Performance of Buildings Directive. Later, energy performance certificates become visible and accessible to buyers when entering residential markets. (Brounen, D., Kok, N., 2011) In May 2010, the European Parliament established the necessary labelling providing basic product information as well as energy efficiency. (Council of the European Union, 2010)

Inspiration for this thesis originates from Evangelista et al. (2020), with study investigating whether energy efficiency impacts the transaction prices in Portugal. The authors used the hedonic pricing model, along with other variables that are assumed to capture energy efficiency effect. Moreover, due to a lack of data lot of studies using this model focus only on some part of the impact. The results showed, as expected, that better energy certificates yield higher price premium. (Evangelista, R., Ramalho, E. A., Silva, J. A., 2020) The impact as well as in this study is expected to be positive. In this case, the better construction materials and other features of buildings, the higher price.

Taruttis and Weber (2022), using a hedonic pricing model for Germany, found a negative effect of energy consumption on demand price for single-family homes. In addition, houses with electric heating, night storage heating, or stove heating are sold at a discount compared to houses with gas heating. On the other hand, renovated properties from 2000 and later have higher prices than older ones. Moreover, in areas with higher population density, home prices increase if energy consumption declines. Regarding the less energy-efficient classes D to H, there is a price premium in case the energy consumption declines. (Taruttis, L., Weber, Ch., 2022)

4. Data

To recognize the correct approach and consequently choose the right model to use, it is necessary to examine the data by performing descriptive statistics, distribution plots, residual plots, and robustness checks. This chapter is devoted to the most relevant characteristics of the dataset.

The dataset is "*Collection of property transaction data from the land register including evaluation, land use and development regulations, local inspection*" published by Stadt Wien online at europa.data (Wien, 2023) Originally, the dataset contains 60 017 observations from year 1987 to 2022. Considering the purposes of the thesis, only the years 2019, 2020, 2021 and 2022 are included. Year 2019 serves as a base year for reflection of increases or decreases in prices over time. Moreover, after cleaning the missing values, 2094 observations are left. It consists of a dependent variable transaction price, several explanatory variables, and variables added by the author. Initially, the dataset provides also detailed information about a building's location and the purpose of each property. This information contributed to construct a final dataset for the research (for full list of variables see Table 1). The online sources to original dataset and manually added variables are provided in Appendix 2.

The selection of the variables is based on availability and consistency with the purpose of the thesis. The transaction price is a sufficient reflection of the property's real value. It is the value the buyer pays to the seller, despite its selling price. On the other hand, selling price compares the offered price to the transaction price. Most of these prices coincide. Hence there wasn't much of a difference.

	Selling price in EUR	*Transaction price in EUR*
Median	770 000	770 000
Min	60 000	60 000
Max	56 940 500	56 940 500
Standard Error	53 883.03	53 791.33

The buy date was used to differentiate between years for the construction of the dummy variables. Nevertheless, the author did not check for time-series characteristics such as trends and autocorrelation, as the time length of 4 is too short. Furthermore, it is possible to eliminate the time effect thanks to year dummy.

As anticipated, there is a 65.9% correlation between the variables floor and height. This makes sense, as a taller building typically has more floors. Both floor and height are closely related to the construction class. Surprisingly, in this dataset the worse the construction class, the taller the building. On the contrary, the better construction class, the lower the building.

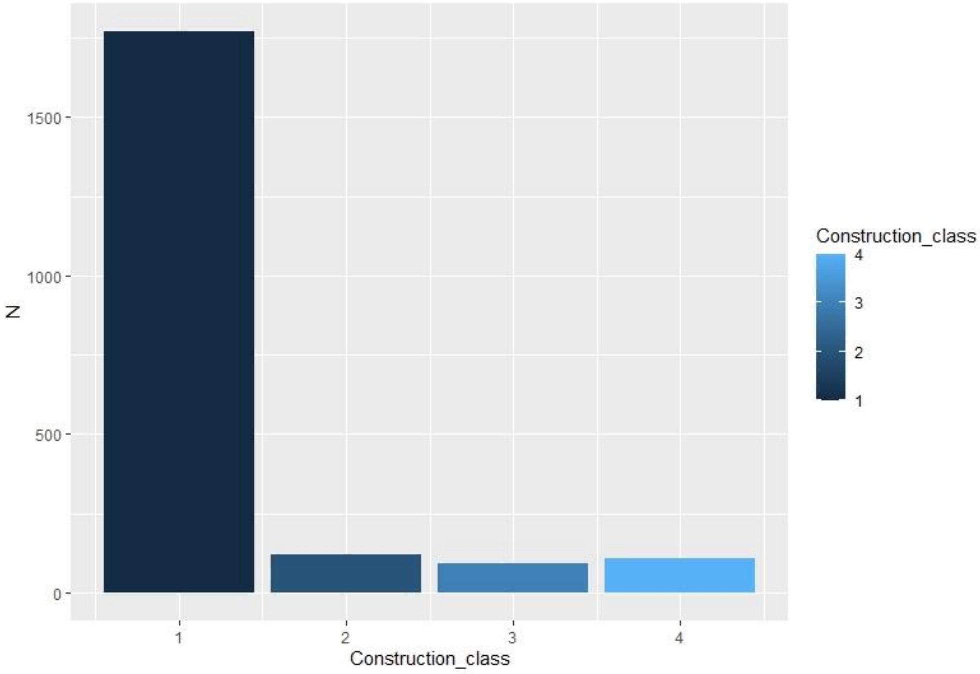

Figure 1 Construction class distribution

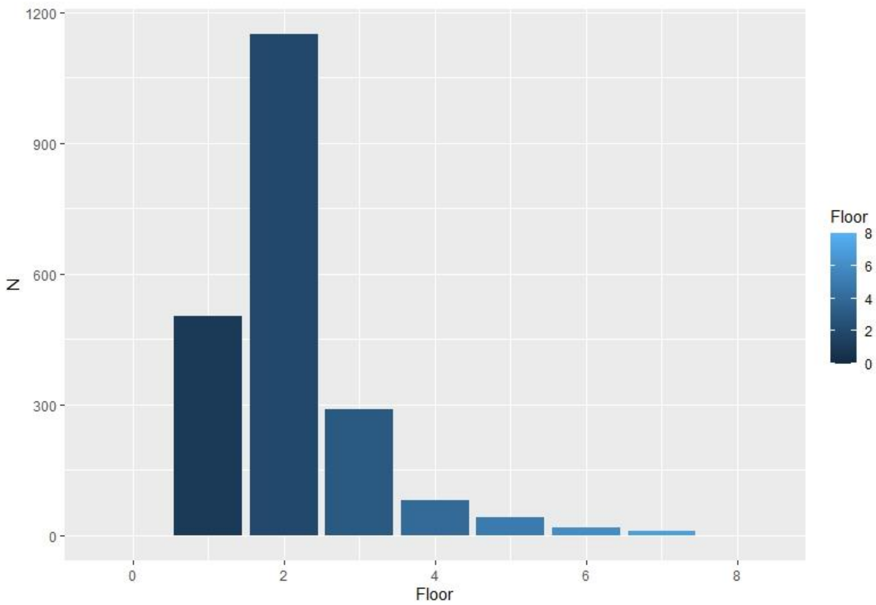

Figure 2 Floor distribution

Most observations are found in class 1, followed by class 2, with a considerable difference in the number of observations, which are the lowest buildings. The distribution of floors peaks at two, indicating that buildings with two floors are the most prevalent. Explanatory variables, electricity price as well as the rental prices, are added to the dataset manually by the author. Both electricity prices and rental prices are monthly observations sourced from the Federal Reserve of economic data and Statista websites. The choice of electricity over other forms of energy is intentional, given that energy usage in buildings is not solely about heating. Electricity as an energy source is widely used not only for heating but for light, cooking, internet, and to keep running all devices demanding electricity. Generally, it is hard to say what type of energy is used the most. Every energy has its own measure, therefore it is very challenging to compare. Adding rental prices into the dataset can shed light on housing affordability in Vienna. The dataset includes a lot of rental houses from an economic perspective, renting and buying are substitute goods for the service of housing. Therefore, changes in the price of one can influence the demand and price for the other.

The districts variable is crucial to distinguish between more and less attractive locations. The original dataset provides the street of each property, which allowed the author to find the exact districts of all the buildings. Certain districts 1 and 4 were missing from the dataset. The district's distribution is uneven thus we can conclude that the number of properties for sale differs across districts.

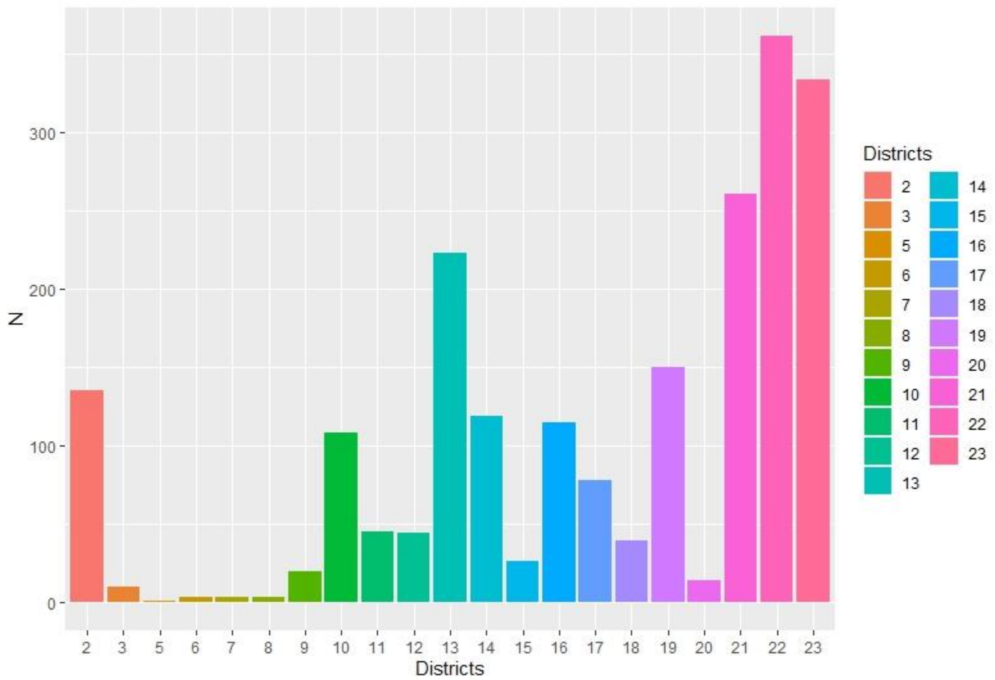

Figure 3 Districts distribution

Construction classes

Building construction classes often refer to a structural type and their resilience to damage. The used materials and the construction method can influence a building's energy performance, on the other hand energy efficiency depends on a variety of factors including insulation, orientation, location, and heating systems.

In this analysis, the construction class is considered a categorical variable, since with higher/worse class, the expected price would decrease or vary across classes. There are five construction classes we know, although construction type 5 will not be described, it is not present in the whole dataset.

Constructions of type 1 are considered as fire resistive and are usually used in higher commercial buildings. Thanks to its construction and used non-combustible material "*reinforced concrete and protected steel*" (NEW ENGLAND, Institute of Technology, 2021) these buildings capable of withstanding elevated temperatures over an extended period. Furthermore, along with expensive used materials it also increases the building's cost, thus price. (NEW ENGLAND, Institute of Technology, 2021)

Construction type 2 is non-combustible, it is often used for modern schools, shopping centres, and reconstructed commercial buildings. They are usually characterized by a metal flooring and roofing, complemented with walls constructed from masonry or tilt-slab. (NEW ENGLAND, Institute of Technology, 2021)

Construction type 3 or in other words ordinary, are commonly brick structures, composed of "*either tilt-slab or reinforced masonry walls*" (NEW ENGLAND, Institute of Technology, 2021), certain interior elements are crafted from flammable materials or wood. These kinds of buildings could be either new or old for instance schools or houses and other. (NEW ENGLAND, Institute of Technology, 2021)

Construction type 4 or heavy timber, primarily constructed using chunks of timber, joined together with metal plates and bolts. This style of construction was prevalent prior to 1960, making it easy to identify structures such as old churches, factories, and barns that typically fall into this category. (NEW ENGLAND, Institute of Technology, 2021)

The specific energy efficiency consumption depends on a variety of factors, including how the building is used and maintained, and the location. The construction class alone provides only a partial view of a building's energy efficiency. (Asdrubali, F., Desideri, U., 2019)

- Wood is a good insulator, but it needs to be used properly to get its benefits. Wood-framed buildings can be very energy efficient when paired with proper insulation and efficient heating and cooling systems. Wood also has a lower embodied energy (the energy consumed by all processes associated with the production of a building) compared to steel and concrete. (Asdrubali, F., Desideri, U., 2019)

- Brick: Brick buildings can provide good thermal mass, absorbing heat during the day and releasing it at night. This can improve energy efficiency in climates with large temperature changes between day and night. The energy efficiency of brick buildings can be highly dependent on the insulation used and the climate. (Asdrubali, F., Desideri, U., 2019)
- Steel and Concrete: Buildings made with steel or concrete can have a high thermal mass, like brick. They can be energy efficient in certain climates, but again, this is highly dependent on the design of the building, insulation, and heating/cooling systems. Concrete and steel often have higher embodied energy compared to wood. (Asdrubali, F., Desideri, U., 2019)

Transaction price

Transaction price is the price that the buyer agrees to pay, and the seller agrees to obtain. In this dataset it varies across variables. It is necessary to examine the transaction price from different perspectives to be able to obtain a relevant result. Some of the impacts are captured by the dataset, although some are not observed, for instance popularity of each district, historical value, or the age of the buildings. All these could substantially shape the impact of the explanatory variables. All the possible impacts are included in this chapter.

Average price per floor could enable insight into how the floor affects the transaction price. Regarding residential properties, higher floors often have better views, less noise, and more privacy, which can make them more desirable and therefore more expensive. If the price per floor increases with floor level, this could indicate that these factors are significantly impacting property values. In commercial properties, the price per floor can indicate how efficiently space is being utilized. Higher prices per floor could suggest efficient use of space, especially in high-rent districts.

The box plots in Figures 4 and 5 show the average price per floor and average price per construction class. Concerning Figure 4, first and the second class are almost on the same level, following by slightly higher floor 3, floors four through seven, however, stand significantly above the lower levels.

Figure 5 displays average price per construction class. Visibly the transaction price across class is steady and doesn't indicate downward or upward trend. 1st and 2nd class average is slightly above 13 log transaction prices, followed by marginal increase in 3rd and 4th class price average. Classes 5, 6 and 7 show around 15 log transaction prices. Older buildings, particularly those with architectural or historical significance, may have higher prices due to their unique characteristics, rarity, or the desirability of preserving them. Most of the buildings class 4 are in 2,9,10 and 20th districts. This class are older buildings, thus slightly lower price is expected. Moreover, older buildings also hold an investment potential, since they may be an opportunity for reconstruction. Classes 2,3 contain newer buildings, resulting in a bit higher average transaction price. (Complete table with distribution of buildings across districts are in Table A.3 in Appendix A.)

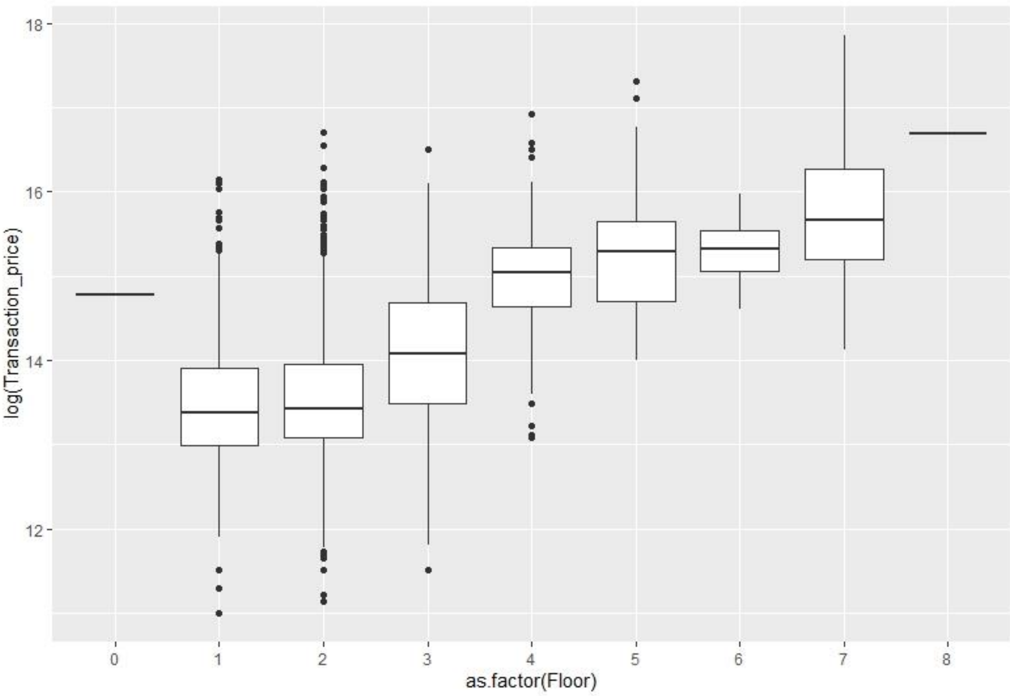

Figure 4 Average price per floor

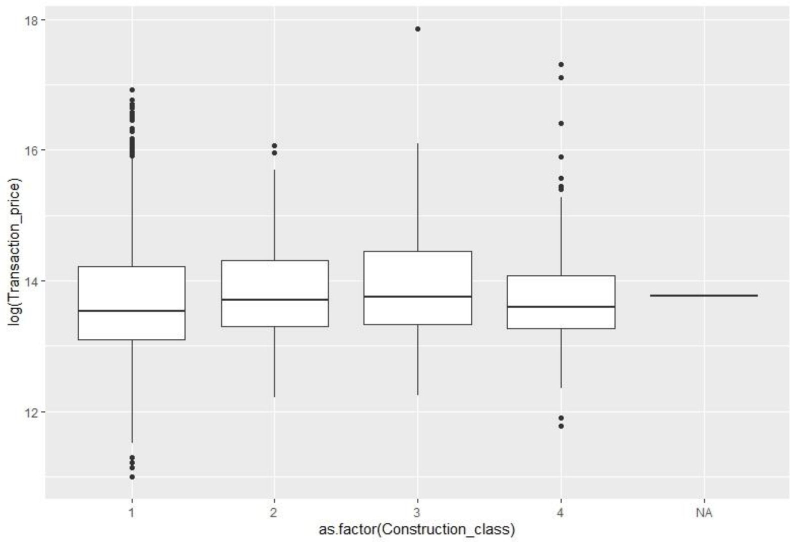

Figure 5 Average price per construction class

Figure 6 shows that the average transaction price per district is significantly varying. Generally, the most popular districts for living in Vienna are 1,2,3,5,8,9,17,18,19, therefore it is expected that the price would be higher in these locations. Nevertheless, property pricing doesn't revolve solely around location. It is crucial to notice what construction classes as well as the type of the buildings dominate in each district. Before moving forward, it is important to understand the specific definitions of villas and family houses. Villa is a single-standing building. Some could be historical Roman or Victorian style and contain more than one building on its land, while the house is a single or two-family free-standing object. In the dataset, houses for rent and permanent living are in separate categories. Moreover, the purpose of the villa isn't necessarily the living but also a shot-term rent for a holiday.

The highest price is clearly in the 9th district, which can surprisingly be attributed to the prevalence of villas in this area. In the provided dataset, there are 18 villas, and 2 family houses is the 9th district. The 6th followed by 3rd district hold the second place in terms of average price. This is likely due to considerable presence of rental and family houses in these districts. The third district is somewhat mixed, with a central bourgeois area featuring historical palais buildings and a more working-class southern region predominantly populated by houses. On the contrary, districts 21,22,23 have the lowest price, which is probably due to predominant demolition objects sold in these areas together with a sizable part of the buildings being class 1, thus commercial. All these lower the transaction price. (Complete tables with distribution of construction class and type of the buildings across districts are in Table A.2 and Table A.3 in Appendix A.)

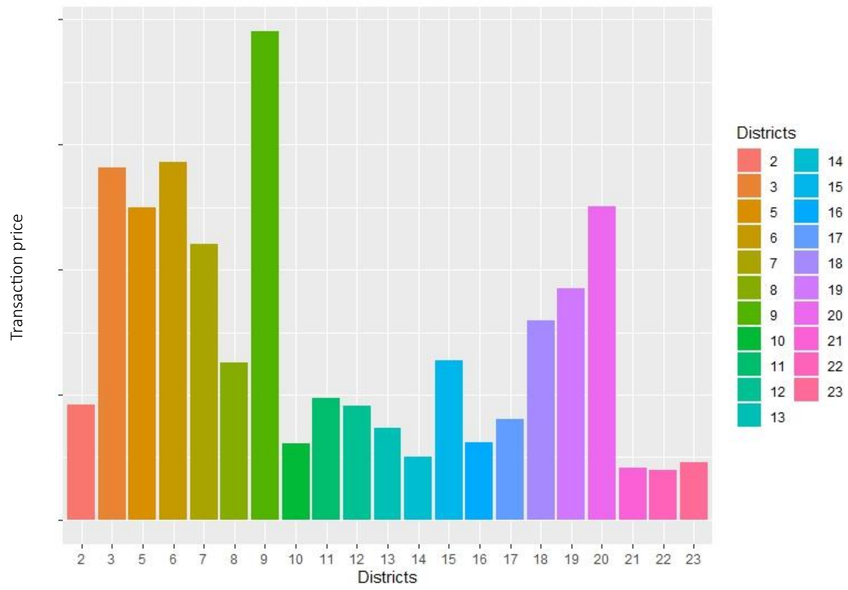

Figure 6 Average transaction price per district

The density plot on figure 7 is right-skewed, indicating that the majority of the transaction prices are on the lower end of the scale, with fewer transactions occurring at higher prices. Therefore, most transaction prices are located on the left side of the mean, whereas there are some properties in the tails on the right side of the mean. In other words, while most of the properties demonstrate average price, there are few with significantly higher prices.

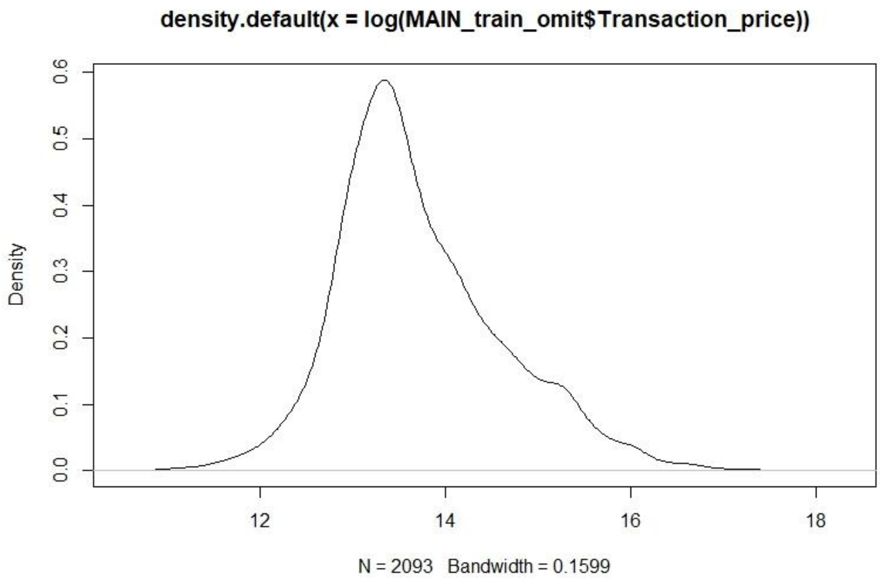

Figure 7 Density plot of the log (Transaction price)

5. Econometrics approach

This chapter describes an empirical strategy used to answer research questions and hypotheses outlined in the previous section. The aim is to provide a credible framework that analyses relationship between transaction price of buildings, their construction class, and other listed variables. Relationship between transaction price and the construction class might depend on various aspects, for instance, energy efficiency of each construction class. Additionally, there are several other reasons, such as the price of used materials, the type of building and corresponding construction class or the potential of the building despite its materials.

To explain transaction prices using several property characteristics, the hedonic pricing model is selected as an appropriate method. Several studies have also been done using this model for specific cases, including energy efficiency measures. (Evangelista, R., Ramalho, E. A., Silva, J. A., 2020) The main feature of hedonic pricing model is that the dependent variable is price. It could be offered, transaction, or index price of the properties. Transaction data rather than asking price have proved to be more effective in predicting the market values of individual houses. (Kolbe, J., Schulz, R., Wersing, M. et al. , 2020) Explanatory variables are various characteristics of the properties, namely location, age, size, energy certificate, type, purpose, and more. This approach is particularly suitable for the study as it acknowledges that the property's price is not a function of the property as a whole, but rather of its distinct characteristics, for instance as named above.

Firstly, it is important to note that only a part of the explanatory variables affecting the price can be provided. The price changes as well because of some other unobserved variables, for instance its purpose, attractiveness of the locations, distance from the city centre or the facilities, and others. Considering the character of the provided data, an appropriate approach is to use both linear and non-linear regression in the analysis. The linear relationship is used for transaction price with floor, height, electricity, and rental price. Furthermore, districts, construction class and floor, in some cases, are used as categorical. The reason why non-linear relationship is used is quite evident. The author doesn't anticipate a straight increase or decrease in the transaction price while the construction class or district number increases or decreases. As for the number of floors, there are two perspectives so that it could be used as a categorical as well as a factor variable. Therefore, in this analysis, every district as well as construction class has its coefficient. Floor is used both ways, however, floor has been shown to have minor impact on the price than the height. According to the R^2, combinations with height turned out to have better explanatory power. It is inevitable to consider that bigger height doesn't necessarily mean more floors, it could also mean higher ceilings. Floor and height can't be used simultaneously in one model, which is logically coherent because the taller the building, the higher the number of floors. It would be indeed surprising if these two were not correlated. An intriguing observation is that buildings of a lower construction class are in fact more costly, despite their lack of modern materials, fire protection, and other factors. A plausible explanation for this could be due to a building's height, historical value, or type of the building. As the building height increases, the construction class relatively rises (lower the construction class), thus proportionally affecting the property price, leading to higher costs for buildings of lower construction classes. On the other hand, the majority of the first construction class buildings have one or two floors, resulting in higher costs for these properties because of expensive materials. (To see the whole distribution of floors across construction class, see Table A.5 in Appendix A)

A full description of variables is provided in Table 1. Only a few variables were extracted from the original dataset to construct the final dataset. District variable was provided in the wrong format, it was necessary to create a District nominal variable with numbers of districts from 1 to 23. Moreover, the rental prices, as well as the electricity prices were added manually.

Table 1: List of variables

Name of variable	*Description*	*Scale of measure*	*Mean*	*SD*
District	Number of districts in which the property is located	Categorical	-	-
Buy_date	Represents date when was building bought	Date	-	-
Transaction_price	Represents real price paid for the building	Numerical	1 501 941.7	53 791.7
Selling_price	Price for which were building offered for sale	Numerical	1 503 434	53 883
Height_of_b.	Height of buildings in meters	Numerical	7.8	0.1
Construction_class	Construction class of buildings	Categorical	1.3	0.0
Name of variable	*Description*	*Scale of measure*	*Mean*	*SD*
Floor	Number of floors that corresponds to each building	Categorical/ Numerical	2.1	0.0

Electricity_price_Mgh	Price of electricity corresponding to every month in which the building was sold	Numerical	102.1	2.2
Rental_prices	Average prices of rents for residential buildings corresponding to every month in which the building was sold	Numerical	119.5	0.1
y19	Year dummy 2019	Dummy	-	-
y20	Year dummy 2020	Dummy	-	-
y21	Year dummy 2021	Dummy	-	-
y22	Year dummy 2022	Dummy	-	-
ε	Error term	Numerical	-	-

Table 1 List of variables

First crucial step in the analysis was to decide the right approach to address the main research questions. Main research question is to explain the behaviour of transaction prices of properties in Vienna, dataset provides sufficient variables to use hedonic pricing model. It is clarified in the chapters before why the hedonic pricing model is suitable for this analysis. Variables that are expected to have a significant influence are especially district, construction class, rental price, electricity price, and size indicator of the building. Additional research question is rather focused on the impact of energy efficiency on the transaction price than influence of other variables. The aim is to investigate whether there is a link between construction class and energy efficiency of the building and how it affects the prices given that construction materials have proved to impact energy efficiency ultimately.

Moving forward, the whole dataset is filtered only for years 2019 to 2022, after adding new variables. The intuition behind this is that 2019 is set as a base year, being pre-covid period hence appearance of positive coefficients in other year dummies isn't surprising. Afterwards, the author omits missing values, and the following equation is used to address research questions.

$$log(Transaction\_price) = \beta_0 + \beta_1 Construction\_class\_cat + + \beta_2 y_{20} + \beta_3 y_{21} + \beta_4 y_{22} + \beta_5 Height\_of\_b. + \beta_6 Districts + \beta_7 Floor\_cat + \beta_8 Electricity\_price + \beta_9 Residental\_prices + \varepsilon$$

As shown, the relationship in the formula is semilogarithmic as dependent variable is in natural logarithm form, and all other variables are not. Moreover, an equation demonstrates a regression formula used in the thesis. β_0 represents an intercept, and all other betas represent coefficients assigned to each variable. ε is an error term. The equation is different for all models, depending on the variables used. The combination of the variables is as follows. Robustness checks are essential to verify the robustness and credibility of the analysis.

Table 2: Combinations of the variables in the model

	All1	*Allh1*	*Allf1*	*Allh3*	*Allf3*
Height of the building	No	Yes	No	Yes	No
Floor	No	No	Yes	No	No
Floor categorical	Yes	No	No	No	Yes
Districts	No	No	No	Yes	Yes

Table 2 Combinations of the variables in the model

Note: Only these variables vary across models, all the other variables stay the constant.

Robustness checks

To confirm of whether results are a true reflection of underlying phenomena, robustness checks are crucial. It strengthens the trustworthiness of results, that the key findings are consistent and reliable. The comparison in Table 3 is made to capture more precisely the effect of construction classes on transaction price. The R^2 is indeed the highest in the model with districts and height accordingly, this model is used in Table 3.

Table 3: Coefficient comparison while base construction class vary

	Estimates			
Base class	*1*	*2*	*3*	*4*
Construction class 1	-	-0.0467	-0.1738	-0.0140
Construction class 2	0.0467	-	-0,1271	0.0327
Construction class 3	0.1738	0.1271	-	0.1598
Construction class 4	0.0140	-0.0327	-0.1598	-

Table 3 Coefficient's comparison while base construction class vary

It shows coefficients of every construction class in 3 different models, where the base construction class vary in each. Consequently, in model 1, the base is class 1 likewise, in the second is base class 2, and so on. By changing the base category, it is possible to see interaction effects between levels of the categorical variables. (To see the entire regressions, see Table A.4 in Appendix A.)

As a result of Table 3 illustrates, there are no signs of bias or contradictions. In conclusion, class 3 significantly increases the transaction price more than class 1, likewise the class 2 and 4. Similarly, when class 2 is a base, construction class 1 coefficient is negative, which coincides with the fact that in the first row, coefficient for class 2 is positive.

According to the Q-Q plots, normality checks were verified.

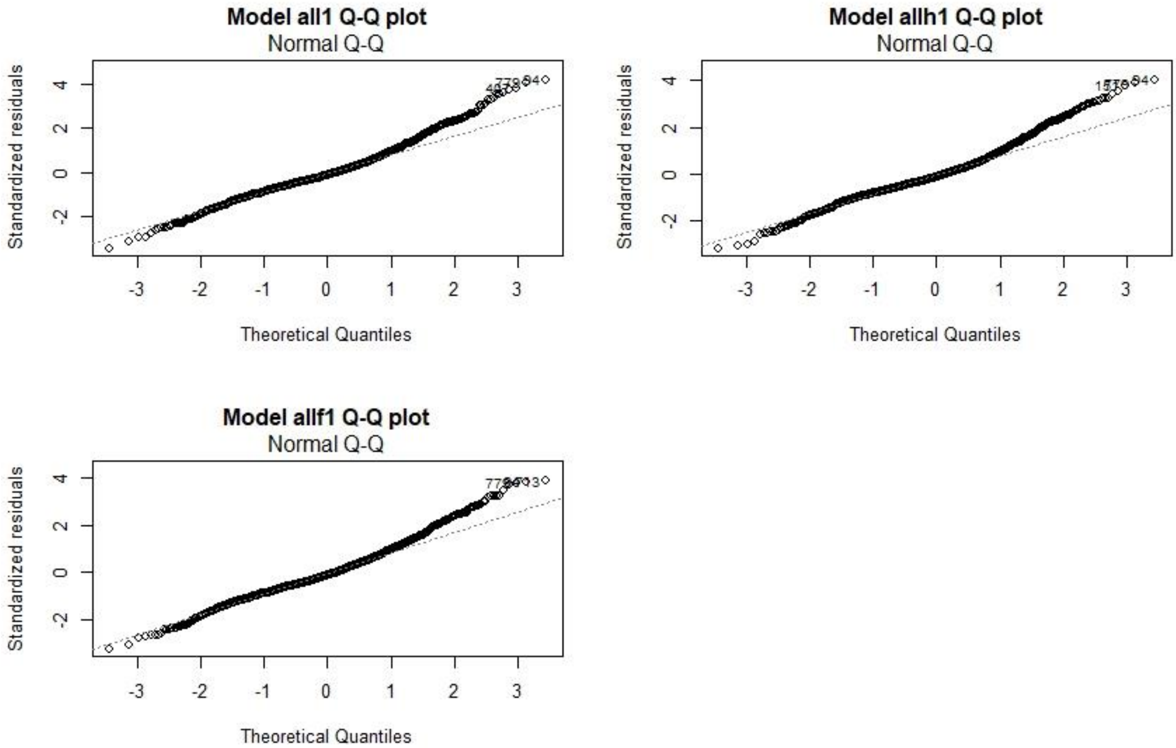

Figure 8 Q-Q Plots of Regression analysis - models without district variable

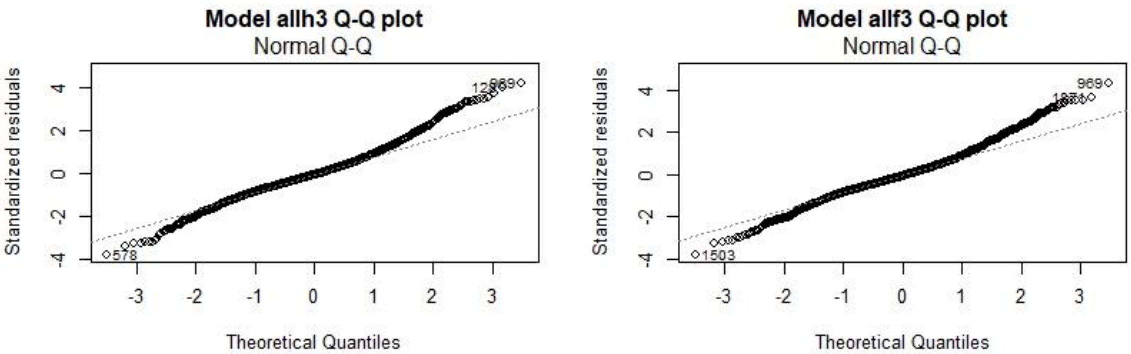

Figure 9 Q-Q Plots of Regression analysis models without district variable

Overall, Figures 9 and 10 indeed show that the residuals are normally distributed since points on the Q-Q plot lie approximately on a diagonal line. In addition, there are no visible outliers in all the graphs. Normality is one of the primary assumptions of ordinary least squares analysis.

Augmented Dickey-Fuller test was performed, to test non-stationarity of dependent variable. The p-value is equal to 0.01, which is lower than the significance level of 0.05 therefore null hypothesis is rejected. The null hypothesis states for non-stationarity, hence when it is rejected, there is not enough evidence to claim presence of non-stationarity. Moreover, heteroscedasticity among the data is a highly frequent feature in the hedonic pricing model. According to Stevenson (2004), "*heteroscedasticity can be caused by factors such as the living area of the property.*" (Stevenson, 2004) The Breusch-Pagan test was implemented across all models in order to increase credibility of the results. Nevertheless, 2 out of 5 performed models show no signs of heteroscedasticity. The models with districts are heteroscedastic, given that they include living areas and locations. The P-value of model with size indicator height without districts is 0.1876, which is higher than 0.05 significance level, while the p-value of model with floor as categorical without districts is 0.02, which is higher than the 0.01 significance level. Even though the heteroscedasticity is present, it suggests that the transaction price varies across different districts, which indeed is true. As a matter of fact, that is why districts are treated as categorical variables. In addition, considering results from robust standard errors effect of the explanatory variables is not an object of unusual variance in this sample, even with the presence of heteroscedasticity. Furthermore, heteroscedasticity could only diminish trustworthiness, but not destroy the analysis results. (See the whole table with robust standard errors in Table A.6 in Appendix A.)

The correlation matrix was created to control for possible correlations. Correlation between height and the floor variable has been foreseen, and truly, these two variables turned out to be 65.9% correlated. Moreover, electricity prices and rental prices show evidence of a 43.5% correlation. In other cases, there is no sign of strong correlations. 65.9% correlation is interpreted to be moderate, while 43.5% is weak, having this in mind, the listed models in Table 2 are used.

Table 4: Correlation matrix

	Height_of_b	*Floor*	*Electricity_price*	*Rental_prices*
Height_of_b	1	0.659	0.015	-0.057
Floor	0.659	1	0.056	-0.011
Electricity_price	0.015	0.056	1	0.435
Rental_prices	-0.057	-0.011	0.435	1

Table 4 Correlation matrix

6. Empirical results

This chapter summarizes all regressions, comparisons, and interpretation of all findings, offering clear insight into the relationship between transaction price and selected variables. The aim is to answer all research questions and shed light on the significance of building attributes as well as the impact of factors like electricity price and rental prices on the transaction price. (The entire regression results are provided in Table A.4 in Appendix A.)

Table 5: OLS results, excluding Districts variable and 2019 year dummy

Model	*Allh1*		*Allf1*		*All1*	
Intercept	12.139***	*(1.366)*	13.429***	*(1.419)*	14.852***	*(1.569)*
Construction class 2	0.074	*(.074)*	0.078	*(.077)*	0.081	*(.075)*
Construction class 3	0.089	*(.087)*	0.141	*(.090)*	0.141	*(.088)*
Construction class 4	-0.038	*(.098)*	0.019	*(.101)*	0.030	*(.0099)*
Year dummy 2020	0.003	*(.075)*	0.020	*(.078)*	-0.0002	*(.076)*
Year dummy 2021	0.234*	*(.099)*	0.249*	*(.103)*	0.237*	*(.100)*
Year dummy 2022	0.329**	*(.120)*	0.379**	*(.124)*	0.328**	*(.121)*
Electricity price	-0.0004	*(.0003)*	-0.001*	*(.0003)*	-0.0006*	*(.0003)*
Rental price	0.002	*(.012)*	-0.005	*(.012)*	-0.0004	*(.012)*
Height of buildings	0.154***	*(.005)*	_	_	_	_
Floor	_	_	0.422***	*(.017)*	_	_
Floor 1	_	_	_	_	-1.403.	*(.766)*
Floor 2	_	_	_	_	-1.322.	*(.765)*
Floor 3	_	_	_	_	-0.758	*(.766)*
Floor 4	_	_	_	_	0.121	*(.770)*
Floor 5	_	_	_	_	0.427	*(.774)*
Floor 6	_	_	_	_	0.430	*(.786)*
Floor 7	_	_	_	_	0.797	*(.802)*
R^2	0.2942		0.236		0.2769	
Adjusted R^2	0.2911		0.2327		0.2713	

Notes: Omitted year dummy 2019 as it is as a base year. Construction class is a categorical variable; therefore, class 1 is in intercept, floor in a third model is as categorical, standard errors in brackets.

Table 5 OLS results, excluding Districts variable and 2019 year dummy

In all results tables, it is necessary to remember that transaction price variable is a natural logarithm of its original value. Therefore, for a one-unit increase in an independent variable, the dependent variable changes by approximately 100 times the coefficient in the model, holding all other variables constant. Additionally, construction class and district variables are in all models categorical. Given that there are four classes, three are visible in the regression with their coefficient, and the first class is used as a base category. Moreover, as a part of robustness analysis, the author provides different perspectives by comparing coefficients of construction classes while the base category is changing.

Table 5 shows a comparison of results from 3 models in regression analysis. The three models differ by using height and floor as indicators of a size of a building. First model uses height as a categorical variable, while second and third model use floor as categorical variables. In the first model, the coefficient for construction class 2 is the lowest in contrast with the other two. The interpretation would be that construction class 2 increases the price by approximately 7.4% more than construction class 1. This might be surprising since, regarding the materials used in first class buildings, we could expect a lower price for class 2. In general, usually class 1 are commercial buildings and lower classes are typically residential properties, schools, churches, factories, and others. The possible explanation could be that the buildings with residential purposes are more expensive, thus lower class buildings. As for the other models, the trend of the coefficients coincides in all three except for the construction class 4, where in model with height coefficient is negative, whereas in models with floor it is positive. It could imply that price increases with construction class up to a certain height, after which they decrease.

Additionally, there may be an interaction effect, such as higher construction classes are associated with lower heights and higher floors. It could also be a matter of perception, and buyers' knowledge about the construction classes and their features, given that it is not common to provide the construction classes in an advertisement of the properties. These might be suggestions for further research.

Yearly dummies don't exceed expectations in all models, the years 2021 and 2022 show an increase in the price in contrast with the base year 2019. Not surprisingly, Russian aggression against Ukraine hit the world in 2021, which caused huge changes in economy and a higher inflation rate that affected the real estate market. (Union C. o., 2023)

Electricity prices development have been turbulent in past year with prices rising, consequently the negative impact on transaction price isn't surprising but couldn't have been anticipated.

Height of the building as well as the number of floors raise the transaction price thus the higher the building, the higher the price. In case floor is a categorical variable, first, second, and third floors reduce the price compared to the ground floor. Regarding the structure of the dataset, thus 1406 observations out of 1653 belong to construction class 1. Possible cause is the purpose of the building class 1 is mostly commercial buildings.

In addition, lower buildings come with a better construction class. In most cases, class 1, particularly commercial buildings, have a lower price than residential properties.

Table 6: OLS results, including Districts variable

Model	*Allh3*		*Allf3*	
Intercept	12.819***	*(1.205)*	14.724***	*(1.391)*
Construction class 2	0.047	*(.065)*	0.050	*(.066)*
Construction class 3	0.174*	*(.076)*	0.212**	*(.077)*
Construction class 4	0.014	*(.086)*	0.059	*(.087)*
Year dummy 2020	0.045	*(.066)*	0.042	*(.067)*
Year dummy 2021	0.245**	*(.087)*	0.259**	*(.088)*
Year dummy 2022	0.347**	*(.105)*	0.352**	*(.107)*
District 3	0.212	*(.226)*	0.412.	*(.243)*
District 5	1.810**	*(.667)*	1.533*	*(.679)*
District 6	0.737.	*(.391)*	0.690.	*(.401)*
District 7	0.370	*(.390)*	0.369	*(.405)*
District 8	1.068**	*(.386)*	0.963*	*(.393)*
District 9	0.725***	*(.166)*	0.930***	*(.176)*
District 10	0.122	*(.085)*	0.149.	*(.087)*
District 11	-0.003	*(.114)*	0.043	*(.116)*
District 12	0.010	*(.117)*	0.311**	*(.117)*
District 13	0.379***	*(.072)*	0.327***	*(.075)*
District 14	0.056	*(.083)*	-0.006	*(.086)*
District 15	0.147	*(.147)*	0.496***	*(.148)*
District 16	0.074	*(.084)*	0.074	*(.086)*
District 17	0.412***	*(.094)*	0.458***	*(.097)*
District 18	0.670***	*(.122)*	0.901***	*(.124)*
District 19	1.375***	*(.079)*	1.339***	*(.082)*
District 20	0.111	*(.197)*	0.468*	*(.199)*
District 21	-0.046	*(.070)*	-0.082	*(.073)*
District 22	-0.016	*(.067)*	-0.068	*(.069)*
District 23	0.091	*(.068)*	0.063	*(.070)*
Electricity price	-0.0004	*(.0002)*	-0.0006*	*(.0003)*
Rental price	-0.004	*(.010)*	-0.008	*(.011)*
Height of buildings	0.141***	*(.006)*	_	_
Floor	_	_	_	_

Model	*All with height*		*All with floor as categorical*	
Floor 1	_	_	-0.569	*(.693)*
Floor 2	_	_	-0.542	*(.693)*
Floor 3	_	_	-0.168	*(.692)*
Floor 4	_	_	0.646	*(.693)*
Floor 5	_	_	0.981	*(.695)*
Floor 6	_	_	1.038	*(.711)*
Floor 7	_	_	1.425*	*(.721)*
R^2	0.4632		0.4487	
Adjusted R^2	0.4556		0.439	

Notes: Omitted year dummy 2019 as it is as a base year. Construction class is a categorical variable, therefore class 1 is in intercept, floor in a second model is as categorical, the third model is with the floor and the height as categorical, standard errors in brackets.

Table 6 OLS results, including Districts variable

Table 6 provides OLS results, including district variables. As R^2 in Table 5 shows, the model with floor as categorical rather than continuous stands for better explanatory power. Hence, Table 6 compares only models with height and floor as categorical.

Unexpectedly, the 4^{th} class exhibit positive coefficient with size indicator height, while in the model without districts, it is negative. That possibly implies an interaction between height and district variable. The majority of class 4 is in districts 2, followed by 9, 10, and 20, District 9 is residential and attractive, 10 and 20 are mostly proletarian and there are family houses as well as rental houses, all these could indicate slightly higher price. (Complete table with distribution of buildings across districts is in Table A.3 in Appendix A.)

Some districts exhibit higher price compared to others, namely 5, 8, 9, 13, 17, 18, 19, whereas others are not significant or even negative. Generally, these are rather attractive and favourite districts in Vienna, and as a result of this, they increase prices more significantly. Conversely, districts 21 and 22 show lower price compared to the base District 2, as they are known to be more affordable districts for living. Further, districts 5, 8, and 9 are advantageous, thanks to their close distance to the city centre, as they share the borders with a first district. On the other hand, districts 17, 18, and 19 are known as family friendly with a close connection to Kahlenberg hill as well as vineyards which add value to the local properties.

7. Limitations

This chapter will introduce a few limitations that occurred during the process. It is essential to acknowledge all demanding constraints that may have impacted the interpretation of the results. The hedonic pricing model, just like OLS regression, carries key assumptions that must be maintained.

First of all, a considerable issue is that lot of building characteristics are unobserved, resulting in vast of the transaction price development being unexplained. This left space for speculation and the possibility of interpreting results differently. For instance, construction class 3 have proved to raise the prices significantly more than class 1 or 2 even though the used material is cheaper. The expectation would be that the price is decreasing. The interpretations remain somewhat a conjecture, as a consequence of missing characteristics, such as size of buildings, distance from the facilities, or age.

Moreover, dependent variable has been tested for stationarity, fortunately it is stationary. However, it is a common problem in OLS regressions. Aside, transaction price was transformed to its natural logarithm and tested again, considering skewness and distribution of the transaction price values. Furthermore, three combinations of variables suffer from heteroscedasticity, in particular model with variable floor as categorical, including districts, the same model but with height as size indicator, and model with floor as categorical but without districts. According to Stevenson, S. (2004) this has proved to be generally an issue in hedonic pricing models, as this model could have biased estimates or lower explanatory power. With this in mind, a robust standard error analysis was performed.

Similarly, it was not likely to provide reliable estimates with both height of the building and floor variable in model, given that these two are 65% correlated. Full table with correlation can be found in Table 4. Indeed, these variables were expected to be correlated however, they are not quite the same, certain buildings could have higher ceilings while not increasing their number of floors.

In conclusion, it is important to carefully consider used data to overcome all difficulties that emerged. Perform all the necessary quality and robustness checks, which help to choose an appropriate attitude and model selection. It all contributes to providing credible results of the analysis.

8. Conclusion

The key findings slightly deviate from the expectations. Despite efficiency of construction materials in the better construction class, the location and the purpose of the building turned out to impact prices more than construction class. It indicates that buyers do not take into account construction class of the buildings. In addition, it was proved that more properties for demolition are in construction class 1 rather than 2,3 and 4, resulting in higher prices for these classes. Furthermore, only construction class 3 in case of model combinations with districts turned up to have statistically significant impact on the transaction price. In models without districts, size indicators markedly influence the price as anticipated. Simply put, the transaction price rises considerably with increasing height or number of floors.

According to expectations, districts exhibit different coefficients as well as relevance. Namely, districts 5, 8, 9, 13, 17, 18, and 19 demonstrate the major influence on the price. It is generally known that certain districts are more suitable for residential properties thanks to their accessibility, availability of facilities and other beneficial factors.

Surprisingly, electricity and rental price barely influence the transaction price by a negligible, negative, and insignificant percent. The idea behind could be that electricity price doesn't change across properties. Consequently, buyer's decisions are not affected by electricity price. The different situations could happen with demand for properties, perhaps an idea to further research.

To sum up, location indisputably impacts the transaction price and plays important role in the selection of property to buy. In a word, some destination is suitable for commercial buildings with lower value, and others for residential or facility buildings. Thanks to robustness checks, it was proved that hedonic pricing model, despite its limitations, is a sufficient estimator for real estate price. Undoubtedly, construction class directly affects energy efficiency, even though in this sense, it doesn't affect the transaction price as anticipated. Only construction class 3 demonstrate a significant positive effect on price. It was expected that other construction classes would have a significant impact as well though. Consequently, without additional information about property location characteristics, it is rather presumption that the property purpose and location effect dominate over construction class. There could be other unobserved effects.

9. Appendix A

Table A.1 – Count of all types of buildings across the construction classes

	Construction class				
Type of the buildings	*1*	*2*	*3*	*4*	*Total*
Building for demolition	734	30	23	8	795
Commercial building	9	1	1	1	12
Office/commercial building occupied	11	1	2	2	16
Office/commercial building free	7			1	8
Family house	901	34	5	1	941
Building under construction	1				1
Gardens	11				11
Rental house free	6	2	8	3	19
Rental house occupied	52	27	52	91	222
Mixed purpose	9	1	2	2	14
Vila	31	23			54
Grand Total	1772	119	93	109	2093

Table A.2 – Count of buildings located in districts across construction classes

	Construction class				
Districts	*1*	*2*	*3*	*4*	*Total*
2	113			88	201
3			3	36	39
5	1				1
6			3	8	11
7				12	12
8	3				3
9		2	6	68	76
10	94			56	150
11	42		3	8	53
12	16	8	45	36	105
13	200	42	6		248
14	111	10	3	8	132
15	6	6	18	44	74
16	89	22	39	8	158
17	56	4	57	4	121
18	1	42	51		94
19	120	50	15		185
20				56	56
21	240	26	21	4	291
22	357	6	6		369
23	323	20	3		346
Grand Total	1772	238	279	436	2725

Table A.3 – Type of the building across districts

	Type of buildings											
Districts	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*Total*
2	130		6		90		2		40	2		270
3									30			30
5									5			5
6									18			18
7	7								14			21
8					24							24
9					18				162			180
10	440		20		480				140			1080
11	187				275				22	11		495
12	156	12			120			36	192	12		528
13	1131			39	1183		13		247	13	273	2899
14	658				756		14		196	14	28	1666
15	75				90			15	180		30	390
16	624		32		864				224	16	80	1840
17	323				680			17	238		68	1326
18	126	18			180			36	270		72	702
19	570		38		1767			38	133	38	266	2850
20	20			20	20			20	200			280
21	2373	63			2688		42	147	168			5481
22	3894	110	88	88	3322	22	110	44	198	88		7964
23	2990	46	69		4140		23		322	46	46	7682
Total	13704	249	253	147	16697	22	204	353	2999	240	863	

Type of building	Code
Building for demolition	A
Commercial building	B
Office/commercial building occupied	C
Office/commercial building free	D
Family house	E
Building under construction	F
Gardens	G
Rental house free	H
Rental house occupied	I
Mixed purpose	J
Vila	K

Table A.4 – Entire regressions and re-levelling the construction classes

	Estimate	*Std. Error*	*t value*	*Pr(>|t|)*
Intercept	12.81953974	1.20589808	10.6306992	9.81E-26
Construction_class_cat2	0.046697197	0.065186284	0.71636539	0.47384688
Construction_class_cat3	0.173770057	0.076398053	2.27453515	0.02303613
Construction_class_cat4	0.013996383	0.086334444	0.16211818	0.87122867
y20	0.045488619	0.066342434	0.68566402	0.49300208
y21	0.245049367	0.087360255	2.8050441	0.00507815
y22	0.347054276	0.105370668	3.29365167	0.00100568
Districts3	0.212521119	0.226529255	0.93816191	0.34827108
Districts5	1.810312351	0.667490313	2.71211779	0.006741
Districts6	0.736991113	0.391173258	1.88405291	0.0596984
Districts7	0.370115623	0.390956436	0.94669275	0.34390629
Districts8	1.067766066	0.386840339	2.76022421	0.00582728
Districts9	0.724956403	0.166975886	4.34168322	1.4824E-05
Districts10	0.122023163	0.085500485	1.4271634	0.15368421
Districts11	-0.003663321	0.11410719	-0.03210421	0.97439205
Districts12	0.010271452	0.116979358	0.08780568	0.93003965
Districts13	0.378988524	0.072719124	5.21167616	2.06E-07
Districts14	0.056366681	0.083551799	0.67463156	0.4999855
Districts15	0.147403589	0.147663072	0.99824274	0.31827879
Districts16	0.073551853	0.083931653	0.87633032	0.38095256
Districts17	0.411553339	0.094128348	4.37225713	1.2909E-05
Districts18	0.670260677	0.122119037	5.48858467	4.55E-08
Districts19	1.374716508	0.078803661	17.4448305	1.12E-63
Districts20	0.110646225	0.197206399	0.56106813	0.57481206
Districts21	-0.046041383	0.070791873	-0.65037668	0.51552139
Districts22	-0.015899379	0.067804121	-0.23448986	0.81462799
Districts23	0.091554533	0.068261289	1.34123652	0.17999138
Electricity_price	-0.000418226	0.000280326	-1.49192887	0.13587076
Rental_prices	-0.004277978	0.010455568	-0.40915784	0.68246633
Height_of_b.	0.141256893	0.00629578	22.436759	6.15E-100

Note: Base is the construction class 1

	Estimate	*Std. Error*	*t value*	*Pr(>|t|)*

Intercept	12.8662369	1.20720886	10.6578384	7.4454E-26
Construction_class_cat1	-0.0466972	0.06518628	-0.71636539	0.47384688
Construction_class_cat3	0.12707286	0.09340982	1.36038014	0.17385835
Construction_class_cat4	-0.03270081	0.09875197	-0.33114088	0.74057172
y20	0.04548862	0.06634243	0.68566402	0.49300208
y21	0.24504937	0.08736025	2.8050441	0.00507815
y22	0.34705428	0.10537067	3.29365167	0.00100568
Districts3	0.21252112	0.22652926	0.93816191	0.34827108
Districts5	1.81031235	0.66749031	2.71211779	0.006741
Districts6	0.73699111	0.39117326	1.88405291	0.0596984
Districts7	0.37011562	0.39095644	0.94669275	0.34390629
Districts8	1.06776607	0.38684034	2.76022421	0.00582728
Districts9	0.7249564	0.16697589	4.34168322	1.4824E-05
Districts10	0.12202316	0.08550049	1.4271634	0.15368421
Districts11	-0.00366332	0.11410719	-0.03210421	0.97439205
Districts12	0.01027145	0.11697936	0.08780568	0.93003965
Districts13	0.37898852	0.07271912	5.21167616	2.0582E-07
Districts14	0.05636668	0.0835518	0.67463156	0.4999855
Districts15	0.14740359	0.14766307	0.99824274	0.31827879
Districts16	0.07355185	0.08393165	0.87633032	0.38095256
Districts17	0.41155334	0.09412835	4.37225713	1.2909E-05
Districts18	0.67026068	0.12211904	5.48858467	4.5506E-08
Districts19	1.37471651	0.07880366	17.4448305	1.1224E-63
Districts20	0.11064622	0.1972064	0.56106813	0.57481206
Districts21	-0.04604138	0.07079187	-0.65037668	0.51552139
Districts22	-0.01589938	0.06780412	-0.23448986	0.81462799
Districts23	0.09155453	0.06826129	1.34123652	0.17999138
Electricity_price	-0.00041823	0.00028033	-1.49192887	0.13587076
Rental_prices	-0.00427798	0.01045557	-0.40915784	0.68246633
Height_of_b.	0.14125689	0.00629578	22.436759	6.149E-100

Note: Base is the construction class 2

	Estimate	*Std. Error*	*t value*	*Pr(>|t|)*
Intercept	12.9933098	1.21552129	10.6894958	5.3904E-26

Construction_class_cat1	-0.17377006	0.07639805	-2.27453515	0.02303613
Construction_class_cat2	-0.12707286	0.09340982	-1.36038014	0.17385835
Construction_class_cat4	-0.15977367	0.09906779	-1.61277119	0.10694725
y20	0.04548862	0.06634243	0.68566402	0.49300208
y21	0.24504937	0.08736025	2.8050441	0.00507815
y22	0.34705428	0.10537067	3.29365167	0.00100568
Districts3	0.21252112	0.22652926	0.93816191	0.34827108
Districts5	1.81031235	0.66749031	2.71211779	0.006741
Districts6	0.73699111	0.39117326	1.88405291	0.0596984
Districts7	0.37011562	0.39095644	0.94669275	0.34390629
Districts8	1.06776607	0.38684034	2.76022421	0.00582728
Districts9	0.7249564	0.16697589	4.34168322	1.4824E-05
Districts10	0.12202316	0.08550049	1.4271634	0.15368421
Districts11	-0.00366332	0.11410719	-0.03210421	0.97439205
Districts12	0.01027145	0.11697936	0.08780568	0.93003965
Districts13	0.37898852	0.07271912	5.21167616	2.0582E-07
Districts14	0.05636668	0.0835518	0.67463156	0.4999855
Districts15	0.14740359	0.14766307	0.99824274	0.31827879
Districts16	0.07355185	0.08393165	0.87633032	0.38095256
Districts17	0.41155334	0.09412835	4.37225713	1.2909E-05
Districts18	0.67026068	0.12211904	5.48858467	4.5506E-08
Districts19	1.37471651	0.07880366	17.4448305	1.1224E-63
Districts20	0.11064622	0.1972064	0.56106813	0.57481206
Districts21	-0.04604138	0.07079187	-0.65037668	0.51552139
Districts22	-0.01589938	0.06780412	-0.23448986	0.81462799
Districts23	0.09155453	0.06826129	1.34123652	0.17999138
Electricity_price	-0.00041823	0.00028033	-1.49192887	0.13587076
Rental_prices	-0.00427798	0.01045557	-0.40915784	0.68246633
Height_of_b.	0.14125689	0.00629578	22.436759	6.149E-100

Note: Base is the construction class 3

	Estimate	*Std. Error*	*t value*	*Pr(>|t|)*
Intercept	12.8335361	1.23533659	10.3886959	1.1209E-24
Construction_class_cat1	-0.01399638	0.08633444	-0.16211818	0.87122867

Construction_class_cat2	0.03270081	0.09875197	0.33114088	0.74057172
Construction_class_cat3	0.15977367	0.09906779	1.61277119	0.10694725
y20	0.04548862	0.06634243	0.68566402	0.49300208
y21	0.24504937	0.08736025	2.8050441	0.00507815
y22	0.34705428	0.10537067	3.29365167	0.00100568
Districts3	0.21252112	0.22652926	0.93816191	0.34827108
Districts5	1.81031235	0.66749031	2.71211779	0.006741
Districts6	0.73699111	0.39117326	1.88405291	0.0596984
Districts7	0.37011562	0.39095644	0.94669275	0.34390629
Districts8	1.06776607	0.38684034	2.76022421	0.00582728
Districts9	0.7249564	0.16697589	4.34168322	1.4824E-05
Districts10	0.12202316	0.08550049	1.4271634	0.15368421
Districts11	-0.00366332	0.11410719	-0.03210421	0.97439205
Districts12	0.01027145	0.11697936	0.08780568	0.93003965
Districts13	0.37898852	0.07271912	5.21167616	2.0582E-07
Districts14	0.05636668	0.0835518	0.67463156	0.4999855
Districts15	0.14740359	0.14766307	0.99824274	0.31827879
Districts16	0.07355185	0.08393165	0.87633032	0.38095256
Districts17	0.41155334	0.09412835	4.37225713	1.2909E-05
Districts18	0.67026068	0.12211904	5.48858467	4.5506E-08
Districts19	1.37471651	0.07880366	17.4448305	1.1224E-63
Districts20	0.11064622	0.1972064	0.56106813	0.57481206
Districts21	-0.04604138	0.07079187	-0.65037668	0.51552139
Districts22	-0.01589938	0.06780412	-0.23448986	0.81462799
Districts23	0.09155453	0.06826129	1.34123652	0.17999138
Electricity_price	-0.00041823	0.00028033	-1.49192887	0.13587076
Rental_prices	-0.00427798	0.01045557	-0.40915784	0.68246633
Height_of_b.	0.14125689	0.00629578	22.436759	6.149E-100

Note: Base is the construction class 4

Table A.5 – Floor distribution across construction class

	Construction class				
Number of floors	*1*	*2*	*3*	*4*	*Total*
0	0.06%	0.00%	0.00%	0.00%	0.05%

1	24.34%	21.01%	24.73%	21.10%	23.98%
2	55.00%	54.62%	53.76%	55.96%	54.95%
3	13.61%	17.65%	10.75%	14.68%	13.81%
4	3.67%	5.88%	6.45%	2.75%	3.87%
5	1.92%	0.84%	1.08%	4.59%	1.96%
6	0.90%	0.00%	1.08%	0.92%	0.86%
7	0.45%	0.00%	2.15%	0.00%	0.48%
Total	100.00%	100.00%	100.00%	100.00%	100.00%

Table A.6 – Robust standard errors

	Estimate	*Std. Error*	*t value*	*Pr(>|t|)*
Min.	-0.007724	0.0003148	-1.5059	0.0000000
1st Qu.	0.075304	0.0796470	0.7008	0.0000405
Median	0.164755	0.0990239	1.6941	0.0909522
Mean	0.783765	0.1650213	3.5712	0.2256134
3rd Qu.	0.487854	0.1458940	4.2430	0.3923147
Max.	13.157753	1.3742476	18.2442	0.8850503
Model with size indicator floor with districts				
	Estimate	*Std. Error*	*t value*	*Pr(>|t|)*
Min.	-0.61260	0.0003228	-1.779	0.0000000
1st Qu.	0.06347	0.0958428	0.570	0.0008975
Median	0.35146	0.1208283	1.783	0.0737474
Mean	0.78863	0.2261557	2.496	0.1764252
3rd Qu.	0.74258	0.3439952	3.356	0.2957987
Max.	15.35634	1.4669658	14.277	0.6753858

10. Appendix 2

Original dataset available to download here;

Purchase price collection Property Vienna - Data Europa EU

Manually added electricity and rental prices available online here;

https://www.statista.com/statistics/1271527/austria-monthly-wholesale-electricity-price/

https://fred.stlouisfed.org/series/CP0410ATM086NEST

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