Specification of a Hedonic Model for Rental Apartment Buildings in Berlin

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This paper focuses on the estimation of a multiple-regression model (hedonic model) for pricing apartment buildings. With the hedonic model, the price of a residential property can be segmented into its various properties in order to subsequently assign individual prices to these properties. In addition to selecting the target size, the specification of a hedonic model also requires ascertaining the price-determining independent variables, choosing the correct functional form and defining the sub-market to be examined. This paper provides various approaches to identify the relevant contributing factors for the target size, and analogously, finds the most optimal functional form (inter alia) via an iterative path of model estimation.

INTRODUCTION

The hedonic method or hedonic regression is used as an instrument for estimating and ascertaining values or for determining the demand for commodities that are not traded on a market (Herath, & Maier, 2010, p. 1). This valuation method evaluates commodities or properties according to their intrinsic (inner) values and does not derive the value from the estate itself, rather from its attributes. With the hedonic model, the price of a residential property can be segmented into its various characteristics in order subsequently assign individual prices to these characteristics (Fahrländer, 2007, p. 17; Day, 2001, p. 25; Haas, 2010, p. 24). The goal is to build a highly explanatory model and depict the market for rental apartment buildings in Berlin with the essential value or price drivers. In addition to defining the submarket to be examined, the specification of a hedonic model also requires selecting the target size, identifying the price-determining independent variables and choosing the correct functional form. Hedonic theory (Malpezzi, 2002, p. 20) gives no indication of the type of price function. This paper presents a plausible approach for specifying a hedonic model to valuate rental apartment buildings.

LITERATURE REVIEW

There is no consensus on when and where the theory of hedonic price determination originated. Colwell and Dilmore (1999) state that the initial regression analyses were created by Haas (1922) and Wallace (1926) and used for valuating agricultural land. Griliches (1991) claims it originated with Waugh (1928) within the scope of agricultural land valuations via a regression analysis. From an economic perspective, the method of hedonic prices is based on Lancaster's (1966) consumption theory, in which the individual characteristics of an asset are beneficial. On the microeconomic level, hedonic price theory was further developed by Rosen (1974). Thus, Lancaster (1966) und Rosen (1974) made important contributions to the hedonic price theory. With Lancaster, there is an implicit linear correlation between the price of the asset and the characteristics the asset contains. Rosen's model, on the other hand, assumes a non-linear correlation between the price of the asset and its respective features.

Recently, hedonic models have again become increasingly important for the analysis and research of housing markets. The focus of the research is primarily on residential submarkets for apartment ownership (Thanasi, 2016; Kryvobokov & Wilhelmsson, 2007; Maurer et al. 2004; Jim & Chen, 2009; Ayan & Erkin, 2014; Berry et al. 2003, Bohl et al. 2012), for single-family dwellings (Sirmans & Macpherson, 2003; Chiodo et al. 2009), semi-detached ('duplex') and terraced houses ('town houses') and for undeveloped properties (Thomsen, 2014; Zeißler, 2012). Here, the actual purchase prices and/or rental prices are paramount (Thomson, 1999).

International research indicates that the scope of application possibilities of hedonic models is very diverse. In addition to the index construction and analysis of individual or multiple contributing factors on target purchase price or rent, hedonic models are used for the valuation of real estate, the identification of substantive or geographic submarkets or for demand analysis of specific building characteristics. Furthermore, questions are raised about the generalisation of hedonic models and the possible transfer of results to other regional and also substantive submarkets. Likewise, some studies also question the model theory and focus on the further development of theory and methodology (Herath & Maier, 2010; Sopranzetti, 2010, 2015).

In Germany, the analyses focus largely on identifying the price determinants by means of regression-analytical methods and subsequently builds upon the use of these results, inter alia, for the development of price indices. With regard to real estate valuation, regression-analytical methods have also been recognized in Germany since the 1970s (Uhde, 1982; Ziegenbein, 1977). Thus far, however, there have been hardly any hedonic analyses for residential investment properties such as multi-family dwellings. This is due to both the significantly greater heterogeneity and to the lack of availability of adequate data. This research deficit is addressed later in this paper.

DATA SET: SELECTION OF THE SUBMARKET AND TARGET SIZE

The data is based on the automatic purchase price compilation of the Committee of Valuation Experts in Berlin [Gutachterausschuss Berlin]. According to §193 of the German Building Code [BauGB], the primary duties of the Committee of Valuation Experts include the collection, administration and analysis of purchase prices. Since purchase prices for apartment buildings are usually determined on a price-per-square-metre basis or as a multiple of the annual rent, in the hedonic model, the purchase price per square meter serves as the target size. For the selected submarket of Berlin, the Committee of Valuation Experts provided a total of 9,260 purchase prices per square metre for rental apartment buildings for the period from 1990 to 2013. Only individual transactions in direct property acquisition (asset deal) were analysed. The average purchase price per square metre for this period is approximately EUR 860, with nearly 90% of the purchase prices having a maximum value of EUR 1,500 per sqm.

All purchase prices of the data set are described in greater detail with additional survey features and their respective characteristic values. The survey features can be divided into four categories. The first is used to uniquely identify the respective purchase case in the automatic purchase price compilation and contains, inter alia, the transaction date. The second category describes the exact location of the respective property. This includes the exact property address with the street number in the respective district and subdivision. Additionally, variables such as the urban residential area, the type of construction typical for the area, the standard land value, the typical floor space index underlying the standard land value, the typical and price-determining usage or the block location of the property are described. The third category depicts the individual property characteristics. Variables such as the year of construction, living space, floor space, number of residential units, condition of the property, any existing property subsidies, but also the buyer and the sales group characterise the respective property. The last category measures the earning power of residential buildings, which includes assessing the net cold rent, the commercial rental income and the income value of the property.

MODEL ESTIMATION. SELECTION OF THE FUNCTIONAL FORM AND EXPLANATORY VARIABLES

The target size in the hedonic model is the purchase price per square metre of a rental apartment building. The respective features of the individual survey characteristics are not assessed in the data set for each purchase case. In the case of missing characteristics, the corresponding purchase case is not included in the regression. Accordingly, in order to keep the data set as large as possible, one must consider whether to omit or use the explanatory variable for the estimation. Survey features with more than 80% missing characteristics were removed from the data set. In all other cases with missing characteristics, the explanatory variable was retained and the respective purchase case was excluded for the regression. The achievable or contractually agreed rent is crucial for determining the price of investment properties. Since in approximately 55% of the cases, the net cold rent was not indicated, which already led to a significant reduction of the data set. On this basis and taking into account all other necessary explanatory variables, a total of 3,401 purchase prices with an average purchase price per square metre of EUR 826 are available for the regression of the apartment buildings for the period from 1993 to 2013.

TABLE 1
PURCHASE PRICE PER SQUARE METRE 1993-2013 (COMPLETE DATA SET)

Quantity	Mean	SD	Median	MAD
3,401	€826	€443	€738	€670

Source: Own Calculation

Table 1 shows the average price and its variation from the mean. The apartment buildings have an arithmetic mean of EUR 826 per square metre and a median of EUR 738 per square metre, resulting in an already recognizable right-skewed distribution. The dispersion around the mean of EUR 443, standard deviation (SD), is relatively large in the apartment buildings and illustrates how less closely the purchase prices are concentrated around the average. The mean absolute deviation (MAD) is from the median. The distribution of the square metre purchase prices still corresponds to the distribution of the original data. Approximately 92% of the purchase prices indicate a maximum value of EUR 1,500. In the great majority of the sample, the purchase price is between EUR 500 and EUR 1,000.

Table 1 shows an asymmetrical, right-skewed distribution (Auer & Rottmann, 2011, p. 44); the purchase prices are not normally distributed. This is also not a mandatory prerequisite (Schendera, 2008, p. 134), but it is more favourable. The skew of the data distribution can be significantly reduced by first aid transformation (Stahel, 2008, p. 66) with the natural logarithm, which also has a positive effect on the distribution of the residuals (Stahel, 2008, p. 64). In the coefficients, initially the model remains additive, yet the effect is multiplicative, i.e. the purchase price changes proportionally. The transformation of the purchase price is statistically explicable and also confirms the hedonic model theory, according to which the price is not linearly derivable.

The variables were selected under consideration of the available data and the value-forming parameters (prominent in land-value determinations) for apartment buildings. The aim is not to build a causal model, rather to use the available influencing variables to estimate a practical and meaningful model. Therefore, the previously mentioned survey features (explanatory variables) are described, analysed and initially selected with regard to their relevance. The specification of the functional form of the hedonic model occurs in parallel during the analysis of the existing survey features in the data set and the model construction.

The explanatory variables with their characteristic values can be in quantitative (metric scaled) or qualitative form (nominal or maximum ordinal scale (Fahrmeir et al. 2011, p. 19). Qualitative characteristics describe various states or characterise attributes verbally. For the regression, only metric scaled variables are considered (Backhaus, 2006, p. 113), therefore qualitative features are to be quantified by transformation into dummy variables (Auer & Rottmann, 2011, p. 11). The analysis of the existing data material occurs by means of a simple correlation analysis or by means of simple relational studies with regard to the factors that explain the purchase price. Table 2 provides an overview of the assessed explanatory variables, subdivided according to building, location and property quality, earning power and transaction date.

TABLE 2
EXPLANATORY VARIABLES

Variable	Code	Unit	Description
Identification			
Transaction year	TYear	D	Calendar year of the transaction
Building			
Year of construction	Year of construction	[-]	Date the building was constructed
Construction year class	yclass1 – yclass7	D	Before 1919 – after 1990
Heating type	Heating	D	Assessed heating type at the time of the transaction
Building condition	Building condition	D	Structural maintenance state at the time of the transaction
actual floor space index	FSI	[-]	Actual floor space
Living and usable space	LVS	sqm	Total living and usable space of the residential building
Average living space per apartment	∅ Living space	sqm	Ratio between the living space and the number of units
Location			
Urban residential area	Resi area	D	Location rating according to Berlin rent rolls
Land value	Land value	EUR/sqm	Ascertained land value prior to the contract date
District	District	D	Respective district where the transaction took place
Plot area	Plot	sqm	Total property area
Earning power			
Net cold rent per square metre	Net rent	EUR/sqm	Average net cold rent per square metre of living space
D = dummy variable			

Source: Own Calculation

Ascertained Building-quality Variables

The building quality characteristics refer to building typology (year of construction or date of building completion), building structure and size as well as the qualitative and quantitative fit-out condition at the time of the transaction.

Construction Year Class (yclass)

The achievable rent as an essential factor for the purchase price is determined, inter alia, by the nature of an apartment, which in turn is characterised by different construction methods in the respective periods. The building architecture and attractiveness is often shaped by the construction period, which, for example, can positively or negatively affect the privatisation potential for apartment buildings. If, via modernisation measures, an adequate economic remaining useful life comparable to new buildings can be assumed for older buildings, the construction year class can be an indicator of the attractiveness of the apartment building and thus the purchase price. For the years of construction, individual construction year classes were created, which are based primarily on the grouping of the Berlin rent rolls because this categorisation takes into account the different rental structures in the respective submarkets.

TABLE 3
CONSTRUCTION YEAR CLASS

construction year class	period of time	share in observations
yclass1	before 1919	51,90%
yclass2	1919 - 1949	9,60%
yclass3	1950 - 1955	3,10%
yclass4	1956 - 1964	13,90%
yclass5	1965 - 1972	5,30%
yclass6East	1973 - 1990	1,30%
yclass6WEST	1973 - 1990	9,60%
yclass7	after 1990	5,10%
Total		**100%**

Source: Own Calculation

In general, a positive influence on the purchase price is assumed for old buildings constructed prior to 1919 and for new buildings constructed after 1990. However, negative influences are expected in the years immediately after the war as well as in the construction period from 1972 in the eastern districts, as residential construction was especially characterised in this construction phase by scarce resources or by the construction of large housing estates. The respective construction year class is considered a dichotomous dummy variable, where the 'yclass1' serves as a reference. However, the construction year class is to be understood as a block of dummy variables (Stahel, 2008, p. 33). Furthermore, in addition to the analysis of the construction year class as the main effect, also the interaction between the year of construction and the condition of the building was examined. However, a significant influence could not be verified in the model.

Heating Type

As an indication of the condition of the building, the type of heating at the time of the transaction also influences the purchase price, since necessary modernisation measures due to outdated heating systems could be pending. Collective heating systems are types of heating where the generation of energy and heat takes place in a central location. Floor heating should be qualitatively equated to collective heating systems (vgl. [Sen11], S. 9). Therefore, lower purchase prices are to be expected for outdated heating systems or stove heating. The heating type variable was divided into two groups: 'HeatingColl' (collective heating) includes the collective and multi-storey heating types, and 'HeatingOther' includes stove heating or residential complexes that are only partially equipped with oven heaters. HeatingColl, with a proportion of approximately 70%, is the reference category. For residential complexes with lower-quality heating possibilities, this feature is included in the model as the dummy variable HeatingOther (other heating).

Building Condition

The average structural maintenance state of the building at the time of the transaction was determined by three state characteristics: good, normal and bad (poor). The regression analysis examines the deviation from the normal state, which represents the reference category. A corresponding decrease or increase in the purchase price is expected for poor and good conditions respectively. Furthermore, price-influencing interactions can also be assumed here. In addition to the combination to the year of construction, an influence by the interaction with the location or with the type of heating was also suspected and investigated. However, a significant effect was only ascertainable in the interaction between the simple residential location of the property and the good condition of the residential building (variable 'InterResiAreaBuilStateGood'). Stable rents are also generated in simple residential areas, but these are vulnerable due to necessary renovation or modernisation measures that have not been carried out. Thus, the purchase prices for multiple-family dwellings in simple locations, in combination with a good maintenance state, proved to be highly significant in the model.

Actual Floor Space Index (FSI)

According to §20 of the Federal Land Utilisation Ordinance [*Baunutzungsverordnung (BauNVO)*], the floor space index expresses the ratio of floor space to property area and is thus a measure of the building use of the property. With an increasing floor space index and thus higher utilisation of the property, less green, open and recreational space can be assumed as well as increasingly dense building development, which are absolutely necessary for the tenant as an attractive residential location. Therefore, prices can be assumed to decrease as floor space increases. Conversely, with greater floor space due to increased utilisation possibilities of the property, relative to the living and usable space, the achievable rental income is also higher. Accordingly, increasing rental income and thus higher purchase prices are initially assumed as the actual floor area increases. However, the willingness to pay decreases for very high property utilisation, so a degressive increase is assumed.

Living and Usable Space (LVS)

The size of the entire residential complex is measured using the variable 'living space' (LVS). Very large flats are considered unattractive by tenants, which is associated with lower demand. However, due to the lack of attractiveness and the associated lower rent levels, demand is more likely to increase among simple/problematic tenant clientele, which leads one to expect declining purchase prices as residential complex size increases. However, this fact opposes more efficient management as total living space or number of units increases, with a corresponding potential positive effect on the purchase price. However, the negative will presumably outweigh the positive effect. The variables 'floor space index' and 'living space' were transformed and considered inversely in the model.

Average Living Space (⌀ Living Space)

The average living space indicates the ratio of the total living space of the apartment and the number of residential units. Flat sizes with very low and very high square footage are risky in terms of letting potential. Therefore, a purchase price discount is to be expected with these units. The variable is entered in the model linearly.

Assessed Location- and Property-quality Variables

The variables of location quality in the assessed data set characterise the prevailing location conditions and their influence on the potential sale price of the apartment building. In addition, the specific property features play an important role in the calculation of the purchase price.

Urban Residential Area (Resi Area)

The location quality of the residential environment is reflected in the residential location and is subdivided according to the Berlin rent index into the four categories: simple, medium, good and very good. The influence of the location quality is assumed to be positive. The location variable is entered in the regression as a block of dummy variables; the reference category is the simple residential location, which comprises 55% of the data set.

Middle residential location
Good residential location
Very good residential location

Land Value

According to §196 of the German Building Code, land values are average location values that are quantified by the land value. Here, the fictitious land value property represents the typical usage for the region, which are firmly defined in a land value zone. Thus, land values also provide information about the location quality and the earning power of the property. With increasing earning power in the form of potential rental income, the land value increases as well. The average land values (median) in this data set are approximately EUR 400 per square metre and increase to approximately EUR 800 per square metre in good and very good locations. Due to the expected increase in purchase prices for higher-quality locations, rising purchase prices can also be expected with increasing land values and additional interaction effects between the upscale residential areas and high land values. Conversely, the study of the relationship between the land value and the net cold rent did not result in any significant increase in rental income with increasing land value. Therefore, the willingness to pay for the land is assumed to be maximally degressive with increasing land values, which expresses the diminishing marginal utility. The explanatory variable 'land value' is therefore included in the model in logarithmic form (lnLandValue).

Districts

Berlin comprises a total of 12 districts, which are very heterogeneous in terms of their social and building structure (housing stock, residential building quality). Due to the very different building and social structure in the districts of Berlin, a significant district-based influence on the purchase price is assumed. The majority of transactions (70.6%) are concentrated primarily in the inner city area with the districts Mitte (17.6%), Friedrichshain-Kreuzberg (13.7%), Tempelhof-Schöneberg (13.3%), Pankow (13.0%), Charlottenburg-Wilmersdorf (9.4%) and Lichtenberg (3.6%). The remaining 29.4% of the transactions primarily took place in the suburbs of Spandau, Reinickendorf, Treptow-Köpenick, Marzahn-Hellersdorf, Steglitz-Zehlendorf and Neukölln. The respective 'district' variable is entered as a dummy variable in the regression and explains the respective deviation from the reference district Mitte, which has the largest proportion of transactions in this period.

Plot Area (Plot)

In general, there are dependencies between the property size and the square metre property price, which is typically incrementally higher as the space decreases (Kleiber et al. 2002, p. 1204). More important, however, is whether one can build on the entire plot or if a section of the property, so-called back land, is designated for development and thus not available for the utilisation of the property. Therefore, very large plots are at risk of containing a superfluous proportion of land that no longer plays a role in the generation of rental income. As a result, rising purchase prices are expected with increasing property area, albeit non-linearly, which even reach a saturation point in some cases. The 'plot area' explanatory variable is thus entered in the regression in logarithmic form (lnPlot).

Net Cold Rent Per Square Metre (Met Rent)

The net cold rent per square metre is examined as an essential survey feature. Net cold rent is the rent that is contractually agreed upon between the owner of the property and the tenant for providing the living space. It is an essential expression of the earning power of the apartment building and also crucial for the purchase price. Thus, the connection between the purchase price and the rent is positive. The average apartment rents per square metre have increased from approximately EUR 4 to EUR 7 per square metre. The rents in the data set are the quotient of the total rent and the living space without considering possible vacant space at the time of the transaction. Thus, the actual rents could be higher in part because vacancy is not taken into account as a survey feature in the data set. The difference between the actual rent and the market rent plays a significant role in determining the purchase price, as the potential for rent increases may have already been calculated in the purchase price. Conversely, higher actual rents than the market rent can pose a risk of maintaining these rent levels in the long term, which also has a negative effect on the purchase price calculation. The same applies to rent-increase potential with regard to reducing the vacancy rate. Therefore, the assumed positive influence of the rent on the purchase price is not necessarily linear.

A first model run already indicated a highly significant linear influence of the actual net cold rent per square metre on the purchase price. Additionally, the net cold rent exerts the greatest influence, expressed in the highest beta value, on the purchase price. As a result, further examinations were conducted with regard to nonlinear relationships. With very high net cold rent values, the square metre purchase prices yet again show a decreasing tendency and are thus still overestimated in the linear model. Thus, the relationship can be described by a quadratic or cubic context. The model was estimated using both second- and third-degree polynomials. However, the coefficients were highly significant only in the model with a second-degree polynomial at a 5% significance level. As a general rule, low-degree polynomials are used, as the resulting estimations are very unstable, especially for larger polynomial degrees on the fringes of the estimates (Fahrmeir, 2009, p. 75). The relationship between rent and price can therefore be better described as quadratic rather than purely linear.

Transaction Date (TYear)

In order to depict the cyclical fluctuations in supply and demand over the entire observation period, the transaction year has been included as a dummy variable in the model. The year 2000 is used as the reference year in this case.

RESULTS

The results of the estimated model are summarized in Table 4. All coefficients with respect to their reference category, with the exception of a few dummy variables, are significantly different from zero and prove to be economically plausible in terms of their portents. The explained 72.5% (R^2 adj.) variance indicates a good adjustment of the data with a sample size of 3,401 purchase prices. In connection with the issue regarding the influence of real estate qualities on purchase price, the adjustment of over 70% is classified as good.

TABLE 4
RESULTS OF THE MODEL

Variable	Coefficient	Beta	Significance level
Constant	4,541		***
resi area-middle	0,087	0,084	***
resi area-good	0,130	0,104	***
resi area-very good	0,159	0,047	***
building state good	0,093	0,073	***
building state poor	-0,113	-0,073	***
yclass2	0,007	0,005	
yclass3	-0,06	-0,023	*
yclass4	-0,054	-0,041	***
yclass5	-0,046	-0,022	*
yclass6East	-0,239	-0,058	***
yclass6WEST	-0,057	-0,037	***
yclass7	0,071	0,034	**
HeatingOther	-0,162	-0,155	***
LVS (invers)	33,021	0,051	***
FSI (invers)	0,101	0,152	***
∅ living space	0,001	0,061	***
lnLandValue	0,17	0,192	***
lnPlot	0,021	-0,036	**
net rent	0,214	0,733	***
$(\text{net rent})^2$	-0,007	-0,264	***
Freidrichshain-Kreuzberg	-0,005	-0,003	
Pankow	0,073	0,027	*
Charlottenburg-Wilmersdorf	0,021	0,013	
Spandau	-0,035	-0,018	
Steglitz-Zehlendorf	-0,011	-0,006	
Tempelhof-Schöneberg	-0,001	-0,001	
Neukölln	-0,072	-0,038	***
Treptow-Köpenick	-0,021	-0,010	
Marzahn-Hellersdorf	0,159	0,034	**
Lichtenberg	-0,082	-0,033	**
Reinickendorf	-0,059	-0,030	*
InterResiAreaBuilStateGood	0,117	0,063	***
TYear1993	0,345	0,070	***
TYear1994	0,356	0,035	***
TYear1995	0,222	0,078	***
TYear1996	0,105	0,037	**
TYear1997	0,114	0,042	***
TYear1998	0,123	0,070	***

Variable	Coefficient	Beta	Significance level
TYear1999	0,113	0,051	***
TYear2001	0,055	0,024	◦
TYear2002	-0,072	-0,030	*
TYear2003	-0,087	-0,031	**
TYear2004	-0,061	-0,025	◦
TYear2005	-0,042	-0,022	
TYear2006	0,145	0,100	***
TYear2007	0,249	0,174	***
TYear2008	0,202	0,103	***
TYear2009	0,143	0,071	***
TYear2010	0,196	0,099	***
TYear2011	0,312	0,187	***
TYear2012	0,365	0,181	***
TYear2013	0,396	0,021	*
R^2	0,729		
R^2_{adj}	0,725		
RMSE (Root Mean Square Error)	0,241		
F-Test	169,58		***
number	3.401		

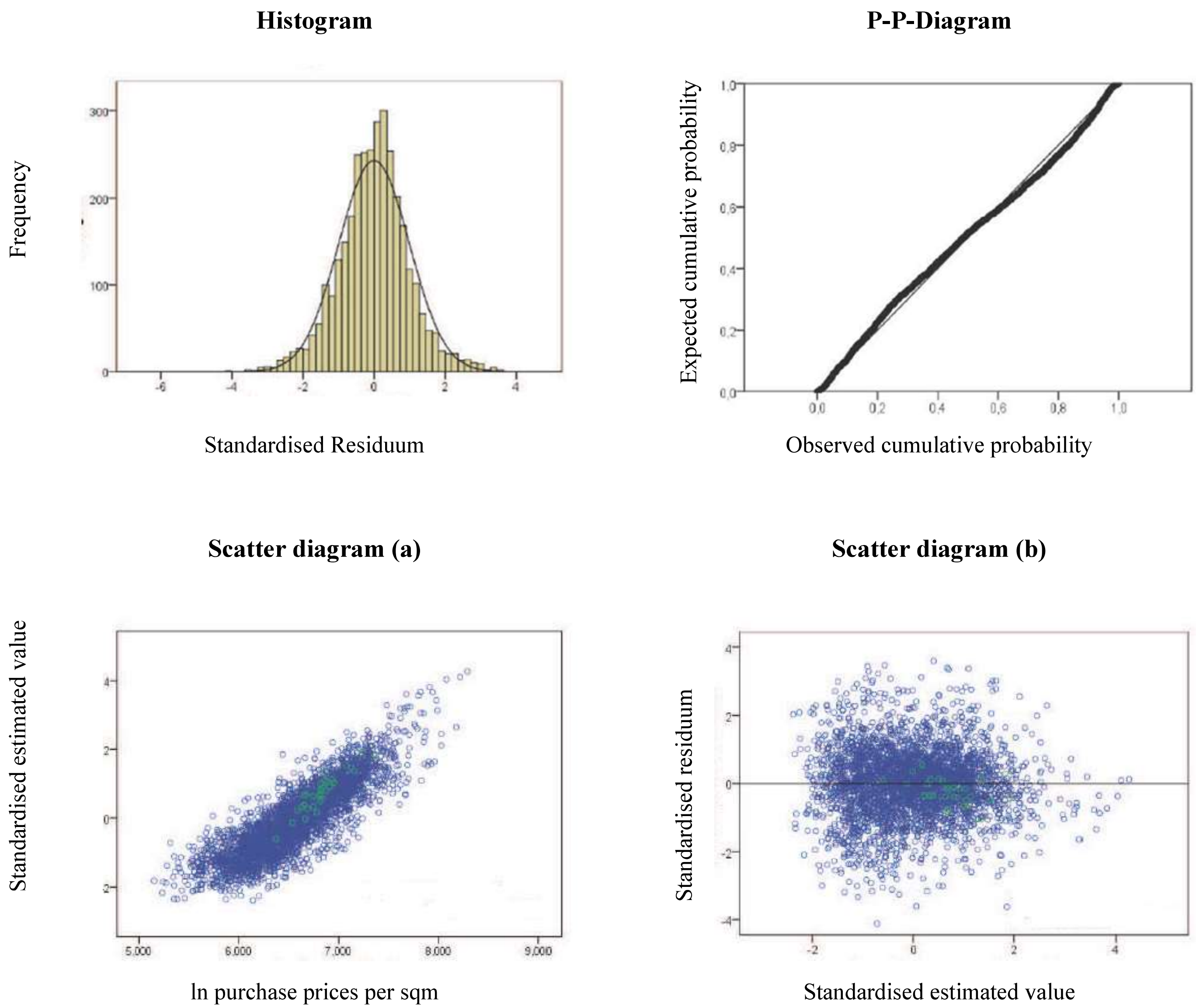
***Signif. < 0,001; **Signif. < 0,01; *Signif. < 0,05; ◦Signif. < 0,10

Source: Own Calcultion

The results of the residual analysis of the hedonic model in Figure 1 indicate that the residuals approximately follow a normal distribution and are not distributed in a long-tailed manner. The scatter diagram (b) (bottom right), which also shows the estimated values against the residuals, inspects signs of normality, variance heterogeneity and outliers (Schendera, 2008, p. 53). The residuals scatter randomly and in a balanced manner around the zero line; the variance of the residuals is constant. The uniform distribution of the residuals can also be seen in scatter diagram (a) (bottom left) of the estimated values against the standardised values.

The exemplary coefficient with the highest beta factor should be explained in more detail. The most influential and highly significant variable with the highest beta value, as assumed, is the net cold rent per square meter. The net cold rent has been included as a second-degree polynomial in the model, with a positive β1 coefficient of 0.214 for the first-degree polynomial and a negative β2 coefficient of -0.007 for the second-degree polynomial. Thus, the connection between the purchase price and the net cold rent is described in the model by a downward-opening parabola (Auer & Rottmann, 2011, p. 494 f.). As the square metre rent increases, the purchase price increases initially, while the positive β1 dominates the purchase price trend up to a certain level of the net cold rent. Here, the rise in purchase prices is increasingly lower, and from a certain net cold rent level, even the purchase price falls. From here on, due to the high rent per square metre, the negative term β2 has a significant impact and determines the purchase price decrease.

FIGURE 1
RESULTS OF THE MODEL



Source: Own Calculation

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