PREDLOG ZA IZBOLJŠAVO MNOŽIČNEGA VREDNOTENJA NEPREMIČNIN V SLOVENIJI NA PODLAGI PRISTOPA GENERALIZIRANIH ADITIVNIH MODELOV

PROPOSAL OF REAL ESTATE MASS VALUATION IN SLOVENIA BASED ON GENERALISED ADDITIVE MODELLING APPROACH

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IZVLEČEK

V prispevku obravnavamo množično določitev vrednosti stanovanj, za kar smo na podlagi podatkov trga nepremičnin razvili model množičnega vrednotenja stanovanj v Republiki Sloveniji. Pri tem smo uporabili generalizirane aditivne modele. V prispevku podrobneje predstavljamo izgradnjo tega modela, v eksperimentalnem delu raziskave pa je izvedena analiza rezultatov ocenjevanja tržnih vrednosti stanovanj dveh modelov, pri katerih je odvisna spremenljivka (cena stanovanja) porazdeljena po Gaussovi ter gama porazdelitvi. Posebej smo obravnavali vpliv trenutka prodaje stanovanja na transakcijsko ceno. Rezultate modela smo primerjali tudi z rezultati modela množičnega vrednotenja v Republiki Sloveniji, ki se izvaja ciklično, iterativno in katerega rezultati so odvisni od rezultatov (in modelov množičnega vrednotenja) predhodnih ciklov vrednotenja.

ABSTRACT

The present paper discusses the heterogeneity of the apartment market. For this purpose, we have developed the model for the mass valuation of apartments in the Republic of Slovenia. The construction of the mass valuation model is based on the generalised additive model approach. In this paper, the development of the model is presented. In the experimental part, the analysis of the results of the two models is performed. The dependent variable (the price of an apartment) is distributed according to the Gaussian and the gamma distributions. Particular attention has been paid to the impact of the transaction time on the apartments' transaction value. The results of the model are also compared with the results of the mass valuation model in the Republic of Slovenia, which is carried out cyclically and iteratively, the results of which depend on the results (and mass valuation models) of previous cycles.

KLJUČNE BESEDE

tržna vrednost, trg nepremičnin, množično vrednotenje, GAM, SPAR, cena stanovanj

KEY WORDS

market value, real property market, mass valuation, GAM, SPAR, sale price, apartments

1 INTRODUCTION

Mass appraisal of real estate is defined as the process of valuing a group of properties as of a given date and using common data, standardised methods and statistical testing (IAAO, 1978, 2017). Valuation of real estate is usually considered from two perspectives: individual and mass (Renigier-Bilozor, Janowski and d'Amato, 2019). Individual real estate valuation is based on the individual treatment of real estate, taking into account a small amount of transaction data and a large amount of descriptive data on real estate and transaction circumstances. On the other hand, mass valuation relies on real estate databases with a large amount of data and automatic processing. Many authors emphasised the importance of mass valuation for pricing, investment decisions, taxation, mortgages, insurance, portfolios and risk analysis, spatial planning, trends of real estate market, etc. (Yousfi et al., 2020). Recently, the real estate market has been extremely thoroughly studied, mainly due to the past economic crisis (Twaroch et al., 2015; McCluskey, 2018; Arribas et al., 2016), but a comprehensive and effective real estate market analyses are still lacking (Renigier-Bilozor, Janowski and d'Amato, 2019). Adequate real estate market analysis requires selecting appropriate methods to analyse the available data and information (D'Amato and Kauko, 2017). The goal of real estate mass valuation is to determine, how the real estate market works and design an appropriate representative mathematical model for assessing real estate market values based on market data and data on real estates (McCluskey and Adair, 1997, 2018). The importance of automated real estate valuation situations is also emphasised by Renigier-Bilozor, Janowski and Walacik (2019).

Widely accepted mass valuation models belong to a group of hedonic models. Here, the real estate price appears as a dependant variable (Borst, 2007; Helbich et al., 2014; Renigier-Bilozor, Janowski and Walacik, 2019; Yousfi et al., 2020). The sale date, location, and quality parameters of the real estate appear in the hedonic model as explanatory variables. Relationship between real estate price and its quality, taking the location into account, is valued through hedonic regression (Rosen, 1974). Among the most important variables that define the real estate value is a location (Orford, 1999; Peterl, 2017). The date of the real estate sale and real estate properties have the next significant impact on the real estate market value. This is also reflected in the residential real estate market (Čeh, Viitanen and Peruš, 2012; Owusu-Ansah, 2012; Arribas et al., 2016; Ulbl, Štembal and Smodiš, 2016; Abdullahi, Usman, Ibrahim, 2018; Čeh et al., 2018). According to Peterl (2017), we expect the impact of the area of real estate on its price to be logarithmic, the construction year of the building will be considered as a spline or polynomial of a higher degree.

Slovenian real estate market covers a large area, for which the real estate market reports show that trends of real estate prices change over different price areas (GURS, 2019; GURS, 2018a; GURS, 2018b). Thus, from the report on the real estate market for 2018 (GURS, 2018b), we find that the growth of apartments prices between 2015 and 2018 was the highest for the Ljubljana area (in 2018, the average price per m^2 of an apartment was 36 % higher than in 2015), for the area of Maribor this percentage is much lower (20 %), while for the area of Nova Gorica the growth was only 10 %. In other European countries, researches are increasingly highlighting the temporal-spatial relationship between the behaviour of the residential market in general. Helbich et al. (2014) found the differences in price growth trends between different regions in Austria. Kuntz and Helbich (2014) emphasised the importance of considering the temporal and spatial component when dealing with real estate market through literature review. In the mentioned research, they used geostatistical methods for modelling real estate prices and thus paid attention to modelling price variation in space. From the temporal and spatial point of view on apartment prices in a larger area, there is a very interesting study. It was published by Palma et al. (2018) and is focused on the spatio-temporal modelling of the residential real estate market in Italy. There have been published several studies dealing with spatio-temporal aspect of modelling residential prices in the real estate market, but most of them refer to the area of one city or smaller rounded areas, starting with one of the first in this field (Nappi-Choulet and Maury, 2011).

In this research, which deals with the residential real estate market for the whole of Slovenia, we pay special attention to the temporal and spatial aspects of changes in apartment prices, by taking into account the moment of sale of the apartment in different price areas. The price areas are formed according to the knowledge of the real estate market's behaviour in Slovenia. An individual price area is formed based on the same forces of demand and supply within the price area, as proposed in the context of real estate mass valuation from Surveying and Mapping Authority of the Republic of Slovenia (Figure 3). The experimental part of the research was performed on the entire Slovenian residential real estate market data, which belongs to heterogeneous markets. As noted in Helbich et al. (2014), the properties of real estate are very special. Among other things, this speciality is due to the unique position in space, so real estate is most often considered a heterogeneous good. Besides, the Slovenian residential real estate market is considered to be very diverse, even in seemingly homogeneous neighbourhoods. According to Draksler (2009), in most residential neighbourhoods, mixed construction of both low and high buildings, as well as different ways of building, predominate. Additionally, due to the large share of owner-occupied dwellings in Slovenia (Lagonja, 2010), dwellings in the same apartment building are very differently maintained. All this is reflected in the heterogeneity of the real estate market. The same is true for many real estate markets in Europe (Renigier-Bilozor, Janowski and Walacik, 2019), so the results of the survey will be of interest to the broader international level. Renigier-Bilozor, Janowski and Walacik (2019) used data mining methods to analyse such a market.

In this research, the method of generalised additive models will be used to address the heterogeneous real estate market for the whole country. Many European countries do not systematically collect real estate market data (Twaroch et al., 2015). This makes model construction extremely difficult. Thus, the nationwide analysis of the real estate market relies on data collected by real estate agencies, banks, web portals with advertisements for the sale and rental of real estate (Helbich et al., 2014; Twaroch et al., 2015). The Slovenian example of a mass real estate valuation system, within which data on the real estate market is systematically collected (see Ulbl, Štembal and Smodiš, 2016; Ulbl and Smodiš, 2019), enables a systematic analysis of such a heterogeneous real estate market. Takats (2012) states that state-level real estate heterogeneity is a really interesting area for future research.

The purpose of the research is to check the possibility of simultaneously taking into account the variables that we assume to have the greatest impact on residential real estate price. These variables primarily include the location of the property (Peterl, 2017; Orford, 1999). The next significant impact on the price of residential real estate has the moment of sale of the property and its physical properties (Čeh, Viitanen and Peruš, 2012; Owusu-Ansah, 2012; Arribas et al., 2016; Ulbl, Štembal and Smodiš, 2016; Abdullahi, Usman and Ibrahim, 2018; Čeh et al., 2018). Nahtigal and Grum (2014) also identified the location, namely micro-location, as the most crucial impact on residential real estate price. Location was followed by the impact of residential real estate's physical characteristics, among which size and age proved to be the most important. Socio-economic factors and functional and relative apartment size factors also proved to be important, but these factors had a significantly smaller impact (Nahtigal and Grum, 2014).

In the research, the building's location data will be considered according to the spatial reference system (coordinates of the centroid for the building in which the apartment is located). The moment of sale is the information that represents the date of the conclusion of the contract in the Real Estate Market Record (hereinafter: ETN). Regarding the physical characteristics of the real estate, we will focus on the size of the apartment and the age of the building. These are variables that, based on recent extracts and the literature review, among all parameters of the properties best describe the properties of the real estates. The apartment's size has been determined in the same way as in the Slovenian mass valuation system. The size of the apartment is thus determined as the sum of living space, office space, storage, drying room or laundry, 25 % of the garage or garage parking space, 3 % of the basement area, 20 % of the terrace, balconies and loggias, 50 % limited use rooms and 70 % of unfinished premises (EMV, 2020). Age is taken into account with data on the year of construction of the building. The impact of years of renewal on residential apartment price is not taken into account in this analysis. Given all the above, we assume that the apartment price in Slovenia will be affected by the location as well as the size and age of the apartment and the time of sale in different price areas.

The article initially presents the data and used methodology. The central part refers to the presentation of the results of the evaluation of two models developed for the purpose of estimating the generalised market value of dwellings. In addition, a comparison of the models' results with the current model of mass valuation in Slovenia is performed. We conclude the article with conclusions.

2 DATA

The analysis is performed on the Slovenian real estate market data. The Surveying and Mapping Authority of the Republic of Slovenia has been systematically monitoring the achieved contract prices of real estate on the Slovenian market since the beginning of 2007. The concluded real estate sale transactions for which real estate transfer tax is charged are provided by the Financial Administration of the Republic of Slovenia. The sellers provide transactions for which value-added tax (VAT) is charged. The data is kept in the Real Estate Market Record (ETN, 2020). The Surveying and Mapping Authority of the Republic of Slovenia checks the data from the ETN and, if necessary, corrects them to the actual situation in the area. The data for each transaction is checked and, if necessary, supplemented based on data from various sources. Thus, the data from the ETN are first systematically supplemented with data from the Real Estate Record (REN), the building cadastre and the data from the land cadastre. Besides, the marketability of the transaction (connection of the contracting parties) is individually checked based on all available records (e.g. data from the Agency of the Republic Slovenia for Public Legal Records and Related Services - AJPES, Central Population Register) and from various data that can be checked online (real estate sales articles, available sales advertisements on sales portals, advertisements for renting flats on websites, etc.). Each transaction is also verified by a field trip and additionally with a virtual tour in Google Street View. Based on all available data, the transaction is checked and, if necessary, the transaction's marketability, the size of the property, the year of construction, and the quality of the apartment are corrected. It is also being examined whether the price could be speculatively reduced or incresed. All this is assessed in the context of the sales review process. In doing so, each transaction is appropriately defined according to the condition in which it was sold. The conditions for sales marketability and data on real estate that is subject of a legal transaction are checked. Verified and supplemented data on considered real estate of a purchase and sale transaction are kept linked to the ETN internally. The analysis was performed for data on sales of apartments in Slovenia in the period from 1 January 2015 to 31 December 2019 are in the ETN (2020) defined as market transactions (relevant transactions). In this way, suitable apartment transactions are defined as transactions performed on the secondary market, that are marketable, construction is completed and which quality corresponds to the population of all apartments. The total number of such relevant apartment sales is 35,309 (Table 1). All calculations in this paper are performed on these data.

Table 1: Descriptive data statistics.

	Minimum	1st quartile	Median	Average	3rd quartile	Maximum
Sale price [€]	3.500	53.000	80.000	98.986	127.897	1.150.000
Area [m²]	15.00	41.44	55.24	58.21	69.76	705.00
Construction year	1435	1965	1978	1975	2003	2019

Data source: ETN (2020); own calculations.

Table 1 shows that the data also includes an apartment with an area of 705 m², which probably does not represent an apartment but a house or even a multiapartment building. As a result, due to errors, we exclude sales of apartments larger than 300 m² (3 examples). We also exclude sales with sale price higher than € 1,000,000 (1 such sale). We assume that this is an error due to real estate record error or error in reviewing real estate sales data. The total number of analysed apartments is thus reduced by 4, to 35,305 (Table 2).

Table 2: Descriptive statistics of data suitable for calculations.

	Minimum	1st quartile	Median	Average	3rd quartile	Maximum
Sale price [€]	3.500	53.000	80.000	98.954	127.841	695.000
Area [m²]	15.00	41.44	55.24	58.16	69.75	230.00
Construction year	1435	1965	1978	1975	2003	2019

Data source: ETN (2020); own calculations.

The contract price of the apartments ranged between € 3,500 and almost € 700,000. The price of € 3,500 seems unrealistic for an apartment, so sales of apartments with a price lower than € 5,000 were checked. It was found that the sales of such apartments are three, one from the year 2016, one from the year 2018 and one from the year 2019. All have 15.9 m² and are located in the same multi-apartment building in Trbovlje. Despite the very low price, these sales are not excluded from the analysis because they are relevant. The median apartment price is € 80,000, and the average is almost € 100,000. Apartments with the area between 15 m² and 230 m² with a median of 55 m² and an average of 58 m² were sold. From the point of view of the apartments' area, the sales sample is representative for the population of all apartments in Slovenia, where the median for the area is 53.6 m² (EMV, 2020). Apartments built between 1435 and 2019 were sold, with an average of 1975 and a median of 1978. The median for the construction year of apartments in the population is 1975 (EMV, 2020). The sales sample is also representative of the population of all dwellings in Slovenia from the construction year's point of view.

The economic lifespan of apartments is about 80-100 years (Polajnar, 2006), which means that only buildings constructed after 1920 are economically justified. The year of construction is therefore corrected by attributing the corrected year of construction 1900 to all buildings built before 1900, as they must be regularly maintained to still be usable. Figure 3 shows price areas, which are areas for which the same demand and supply forces are assumed. Table 3 lists descriptive statistics by price ranges. Figure 1 shows the boxplots for prices by price areas.

Table 3: Descriptive statistics of sale prices of apartments by price areas.

The label of price area	Number of sales	Median of prices (rounded to 1000)	Average of prices (rounded to 1000)	Median of area	Median of construction year
Alpe in idrijsko območje	359	52,000	55,000	53.1	1974
Celje	1,382	58,000	62,000	51.8	1971
Dolenjsko območje in Posavje	1,759	55,000	59,000	51.8	1978
Gorenjsko območje	2,016	74,000	83,000	50.6	1977
Koroško območje s Pohorjem	927	50,000	52,000	52.9	1975
Ljubljana	10,204	130,000	147,000	55.7	1977
Maribor	4,376	58,000	64,000	52.0	1971
Nova Gorica	518	85,000	86,000	57.0	1975
Obala in slovenska Istra	3,193	125,000	136,000	55.1	1989
Okolica Celja	2,133	56,700	60,000	54.1	1977
Okolica Maribora	813	55,000	57,000	53.8	1985
Osrednjeslovensko območje brez Ljubljane	3,690	105,000	114,000	56.4	2001
Postojnsko in Kočevsko območje	959	53,000	57,000	54.1	1973
Prekmursko območje	526	43,000	52,000	51.7	1977
Slovenske gorice, Haloze in Kozjansko	1,068	49,000	52,000	54.0	1977
Zaledje obale, Kras in Vipavska dolina	590	70,000	72,000	55.4	1978
Zasavsko območje	792	40,000	42,000	52.0	1969

Data source: ETN (2020); own calculations.

The highest prices of apartments are in Ljubljana's price area, which includes the area of Ljubljana within the ring bounded by the bypass motorway. This is also the area with the most apartments and consequently the most sales of them. Prices from the coast with Slovenian Istria (*Obala in slovenska Istra*) and the surroundings of Ljubljana (*Osrednjeslovensko območje brez Ljubljane*) are followed. These areas have many new apartments in the structure of sold apartments (median of construction year is 2001). Prices are comparable in the Gorenjska area (Gorenjsko območje), Nova Gorica and the hinterland of the coast, the Karst and the Vipava Valley (*Zaledje obale, Kras in Vipavska dolina*). Prices in Maribor, Celje, their surroundings (*Okolica Maribora, Okolica Celja*) and in the Dolenjska area (*Dolenjsko območje in Posavje*) are also comparable. Other areas have comparatively lower contract prices.

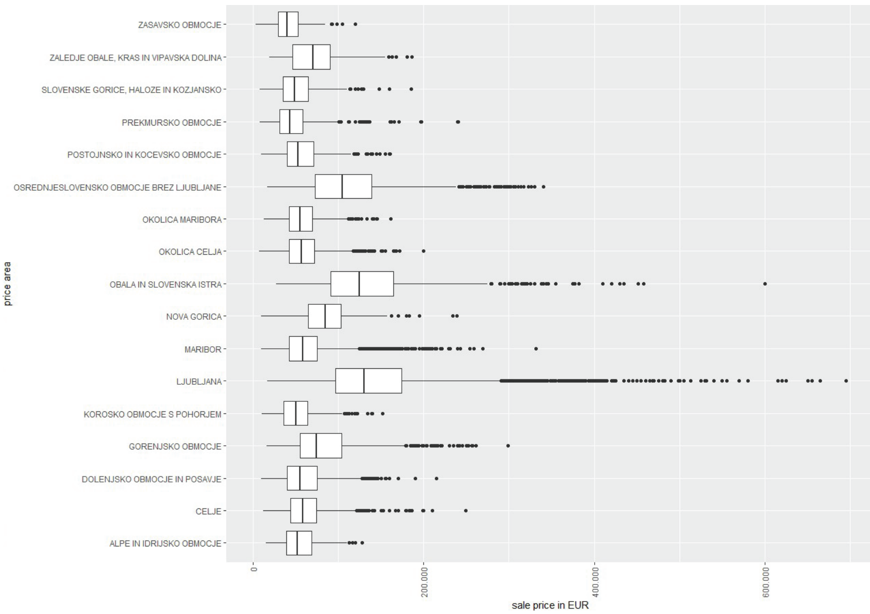


Figure 1: Box plots for prices by price areas (Data source: ETN (2020); own graphics).

The distribution of the contract price as a dependent variable is shown in Figure 2.

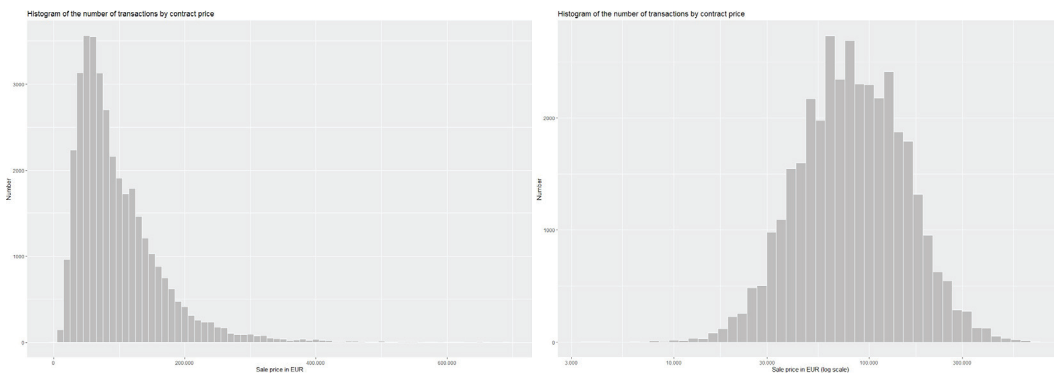


Figure 2: Histogram of the number of transactions by sale price; left: basic data; right: logarithmic data (Data source: ETN (2020); own graphics).

The distribution of the sale price shows that there is an asymmetry of the data, so the data are also shown on the logarithmic scale (Figure 2, on the right).

3 METHODOLOGY

The generalised additive model (GAM) approach is used to build the model, where the sale price of apartments (*pog_cena*) appears as a dependent variable. The explanatory variables are location given by cartesian coordinates of the centroid of the building in states reference coordinate system (*x*, *y*), date of sale of the apartment (*time*), corrected year construction (*leto_izg_cor*) and the area of the apartment (*izmera_pop*). Due to the distribution of residential real estate prices (Figure 2), the price is transformed by a logarithm in the model. Explanatory variables are also transformed, for which splines are used.

The lognormal and gamma distributions of the dependent variable and generalised additive models with splines are used. According to Wood (2010), smoothing parameters are selected to calculate splines according to two groups of criteria. The first group (asymptotic methods) attempts to minimise the error of the predictive model by optimising criteria such as the Akaike Information Criterion (AIC), cross-checking, or generalised cross-validation (GCV) (Craven and Wahba, 1979). The second group treats smooth functions as random effects (Kimeldorf and Wahba, 1970), so that smoothing parameters are parameters of variance that can be estimated by the maximum likelihood estimator (ML; Anderssen and Bloomfield, 1974), restricted maximum likelihood or generalised maximum likelihood (REML/GML; Wahba, 1985). It turns out that GCV develops more minima and gives more variable smoothing parameters (Wood, 2010). It only weakly punishes the predetermination of the model, with the minimum being low in terms of sample variability during smoothing. This can lead to the predetermination of the model. REML, on the other hand, penalises predetermination more strongly, which gives a more pronounced optimum given the variability of the sample.

Extreme smoothing can be avoided by using a synthetic measure of suitability, such as Akaike's information criterion (AIC; Hurvich, Simonoff and Tsai, 1998). In practice, the use of low to intermediate ranges for smoothing parameters inhibits overdetermination, resulting in AIC offering only a few additional benefits relative to GCV. Greater resistance to predetermination, less variability of smoothing parameters, and reduced tendency to more minima give preference to REML and ML methods over GCV and AIC methods. However, these advantages must be weighed against the fact that the REML and ML methods are less reliable compared to GCV and AIC. Due to all the above, the fREML (fast stable restricted maximum likelihood) method was used to determine an individual model optimally. The percentage of explained deviance or the variability of the dependent variable (Greenacre and Primicerio, 2014), and AIC are used to compare final models. The explained deviance represents the generalisation of the determination coefficient for the case of generalised models, such as GLM – generalised linear model and GAM – generalised additive model. It serves to compare the differences between the models according to their ability to explain the variability of the dependent variable. The simplified equation of the model is (1):

$$log(pog\_cena) \approx f_{t\_co}(time,\ ime\_co) + f_{xy}(x,\ y) + f_i(izmera\_pop) + f_l(leto\_izg\_cor) + \varepsilon \qquad (1)$$

Here are:

- f_i and f_l: splines for influences of area and construction year on the sale price,
- f_{t_co}: splines for the influence of date of sale by each price area on the sale price and
- f_{xy} 2d spline for location influence on the sale price of an apartment.

Price areas (Figure 3) are designed to anticipate the same supply and demand forces within them and on the basis of multi-year monitoring of Slovenia's real estate market (Ulbl, Štembal and Smodiš, 2016).

The results for the trends of such models will be compared with the trends calculated based on of the SPAR method for each price area. Surveying and Mapping Authority of the Republic of Slovenia uses the SPAR method to determine the impact of the date of sale on the residential real estate price. The Sale Price Appraisal Ratio Method (SPAR) is used in New Zealand, Sweden, Denmark, and the Netherlands (Vries et al., 2009) to determine the impact of the sale date on the price of the real estate. Bourassa, Hoesli and Sun (2006) presented the SPAR method as a method for generating real estate price indices. The SPAR method takes quotient between the real estate price and the previously estimated value for calculating the real estate price index.

According to Eurostat (2013), the SPAR method refers to all data on purchase and sale transactions and is only applicable where reliable estimated real estate values are available. Based on the already formed valuation models, the calculated value based on the current model is assigned to the sold real estate. The generalised value for apartments serves for calculating the trend according to the SPAR method. It is calculated as the product of value from value tables (influence of location, size, and year of construction), a factor of renovations, a factor of properties, a factor of additional spaces, a factor of position, and factor of distance from line objects of public infrastructure (EMV, 2020). All data on the calculation of values are presented on the web site for Valuation Models Register under the tab description and quality of the model, value table and factors and other parameters.

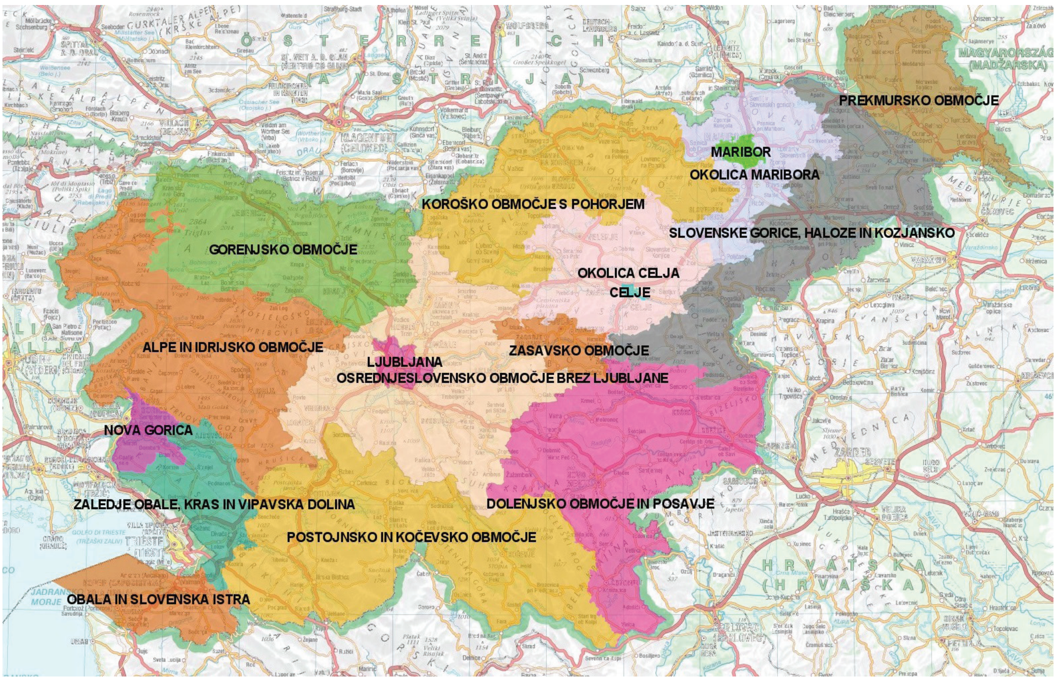


Figure 3: Price areas (Data source: ETN (2020); own graphics).

To present the impact of the date on the price of real estate in the model, which takes all variables at the same time into account, we additionally add presentations of trends used by Surveying and Mapping Authority of Slovenia (SPAR method with moving average method where the geometric mean is used for average ratio between price and calculated value for the sales period 120 days before and 90 days after the date for which the trend is calculated). The location will affect the price with a spatial spline. This will be compared with the value zones published in the Valuation Models Register (Figure 4). The Surveying and Mapping Authority of the Republic of Slovenia takes the impact of the location into account through value zones (Ulbl, Štembal, and Smodiš, 2016, Ulbl and Smodiš, 2019). These are areas where properties with the same data have the same generalised value. Each value zone has a defined value level that represents the value of the valuation reference unit. In the case of apartments, this apartment is in a building with 6 to 50 dwellings, 50 m^2 in area, built between 1975 and 1983, not renovated, no lift provided, located on the ground, first, second or third floor and not located within the influential areas of linear facilities of public infrastructure. Figure 4 shows the value zones that are coloured according to the value levels assigned to each value zone.

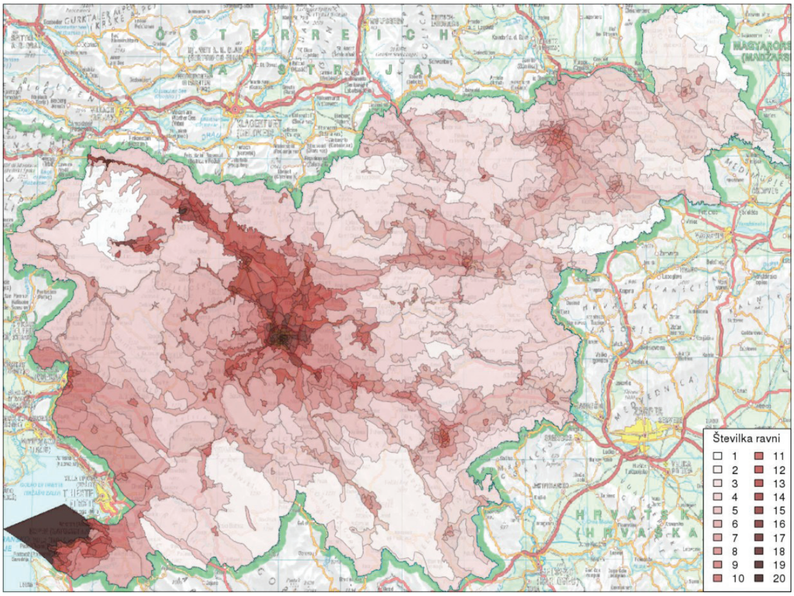


Figure 4: Value zone for apartments (Data source: Record of valuation models (EMV, 2020)).

4 RESULTS

In this chapter, we present the research results. First, the results of estimating the market value of apartments according to developed models and assessing the suitability of models are presented, followed by the impact analysis results of the moment (time) of sale on the transaction price.

4.1 Results of model estimation

Generalised additive models are used to calculate the estimated real estate values. The dependent variable is taken into account by gamma and lognormal distribution. In both cases, the logarithmic transformation of the dependent variable is used.

```
Family: gaussian
Link function: log

Formula:
pog_cena ~ s(time, bs = »cr«, by = as.factor(ime_co), k = 6) +
    s(x, y, bs = »tp«, k = 100) + s(izmera_pop, bs = »cr«,
    k = 20) + s(leto_izg_cor, bs = »cr«, k = 10)

Parametric coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 11.331127   0.001791    6328   <2e-16 ***

Signif. Codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
                                                                   edf Ref.df        F  p-value
s(time):as.factor(ime_co)ALPE IN IDRIJSKO OBMOCJE                3.262  3.886    2.707  0.04011 *
s(time):as.factor(ime_co)CELJE                                   1.900  2.359   31.980 5.55e-16 ***
s(time):as.factor(ime_co)DOLENJSKO OBMOCJE IN POSAVJE            2.118  2.617   43.267  < 2e-16 ***
s(time):as.factor(ime_co)GORENJSKO OBMOCJE                       3.192  3.833   71.247  < 2e-16 ***
s(time):as.factor(ime_co)KOROSKO OBMOCJE S POHORJEM              1.559  1.921    6.209  0.00241 **
s(time):as.factor(ime_co)LJUBLJANA                               4.977  5.000 1164.922  < 2e-16 ***
s(time):as.factor(ime_co)MARIBOR                                 3.252  3.899   60.458  < 2e-16 ***
s(time):as.factor(ime_co)NOVA GORICA                             3.265  3.909   14.095 4.95e-11 ***
s(time):as.factor(ime_co)OBALA IN SLOVENSKA ISTRA                4.822  4.984  129.699  < 2e-16 ***
s(time):as.factor(ime_co)OKOLICA CELJA                           3.225  3.869   22.343  < 2e-16 ***
s(time):as.factor(ime_co)OKOLICA MARIBORA                        2.040  2.529   10.071 1.17e-05 ***
s(time):as.factor(ime_co)OSREDNJESLOVENSKO OBMOCJE BREZ LJUBLJANE  4.109  4.654  185.696  < 2e-16 ***
s(time):as.factor(ime_co)POSTOJNSKO IN KOCEVSKO OBMOCJE          1.985  2.457   22.831 6.04e-12 ***
s(time):as.factor(ime_co)PREKMURSKO OBMOCJE                      3.196  3.828    7.430 1.00e-05 ***
s(time):as.factor(ime_co)SLOVENSKE GORICE, HALOZE IN KOZJANSKO   2.100  2.603    4.449  0.00671 **
s(time):as.factor(ime_co)ZALEDJE OBALE, KRAS IN VIPAVSKA DOLINA  1.685  2.093   11.977 4.88e-06 ***
s(time):as.factor(ime_co)ZASAVSKO OBMOCJE                        2.298  2.829    7.567 8.82e-05 ***
s(x,y)                                                          95.162 98.549  680.691  < 2e-16 ***
s(izmera_pop)                                                   11.621 13.468 6532.887  < 2e-16 ***
s(leto_izg_cor)                                                  8.211  8.784  845.058  < 2e-16 ***

Signif. Codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.888   Deviance explained = 88.9%
fREML = -4.0398e+05  Scale est. = 4.9836e+08  n = 35305
```

Figure 5: Results of a model in which the dependent variable appears as lognormally distributed (Data source: ETN (2020); own calculations).

The model in which the dependent variable occurs with a lognormal distribution (Gaussian with logarithmic transformation) explains almost 89 % of the variability of the dependent variable. All variables have a statistically significant impact on price (Figure 5).

```
Family: Gamma
Link function: log

Formula:
pog_cena ~ s(time, bs = »cr«, by = as.factor(ime_co), k = 6) +
    s(x, y, bs = »tp«, k = 100) + s(izmera_pop, bs = »cr«,
    k = 20) + s(leto_izg_cor, bs = »cr«, k = 10)

Parametric coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 1.132e+01  9.868e-04   11474   <2e-16 ***

Signif. Codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Approximate significance of smooth terms:
                                                                       edf Ref.df       F  p-value
s(time):as.factor(ime_co)ALPE IN IDRIJSKO OBMOCJE                    4.604  4.923   12.88 1.86e-11 ***
s(time):as.factor(ime_co)CELJE                                       2.086  2.584   94.01  < 2e-16 ***
s(time):as.factor(ime_co)DOLENJSKO OBMOCJE IN POSAVJE                3.436  4.084  102.39  < 2e-16 ***
s(time):as.factor(ime_co)GORENJSKO OBMOCJE                           2.972  3.602  150.36  < 2e-16 ***
s(time):as.factor(ime_co)KOROSKO OBMOCJE S POHORJEM                  1.000  1.000   70.74  < 2e-16 ***
s(time):as.factor(ime_co)LJUBLJANA                                   4.853  4.989  954.08  < 2e-16 ***
s(time):as.factor(ime_co)MARIBOR                                     3.950  4.538  271.53  < 2e-16 ***
s(time):as.factor(ime_co)NOVA GORICA                                 2.658  3.245   33.35  < 2e-16 ***
s(time):as.factor(ime_co)OBALA IN SLOVENSKA ISTRA                    4.381  4.822  131.82  < 2e-16 ***
s(time):as.factor(ime_co)OKOLICA CELJA                               4.242  4.743   49.93  < 2e-16 ***
s(time):as.factor(ime_co)OKOLICA MARIBORA                            2.037  2.527   31.78  < 2e-16 ***
s(time):as.factor(ime_co)OSREDNJESLOVENSKO OBMOCJE BREZ LJUBLJANE    4.009  4.584  237.29  < 2e-16 ***
s(time):as.factor(ime_co)POSTOJNSKO IN KOCEVSKO OBMOCJE              2.112  2.607   69.56  < 2e-16 ***
s(time):as.factor(ime_co)PREKMURSKO OBMOCJE                          3.569  4.203   25.03  < 2e-16 ***
s(time):as.factor(ime_co)SLOVENSKE GORICE, HALOZE IN KOZJANSKO       1.000  1.000   34.96 3.39e-09 ***
s(time):as.factor(ime_co)ZALEDJE OBALE, KRAS IN VIPAVSKA DOLINA      1.000  1.000   60.43 7.78e-15 ***
s(time):as.factor(ime_co)ZASAVSKO OBMOCJE                            3.516  4.160   32.34  < 2e-16 ***
s(x,y)                                                              97.674 98.953 1373.64  < 2e-16 ***
s(izmera_pop)                                                       13.395 15.303 7220.64  < 2e-16 ***
s(leto_izg_cor)                                                      7.950  8.640 1236.00  < 2e-16 ***

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.879   Deviance explained = 91.1%
fREML = -9334.6  Scale est. = 0.033707  n = 35305
```

Figure 6: Results of a model in which the dependent variable occurs with a gamma distribution (Data source: ETN (2020); own calculations).

The model in which the dependent variable occurs with a gamma distribution explains more than 91 % of the dependent variable. All variables have estimated values of regression coefficients that are statistically significantly different from zero (Figure 6). Table 4 provides data for comparison between the results of models in which the dependent variable was modelled according to the Gaussian and gamma distributions.

Table 4: Comparison of the explained variability of the dependent variable and AIC for both models.

Model	**Explained variability of the dependent variable**	**AIC**
Gauss distribution	88.9 %	807432.1
gamma distribution	91.1 %	780502.2

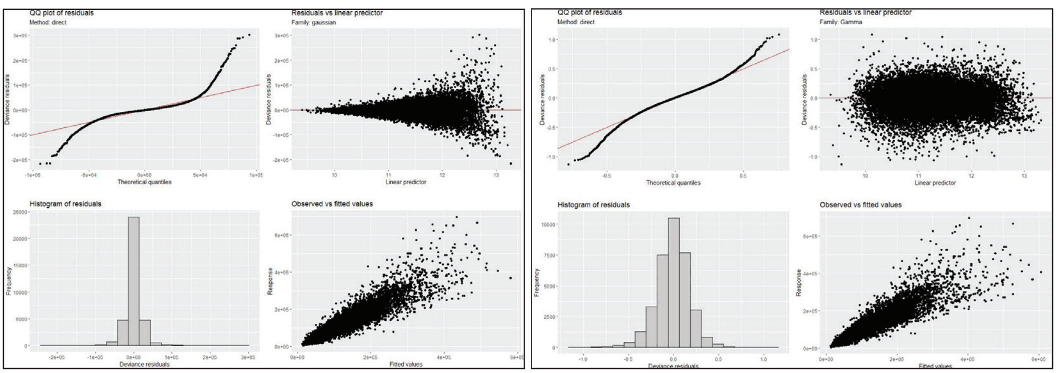


Figure 7: Image of residuals; left: distribution of the dependent variable according to the Gaussian distribution; right: distribution of the dependent variable according to the gamma distribution (Data source: ETN (2020); own calculations).

From the table, we see that the model that uses the gamma distribution with logarithmic transformation for the dependent variable is better. It explains more variability of the dependent variable, AIC is also lower. Figure 7 shows the residuals of models in which the dependent variable was modelled according to Gaussian (4 left plots) and gamma distribution (4 right plots).

A similar situation, as in Table 4, in which a model with a gamma distribution turns out to be a better model, is also shown by the image of residuals. It shows a less appropriate distribution of residuals for a model with a Gaussian distribution of the dependant variable. Residuals are inappropriately better distributed in the case of the gamma distribution. The QQ plot suggests that even a model with a gamma distribution of the dependent variable still has a potential for improvement. The results of both models are presented in continuation. The partial effects of each variable on the calculated value are shown. A comparison with the current evaluation model will also be performed.

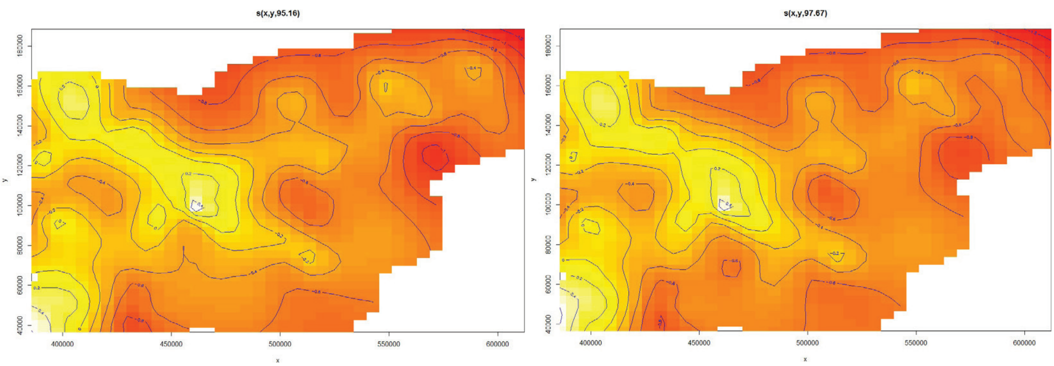


Figure 8: Partial residuals of a model for location; left: distribution of the dependent variable according to the Gaussian distribution; right: distribution of the dependent variable according to the gamma distribution (Data source: ETN (2020); own calculations).

Figure 8 shows the residential real estate values according to the location within Slovenia. Both models give very similar results. The model, which takes the dependent variable's distribution according to the gamma distribution into account, shows a slightly lower estimated value in the north-east of Slovenia, and there is also some difference in Carinthia (north) and the south-east (Haloze). The lowest prices and consequently the values are in Prekmurje (red) and Haloze, and the highest in Ljubljana and on the coast. High prices are also observed in Gorenjska, slightly lower in Nova Gorica. Maribor and Novo mesto have approximately the same prices or values. Somewhat lower prices are in Celje and its surroundings and Slovenj Gradec. All this corresponds to the relationship between the prices published in the semi-annual report on the Slovenian real estate market (GURS, 2019). This result can be further compared with the value zones published in the Valuation Models Register (Figure 4), which reflects the impact of the location on the price of the property. Figure 9 shows the partial influence of size on the price of apartments. The shaded part represents the 95% confidence interval for the mean.

We can see (Figure 9) that the apartment area in the model could be taken into account by logarithmic transformation. Both models give a very similar result for the area effect. More significant variability is observed for larger apartments in the case of the gamma distribution of the dependent variable.

Figure 10 shows the partial impact of the year of construction on the price of apartments

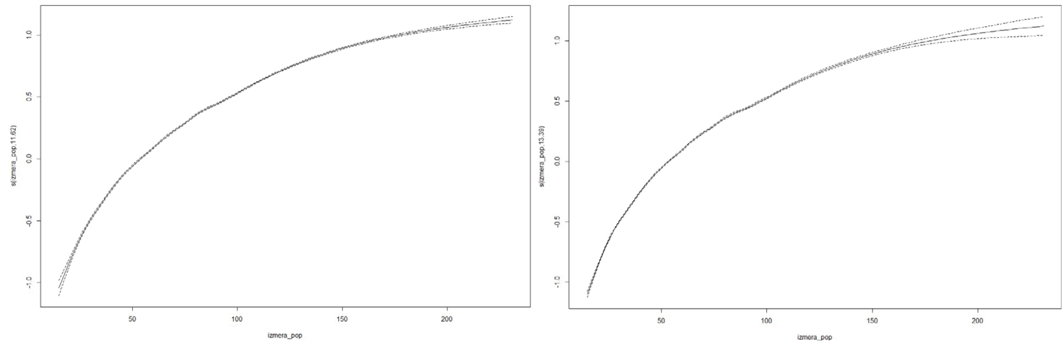


Figure 9: Partial residuals of the model for area; left: distribution of the dependent variable according to the Gaussian distribution; right: distribution of the dependent variable according to the gamma distribution (Data source: ETN (2020); own calculations).

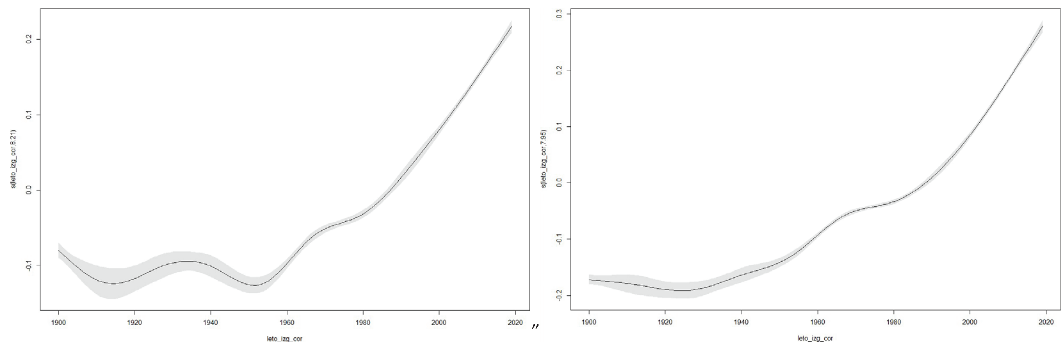
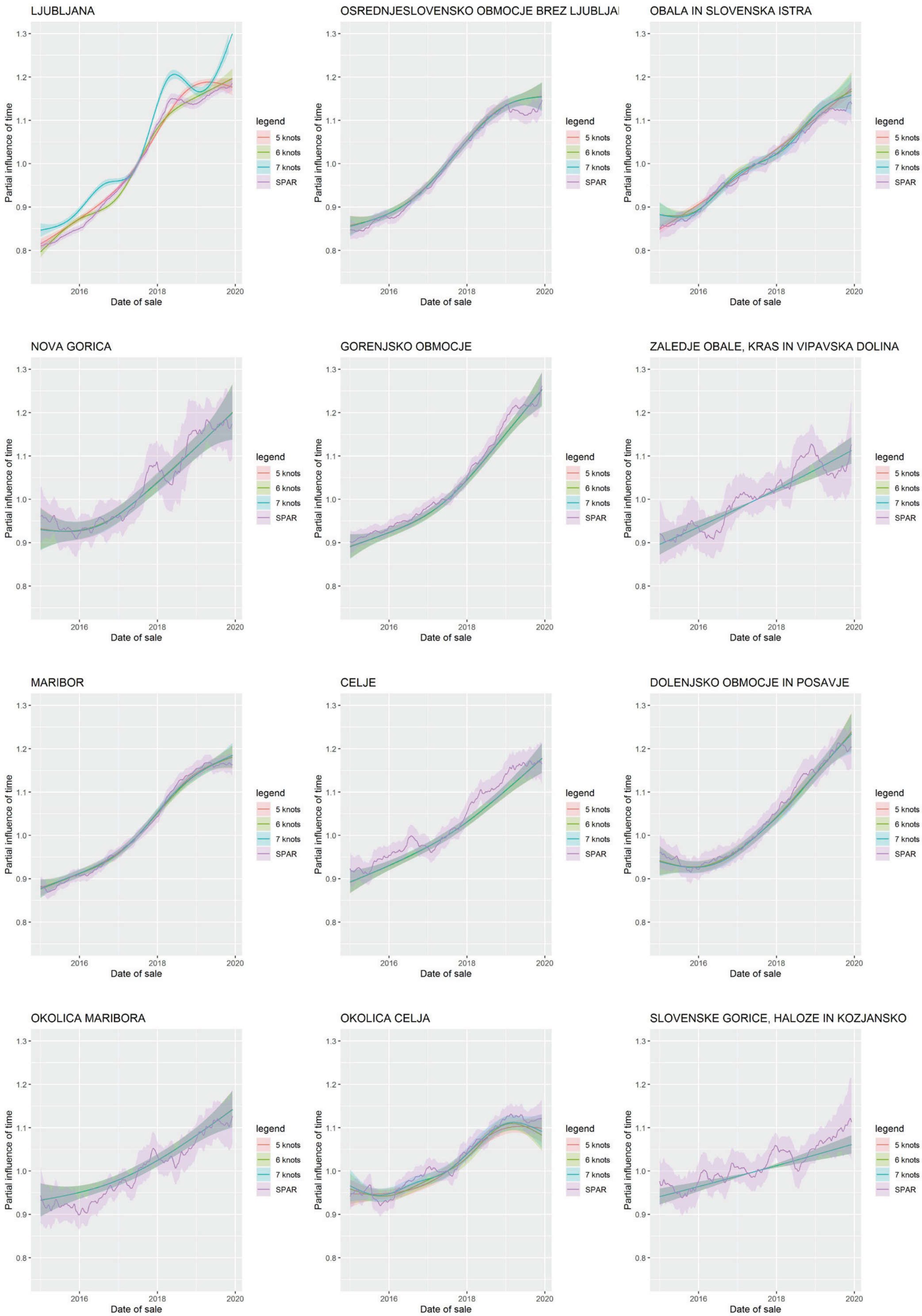


Figure 10: Partial residuals of a model for the corrected year of construction; left: distribution of the dependent variable according to the Gaussian distribution; right: distribution of the dependent variable according to the gamma distribution (Data source: ETN (2020); own calculations).

The lowest prices for apartments are for those that were built around 1925. Older apartments have a slightly higher price. The residential real estate price by the year of construction increases almost linearly from 1925 to about 1955, then the price increase according to the year of construction is somewhat steeper. Apartments built between 1970 and 1985 have nearly the same prices. This is also the period in which most apartments in Slovenia were built (EMV, 2020). The rise in prices of apartments built after 1985 is very steep. In thirty years it reaches a 30% higher value. The most significant variability in the data can be observed for apartments built before 1955. The price of these apartments is highly dependent on apartment maintenance, which is why it would make sense to include apartment maintenance data in the model in future research.

4.2 Partial impact of the date of sale on the price of apartments

The partial impact of the date of sale from the model is for each price area compared with the trend calculated by the moving average method based on the SPAR ratio. The geometric mean is used as a measure to calculate the mean value. Data with up to 120 days before the day and 90 days after the day on which the mean is calculated are taken into account for the calculation of price-to-value ratios. Several models with different numbers of knots (3, 5, 6, 7, and 10) are assembled to determine the appropriate number of knots in the splines. Below (Figure 11), trends for price areas are shown to compare 5, 6, and 7 knots and for the trend according to the SPAR method.


LJUBLJANA
OSREDNJESLOVENSKO OBMOCJE BREZ LJUBLJA
OBALA IN SLOVENSKA ISTRA
NOVA GORICA
GORENJSKO OBMOCJE
ZALEDJE OBALE, KRAS IN VIPAVSKA DOLINA
MARIBOR
CELJE
DOLENJSKO OBMOCJE IN POSAVJE
OKOLICA MARIBORA
OKOLICA CELJA
SLOVENSKE GORICE, HALOZE IN KOZJANSKO
Partial influence of time
Date of sale
2016
2018
2020
0.8
0.9
1.0
1.1
1.2
1.3
legend
5 knots
6 knots
7 knots
SPAR

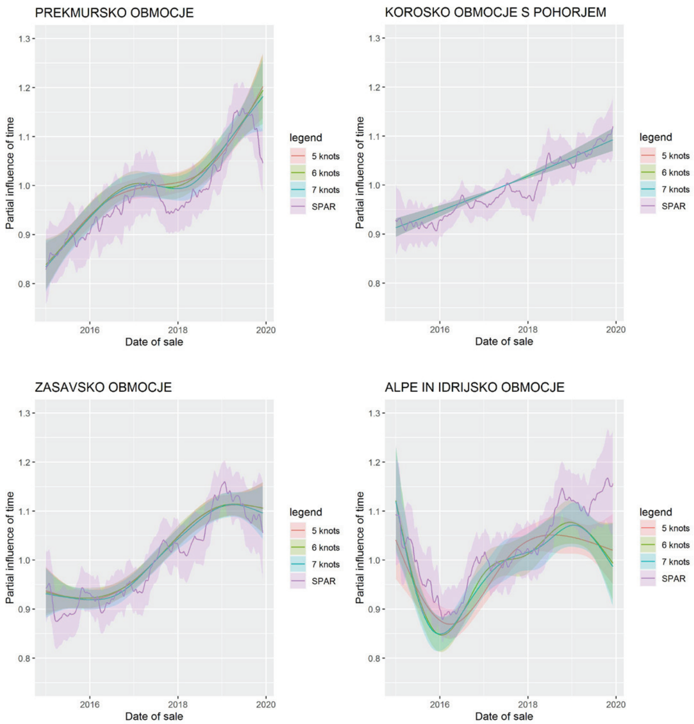


Figure 11: Trends by price areas (Data source: ETN (2020); own calculations).

There are no significant differences in the results between models with different numbers of knots to influence sale date. The most notable differences were shown only in the price area of Ljubljana. This is the price area with the largest amount of data. It turns out that the 6-knots model is the most sensible.

In all price areas, the use of a model that takes the date of sale into account at the same time as other variables proves to make sense. According to the SPAR method, the trend fluctuates more, but the real estate market prices do not change so quickly in a short time. The fluctuation is due to seasonal trends and, above all, the small amount of data by area. The small amount of data results in a high sensitivity of the trend to all deviations in the data. At some point, more apartments can be sold in better condition, with better equipment, leading to a higher price, and the next moment, apartments in worse condition are sold, leading to lower prices. As the data on quality of apartments and equipment are not available, it is not considered in the model. Consequently, its impact on price is not taken into account. Such short-term effects are detected and displayed by the SPAR method, while a spline with fewer knots does not detect such oscillations.

5 CONCLUSIONS

The paper presents an innovative approach to modelling the estimated market value of apartments. At the same time, the location, the area, year of construction, the date of the sale, and the property's location have been taken into account. The research has focused on the analyses, whether all of these impacts can be identified and considered at the same time. The Surveying and Mapping Authority of the Republic of

Slovenia currently carries out calibrating the model cyclically. Based on the currently valid model and real estate prices, the real estate price trend is calculated for each price area. All prices are then adjusted based on the time adjustment factor. This is followed by calculating the model parameters, especially the area of apartment and year of construction. Based on the new models, the impact of the location, which is defined in the model by value zones and appropriate value levels, is checked and corrected if necessary. A recalculation of the trend follows. This cycle is repeated until the result is satisfactory. A model error is observed.

The approach presented in this paper simultaneously considers the impact of the following variables: location, date of sale by price area, area, and year of construction. Such an approach is significantly more economical and enables better control over the results. It turns out that taking into account the dependent variable distributed by the gamma distribution is better than taking into account the lognormal distribution. This is shown by both the results of calculations as well as the graphical representation of the residuals. The residuals indicate that the gamma distribution is not optimal either. Thus, in future research, it would make sense to upgrade the model with generalised additive models for location, scale and shape (Ulbl, Štembal and Smodiš, 2016).

We have further compared the results of the developed model with the current model of mass valuation in Slovenia. It turns out that the results of the influence of the location between the two models are similar. Also, the impact of the date of sale between the models is comparable for all price areas. The number of relevant fractures in the spline for the effect of the date of sale was also analysed. Six knots proved to be the optimal number.

A model that takes all impacts simultaneously into account could improve the model of mass valuation in Slovenia since all variables are considered at the same time. As implemented by the Surveying and Mapping Authority of the Republic of Slovenia, the result of the cyclical method depends on the result of previous cycles and on the subjective opinion, based on which the influence of the location within the value zones is taken into account. Thus, this research brings an innovative approach to defining a uniform model at the level of the entire country. An essential advantage of this approach is the consideration of the impact of the variables considered at the same time, the consideration of location as a continuous variable and the continuous consideration of the year of construction without prior assumptions about the corresponding impact curve. A major advantage of the proposed approach is certainly the monitoring of the distribution of the dependent variable.

Literature and references:

Abdullahi, A., Usman, H., Ibrahim, I. (2018). Determining House Price for Mass Appraisal Using Multiple Regression Analysis Modeling in Kaduna North, Nigeria. ATBU Journal of Environmental Technology, 11 (1), 26–40.

Anderssen, R., Bloomfield, P. (1974). A time series approach to numerical differentiation. Technometrics, 16 (1), 69–75. DOI: https://doi.org/10.1080/00401706.1974.10489151

Arribas, I., Garcia, F., Guijaroo, F., Oliver, J., Tamošiouniene, R. (2016). Mass appraisal of residential real estate using multilevel modeling. International Journal of Strategic Property Management, 20 (1), 77–87. DOI: https://doi.org/10.3846/1648715x.2015.1134702

Borst, R. A. (2007). Discovering and Applying Location Influence Patterns in the Mass Valuation of Domestic Real Property. Submitted for the degree of Doctor of Technology. Ulster: Faculty of Engineering of the University of Ulster.

Bourassa, S. C., Hoesli, M., Sun, J. (2006). A Simple Alternative House Price Index Method. Journal of Housing Economics, 15 (1), 80–97. DOI: https://doi.org/10.1016/j.jhe.2006.03.001

Craven, P., Wahba, G. (1978). Smoothing noisy data with spline functions. Numerische Mathematik, 31 (4), 377–403. DOI. https://doi.org/10.1007/bf01404567

Čeh, M., Kilibarda, M., Lisec, A., Bajat, B. (2018). Estimating the performance of random forest versus multiple regression for predicting prices of the apartments.

ISPRS international journal of geo-information, 7 (5), 168. DOI: https://doi.org/10.3390/ijgi7050168

Čeh, M., Viitanen, K., Peruš, I. (2012). A non-parametric CAE approach to office rents: Identification of Helsinki metropolitan area submarkets. Expert Systems with Applications, 39 (1), 460–471. DOI: https://doi.org/10.1016/j.eswa.2011.07.037

D'Amato, M., Kauko, T. (2017). Advances in Automated Valuation Modeling. AVM After the Non-Agency Mortgages Crisis. Springer. DOI: https://doi.org/10.1007/978-3-319-49746-4.

Draksler, V. (2009). Prestrukturiranje odprtega prostora stanovanjskih sosesk zgrajenih od 1960 do 1980 v Ljubljani. Diploma thesis. Ljubljana: University of Ljubljana, Biotechnical Faculty.

EMV (2020). Opis in kakovost modela (= The presentation and quality of the model). Portal e-prostor. https://eprostor.gov.si/EV_EMV/emv/data?action=getDocFile&ID=3, accessed 20. 5. 2020.

Eurostat (2013). Handbook on residential property price indices (RPPIs). Eurostat. https://ec.europa.eu/eurostat/documents/3859598/5925925/KS-RA-12-022-EN.PDF, accessed 15. 2. 2020.

ETN (2020). Evidenca trga nepremičnin (= Real Estate Market Records). Ljubljana, Surveying and Mapping Authority of the Republic of Slovenia. http://prostor3.gov.si/zvn/spremljanje.html, accessed 19. 1. 2020.

GURS. (2018a). Poročilo o slovenskem nepremičninskem trgu za I. polletje 2018 (= Slovenian Real Estate Market Report for the first half of 2018). Ljubljana, Surveying and Mapping Authority of the Republic of Slovenia. http://www.trgnepremicnin.si/media/polletno_porocilo_2019_i.pdf, accessed 19. 1. 2020.

GURS. (2018b). Poročilo o slovenskem nepremičninskem trgu za leto 2018 (= Slovenian Real Estate Market Report for 2018). Surveying and Mapping Authority of the Republic of Slovenia. http://www.trgnepremicnin.si/media/porocilo_za_leto_2018.pdf, accessed 19. 1. 2020.

GURS. (2019). Poročilo o slovenskem nepremičninskem trgu za I. polletje 2019 (= Slovenian Real Estate Market Report for the first half of 2019). Surveying and Mapping Authority of the Republic of Slovenia. http://www.trgnepremicnin.si/media/polletno_porocilo_2019_i.pdf, accessed 19. 1. 2020.

Greenacre, M., Primicerio, R. (2014). Multivariate Analysis of Ecological Data. Bilbao: Fundacion BBVA.

Hurvich, C. M., Siminoff, J. S., Tsai, C-L (1998). Smoothing parameter selection in nonparametric regression using an improved Akaike information criterion. Journal of the Royal Statistical Society, Series B, 60 (2), 271–293. DOI: https://doi.org/10.1111/1467-9868.00125

Helbich, M., Brunauer, W., Vaz, E., Nijkamp, P. (2014). Spatial Heterogeneity in Hedonic House Price Models: The Casse of Austria. Urban Studies, 51 (2), 390–411. DOI: https://doi.org/10.1177/0042098013492234.

IAAO. (1978). Improving Real Property Assessment: A Reference Manual. Chicago: International Association of Asssessing Officers.

IAAO. (2017). Standard on Mass Appraisal of real Property. Kansas City: International Association of Assessing Officers.

Kimeldorf, G. S., Wahba, G. (1970). A correspondence between Bayesian estimation on stochastic processes and smoothing by splines. The Annals of Mathematical Statistics, 41 (2), 495–502. DOI: https://doi.org/10.1214/aoms/1177697089

Kuntz, M., Helbich, M. (2014). Geostatistical mapping of real estate prices: an empirical comparison of kriging and cokriging. International Journal of Geographical Information Science, 29, 1904–1921. DOI. https://doi.org/10.1080/13658816.2014.906041

McCluskey, W. J., Adair, A. S. (1997). Computer Assisted Mass Appraisal. An International review. New York: Ashgate Publishing.

McCluskey, W. J., Adair, A. S. (2018). Computer Assisted Mass Appraisal. An International review. New York: Ashgate Publishing. DOI: https://doi.org/10.4324/9780429461699

McCluskey, W. J. (2018). Property Tax. An international Comparative Review. New York: Ashgate Publishing. DOI: https://doi.org/10.4324/9780429431845

Nahtigal, D., Grum, B. (2014). Segmentaija in vrednostni okvir preferenc potencialnih kupcev stanovanj. Geodetski vestnik, 59 (1), 71–101. DOI: https://doi.org/10.15292/geodetski-vestnik.2015.01.071-101

Nappi-Choulet, I., Maury, T. P. (2011). A spatial and temporal autoregressive local estimation for the Paris housing market. Journal of Regional Science, 51 (4), 732–750. DOI: https://doi.org/10.1111/jors.2011.51

Owusu-Ansah, A. (2012). Examination of determinants of housing values in urban Ghana and implications for policy markers. Journal of African Real Estate Research, 2 (1), 58–85.

Orford, S. (1999). Valuing the Build Environment. Bristol: Ashgate Publishing Ltd.

Palma, M., Cappello, C., De Iaco, S., Pellegrino, D., (2018). The residential real estate market in Italy: a spatio-temporal analysis. Qual Quant, 53, 2451–2472. DOI. https://doi.org/10.1007/s11135-018-0768-8

Peterl, S. (2017). Smooth Spatial and Time Effect Models to Forcast House Prices in Sydney. Master thesis. Graz: Graz University of Technology.

Polajnar, M. (2006). Vpliv starosti in vzdrževanosti stavbe in stanovanja na vrednost stanovanja. Diploma thesis. Ljubljana: University of Ljubljana, Faculty of Civil and Geodetic Engineering.

Renigier-Bilozor, M., Janowski, A., d'Amato, M. (2019). Automated Valuation Model based on fuzzy and rough set theory for real estate market with insufficient source data. Land Use Policy, 87. DOI: https://doi.org/10.1016/j.landusepol.2019.104021

Renigier-Bilozor, M., Janowski, A., Walacik, M. (2019). Geoscience methods in real estate market Analysis subjectivity decrease. Geoscience, 9 (3), 130. DOI: https://doi.org/10.3390/geosciences9030130

Rosen, S. (1974). Hedonic prices and implicit markets: product differentiation in pure competition. Journal of Political Economy, 82, 34–55. DOI: https://doi.org/10.1086/260169

Takats, E. (2012). Aging and house prices, Journal of Housing Economics, 21 (2), 131-141. DOI: http://dx.doi.org/10.1016/j.jhe.2012.04.001

Twaroch, Ch., Wessely, R., Ernst, J., Lisec, A., Mansberger, R., Muggenhuber, G., Navratil, G., Unger, E.-M., (2015). Liegenschaft und Wert: Geodaten als Grundlage einer österreichweiten Liegenschaftsbewertung : mit einem Vergleich der Wertermittlung von Liegenschaften in ausgewählten Ländern Europas. Wien; Graz: NWV, Neuer Wissenschaftlicher Verlag, 215 p.

Ulbl, M., Smodiš, M. (2019). Razvojni model množične ocene vrednosti tržnih najemnin za pisarne. Geodetski vestnik, 63 (3), 325–343. DOI: https://doi.org/10.15292/geodetski-vestnik.2019.03.325-343

Ulbl, M., Štembal, R., Smodiš, M. (2016). Prenova sistema množičnega vrednotenja nepremičnin v Sloveniji. Geodetski vestnik, 60 (3), 627–643. DOI: https://doi.org/10.15292/geodetski-vestnik.2016.04.627-643

Yousfi, S., Dubé, J., Legros, D., Legros, D. (2020) Mass appraisal without statistical estimation: a simplified comparable sales approach based on a spatiotemporal matrix. The Annals of Regional Science, 64 (2), 349–365. DOI: https://doi.org/10.1007/s00168-019-00959-2

Vries, P., Haan, J., Wal, E., Mariën. (2009) A house price index on the SPAR method. Journal of Housing Economics, 18 (3), 214–223. DOI: https://doi.org/10.1016/j.jhe.2009.07.002

Wahba, G. (1985). A comparison of GCV and GML for choosing the smoothing parameter in the generalised spline smoothing problem. The Annals of Statistics, 13 (4), 1378–1402. DOI: https://doi.org/10.1214/aos/1176349743

Willenborg, L., Scholtus, S. (2018). The SPAR index and some alternative house price indices.

Wood, S. (2010). Fast stable REML and ML estimation of semiparametric GLMs. Journal of the Royal Statistical Society. Series B (Statistical Methodology), 73 (1), 3-36.

Ulbl M., Verbič M., Lisec A., Pahor M. (2021). Proposal of real estate mass valuation in Slovenia based on generalised additive modelling approach. Geodetski vestnik, 65 (1), 46-81.
DOI: https://doi.org/10.15292/geodetski-vestnik.2021.01.46-81

PREDLOG ZA IZBOLJŠAVO MNOŽIČNEGA VREDNOTENJA NEPREMIČNIN V SLOVENIJI NA PODLAGI PRISTOPA GENERALIZIRANIH ADITIVNIH MODELOV

OSNOVNE INFORMACIJE O ČLANKU:
GLEJ STRAN 46

1 UVOD

Množično vrednotenje nepremičnin je opredeljeno kot sistematična ocena tržne vrednosti skupine nepremičnin na določen datum z uporabo standardiziranih metod in statističnih analiz (IAAO, 1978, 2017). Po Renigier-Bilozor, Janowski in d'Amato (2019) je vrednotenje nepremičnin običajno obravnavano z dveh vidikov: individualnega oziroma posamičnega in množičnega. Posamično vrednotenje sloni na posamični obravnavi nepremičnine ob upoštevanju velikega števila opisnih podatkov o nepremičninah in okoliščinah transakcij, a se pri tem v splošnem srečujemo z majhno količino podatkov, medtem ko množično vrednotenje sloni na nepremičninskih evidencah z veliko količino podatkov in njihovi samodejni obdelavi, pri tem pa praviloma obravnavamo množico nepremičnin, a manjše število dejavnikov, ki vplivajo na tržno vrednost nepremičnine. Številni avtorji (Yousfi et al., 2020) poudarjajo pomen množičnega vrednotenja, ki se uporablja za spremljanje cen in ocenjevanje tržnih vrednosti nepremičnin, tudi v podporo pri odločanju glede investicij in aktivnostih na hipotekarnem trgu, pri obdavčenju, zavarovanjih, portfeljih in analizah tveganja, pri prostorskem planiranju, za namene izračunov trendov na področju tržnih vrednosti nepremičnin ipd. V zadnjem obdobju se v številnih državah nepremičninski trg izredno temeljito preučuje, kar je posledica predvsem pretekle gospodarske krize (Twaroch et al., 2015; McCluskey, 2018; Arribas et al., 2016), celovite in učinkovite analize trga nepremičnin pa še vedno manjkajo (Renigier-Bilozor, Janowski in d'Amato, 2019). Ustrezna analiza nepremičninskega trga zahteva izbiro ustreznih metod za analizo razpoložljivih podatkov in informacij (D'Amato in Kauko, 2017). Po McCluskey in Adair (1997, 2018) je pri množičnem vrednotenju cilj ugotoviti, kako deluje trg nepremičnin, ter oblikovati ustrezen reprezentativni matematični model za ocenjevanje najverjetnejše cene nepremičnine na trgu na podlagi tržnih podatkov in podatkov o nepremičninah. Tudi Renigier-Bilozor, Janowski in Walacik (2019) poudarjajo pomen samodejnih rešitev na področju vrednotenja nepremičnin.

Zelo široko sprejeti modeli za množično vrednotenje nepremičnin spadajo v kategorijo tako imenovanih hedoničnih modelov (Borst, 2007; Helbich et al., 2014; Renigier-Bilozor, Janowski in Walacik, 2019; Yousfi et al., 2020). V njih kot odvisna spremenljivka nastopa cena nepremičnine, trenutek prodaje, lokacija in parametri kakovosti nepremičnine pa v modelu nastopajo kot pojasnjevalne spremenljivke. Razmerje med ceno in kakovostjo nepremičnine ob upoštevanju lokacije se ocenjuje v obliki hedonične regresije (Rosen, 1974). Med pomembnejšimi spremenljivkami, ki opredeljujejo vrednost nepremičnin, je lokacija (Orford, 1999; Peterl, 2017). Naslednji bistven vpliv na vrednost nepremičnin imajo trenutek prodaje nepremičnine ter njene lastnosti, kar se kaže tudi na trgu stanovanjskih nepremičnin (Čeh, Viitanen in Peruš, 2012; Owusu-Ansah, 2012; Arribas et al., 2016; Ulbl, Štembal in Smodiš, 2016; Abdullahi, Usman, Ibrahim, 2018; Čeh et al., 2018) in je tudi predmet obravnave v tej raziskavi. Po Peterl (2017) pričakujemo, da bo vpliv velikosti stanovanja na ceno nepremičnine logaritemski, leto izgradnje stavbe pa bo upoštevano kot zlepek ali polinom višje stopnje.

Slovenski trg stanovanjskih nepremičnin obsega veliko območje, za katero iz poročil o trgu nepremičnin (GURS, 2019; GURS, 2018a; GURS, 2018b) ugotavljamo, da so trendi spreminjanja cen po različnih območjih različni. Tako iz poročila o trgu nepremičnin za leto 2018 (GURS, 2018b) ugotavljamo, da je bila rast cen stanovanj med letoma 2015 in 2018 največja za območje Ljubljane (leta 2018 je bila povprečna cena na kvadratni meter stanovanja 36 % višja kot leta 2015), za območje Maribora je ta odstotek precej nižji (20 %), za območje Nove Gorice pa je rast znašala le 10 %. Tudi v drugih evropskih državah raziskovalci vse bolj izpostavljajo časovno-prostorsko povezanost obnašanja stanovanjskega in na splošno nepremičninskega trga. Helbich et al. (2014) so ugotavljali razlike v trendih rasti cen med različnimi regijami v Avstriji. Kuntz in Helbich (2014) sta v pregledu literature poudarila pomen upoštevanja časovne in prostorske komponente pri obravnavi trga nepremičnin; v navedeni raziskavi sta uporabila geostatistične metode za modeliranje cen nepremičnin in s tem pozornost namenila modeliranju variacije cen v prostoru. Z vidika preučevanja časovnega in prostorskega spreminjanja cen stanovanj na večjem območju je zagotovo zanimiva študija, katere rezultate so objavili Palma et al. (2018), ki so se posvetili časovno-prostorskemu modeliranju trga stanovanjskih nepremičnin na primeru Italije. Študij, v katerih obravnavajo prostorsko-časovni vidik pri modeliranju cen stanovanj na nepremičninskem trgu, je sicer več, a se večina nanaša na območje enega mesta oziroma manjša zaokrožena območja, začenši z eno prvih študij na tem področju (Nappi-Choulet in Maury, 2011).

V raziskavi, v kateri obravnavamo trg stanovanj za celotno Slovenijo, bomo posebno pozornost namenili časovnemu in prostorskemu vidiku spreminjanja cen stanovanj, in sicer tako, da bomo trenutek prodaje stanovanja različno upoštevali po različnih cenovnih območjih. Pri tem bodo cenovna območja oblikovana glede na poznavanje obnašanja trga nepremičnin v Sloveniji. Posamezno cenovno območje je oblikovano na podlagi predpostavke enakih silnic povpraševanja in ponudbe v cenovnem območju, kot je predlagano v okviru množičnega vrednotenja nepremičnin na Geodetski upravi Republike Slovenije (GURS) (slika 3). Eksperimentalni del raziskave je opravljen na podatkih celotnega slovenskega stanovanjskega nepremičninskega trga, ki spada med heterogene trge. Kot je navedeno v Helbich et al. (2014), so lastnosti nepremičnin zelo posebne, med drugim že zaradi unikatnega položaja v prostoru, zaradi česar se nepremičnine najpogosteje upoštevajo kot heterogena dobrina. Poleg tega za slovenski stanovanjski nepremičninski trg velja, da so nepremičnine zelo raznolike tudi v na videz homogenih soseskah. Po Draksler (2009) v večini stanovanjskih sosesk prevladuje mešana zazidava tako nizkih kot visokih objektov kakor tudi različen način zazidave. Dodatno so zaradi velikega deleža lastniških stanovanj v Sloveniji (Lagonja, 2010) stanovanja v istem bloku zelo različno vzdrževana. Vse to se odraža v heterogenosti nepremičninskega trga. Podobno velja za mnoge nepremičninske trge v Evropi (Renigier-Bilozor, Janowski in Walacik, 2019), zato bodo rezultati raziskave zanimivi za širšo mednarodno raven. Renigier-Bilozor, Janowski in Walacik (2019) so za analizo takšnega trga uporabili metode rudarjenja podatkov.

V raziskavi smo za obravnavanje heterogenega nepremičninskega trga za območje celotne države uporabili metodo generaliziranih aditivnih modelov. Mnoge evropske države podatkov o trgu nepremičnin ne spremljajo sistematično (Twaroch et al., 2015), zaradi česar je izgradnja modela množičnega vrednotenja izredno zahtevna. Analiza trga nepremičnin na ravni celotne države se tako naslanja na podatke, ki jih o prodajah zbirajo nepremičninske agencije, banke, spletni portali z oglasi za prodajo in najem nepremičnin (Helbich et al., 2014; Twaroch et al., 2015). Slovenski primer sistema množičnega vrednotenja nepremičnin, v okviru katerega se sistematično zbirajo podatki o trgu nepremičnin (glej Ulbl, Štembal in Smodiš, 2016; Ulbl in Smodiš, 2019), omogoča sistematično analizo tako heterogenega trga nepremičnin. Takats (2012) navaja, da je heterogenost nepremičnin na ravni države resnično zanimivo področje prihodnjega raziskovanja.

Namen raziskave je preveriti, ali je mogoče hkrati upoštevati spremenljivke, za katere predvidevamo, da imajo največji vpliv na ceno stanovanja. Mednje spada predvsem lokacija nepremičnine (Peterl, 2017; Orford, 1999). Naslednji bistven vpliv na ceno stanovanjskih nepremičnin imajo trenutek prodaje nepremičnine ter njene fizične lastnosti (Čeh, Viitanen in Peruš, 2012; Owusu-Ansah, 2012; Arribas et al., 2016; Ulbl, Štembal in Smodiš, 2016; Abdullahi, Usman in Ibrahim, 2018; Čeh et al., 2018). Tudi Nahtigal in Grum (2014) sta kot najpomembnejši vpliv na ceno stanovanj opredelila lokacijo, in sicer mikrolokacijo, sledil je vpliv fizičnih lastnosti stanovanj, med katerimi sta se kot najpomembnejša izkazala velikost in starost. Kot pomembni so se pokazali še družbeno-ekonomski dejavniki ter dejavniki funkcionalne in relativne velikosti stanovanja, vendar je bil njihov vpliv bistveno manjši (Nahtigal in Grum, 2014).

V raziskavi bomo lokacijo upoštevali s podatkom o položaju stavbe v referenčnem prostorskem sistemu (položajne koordinate centroida stavbe, v kateri je stanovanje). Trenutek prodaje je podatek, ki je v evidenci trga nepremičnin (v nadaljevanju: ETN) naveden kot datum sklenitve pogodbe. Glede lastnosti nepremičnine se bomo osredotočili na spremenljivki, ki na podlagi lastnih izkustev in pregledane literature med parametri lastnosti kvantitativno najbolj pojasnita ceno nepremičnin; to sta velikost stanovanja in starost stavbe. Velikost stanovanja v tem prispevku opredelimo enako, kot ga obravnava geodetska uprava v sistemu množičnega vrednotenja. Velikost stanovanja je tako določena kot vsota bivalne površine, površine poslovnega prostora, shrambe, sušilnice oziroma pralnice, 25 % površine garaže oziroma garažnega parkirnega prostora, 3 % površine kleti, 20 % površine teras, balkonov in lož, 50 % prostorov z omejeno uporabo ter 70 % nedokončanih prostorov (EMV, 2020). Starost je upoštevana s podatkom o letu izgradnje stavbe. Vpliv let obnov na ceno stanovanja v tej analizi ni upoštevan. Glede na vse navedeno domnevamo, da bodo na ceno stanovanj v Sloveniji vplivali tako lokacija kot tudi velikost in starost stanovanja ter trenutek prodaje po različnih cenovnih območjih.

V članku so najprej predstavljeni uporabljeni podatki in metodologija. Osrednji del se nanaša na predstavitev rezultatov vrednotenja dveh modelov, ki smo ju razvili za namen ocenjevanja posplošene tržne vrednosti stanovanj. Dodatno je izvedena primerjava rezultatov modelov z aktualnim modelom množičnega vrednotenja v Sloveniji. Članek zaključujemo s sklepnimi ugotovitvami.

2 UPORABLJENI PODATKI

Analizo trga stanovanj smo opravili na podatkih slovenskega nepremičninskega trga. GURS sistematično spremlja dosežene pogodbene cene nepremičnin na slovenskem trgu od začetka leta 2007. Podatke o sklenjenih kupoprodajnih poslih z nepremičninami, za katere je obračunan davek na promet nepremičnin (DDV/DPN), posreduje Finančna uprava Republike Slovenije (FURS), medtem ko prodajalci posredujejo podatke za posle, za katere se obračuna davek na dodano vrednost (DDV). Ti podatki se hranijo in vzdržujejo v evidenci trga nepremičnin (ETN, 2020). Geodetska uprava podatke iz ETN preverja in jih po potrebi popravi na dejansko stanje v prostoru, po potrebi jih tudi dopolni s podatki iz različnih evidenc. Tako se podatki iz ETN najprej sistemsko dopolnijo s podatki registra nepremičnin (REN), katastra stavb in zemljiškega katastra. Dodatno se tržnost posla (povezanost pogodbenih strank) posamično preverja na podlagi vseh razpoložljivih evidenc (na primer podatkov Agencije Republike Slovenije za javnopravne evidence in storitve – AJPES, centralnega registra prebivalstva) ter različnih podatkov, ki jih je mogoče preveriti na spletu (članki na temo prodaje nepremičnine, dostopni oglasi za prodajo na prodajnih portalih, oglasi za najeme stanovanj na spletnih straneh ipd.). Vsaka transakcija se preveri tudi s terenskim ali še z virtualnim ogledom v rešitvi *Google Street View*. Transakcija se torej preveri na podlagi vseh dostopnih podatkov, po potrebi se popravi tržnost posla, velikost nepremičnine, leto izgradnje, kakovost stanovanja. Prav tako se preveri, ali bi bila cena lahko špekulativno znižana ali zvišana. Vse to se presoja v okviru postopka pregleda prodaj. Pri tem se vsaka transakcija glede na stanje, v kakršnem je bila prodana, ustrezno opredeli. Preverjajo se pogoji za tržno prodajo in podatki o nepremičninah, ki so predmet kupoprodajnega pravnega posla. Preverjeni in dopolnjeni podatki o nepremičninah, ki so predmet kupoprodajnega pravnega posla, se povezani z ETN interno shranjujejo. Analizo smo opravili za podatke prodaj stanovanj v Sloveniji v obdobju od 1. 1. 2015 do 31. 12. 2019, ki so bili predhodno preverjeni in dopolnjeni ter opredeljeni kot ustrezni za uporabo v modelu (ustrezne transakcije). Kot ustrezne transakcije stanovanj se za to analizo upoštevajo transakcije na sekundarnem trgu, ki so tržne, katerih gradnja je končana in katerih kakovost ustreza populaciji vseh nepremičnin. Skupno število tako ustreznih prodaj stanovanj je 35.309 (preglednica 1). Vsi izračuni v tem prispevku so izvedeni na teh podatkih.

Preglednica 1: Opisne statistike uporabljenih podatkov o trgu stanovanj.

	Minimum	1. kvartil	Mediana	Povprečje	3. kvartil	Maksimum
Pogodbena cena [€]	3.500	53.000	80.000	98.986	127.897	1.150.000
Velikost [m^2]	15,00	41,44	55,24	58,21	69,76	705,00
Leto izgradnje	1435	1965	1978	1975	2003	2019

Vir podatkov: ETN (2020), lastni izračuni.

Preglednica 2: Opisne statistike uporabljenih podatkov, ustreznih za nadaljnje analize.

	Minimum	1. kvartil	Mediana	Povprečje	3. kvartil	Maksimum
Pogodbena cena [€]	3.500	53.000	80.000	98.954	127.841	695.000
Velikost [m^2]	15,00	41,44	55,24	58,16	69,75	230,00
Leto izgradnje	1435	1965	1978	1975	2003	2019

Vir podatkov: ETN (2020), lastni izračuni.

Preglednica 1 prikazuje, da je med podatki tudi stanovanje, veliko 705 m^2, kar najbrž ni stanovanje, temveč hiša. Zaradi takih napak izločimo prodaje stanovanj, večjih od 300 m^2 (tri takšne prodaje). Prav tako izločimo prodaje, pri katerih je cena presegala 1.000.000 € (ena takšna prodaja). Predpostavljamo, da gre za napako pri evidentiranju nepremičnin ter pregledu podatkov o prodajah. Skupno število analiziranih stanovanj se tako zmanjša za 4, in sicer na 35.305 (preglednica 2).

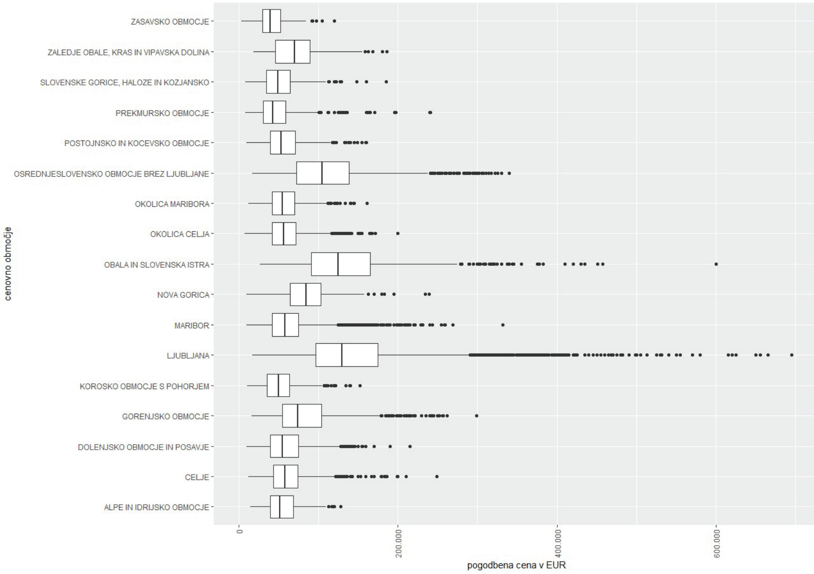
Pogodbena cena stanovanj se je gibala med 3.500 € in skoraj 700.000 €. Cena 3.500 € se za stanovanje zdi nerealna, zato so bile preverjene prodaje stanovanj z nižjo ceno od 5.000 €. Ugotovljeno je bilo, da so prodaje takšnih stanovanj tri, ena iz leta 2016, ena iz 2018 in ena iz 2019. Vsa so velika le 15,9 m^2 in so v istem bloku v Trbovljah. Kljub zelo nizki ceni teh prodaj iz analize ne izločimo, ker so ustrezne. Mediana cen stanovanj znaša 80.000 €, povprečje pa skoraj 100.000 €. Prodana so bila stanovanja, velika med 15 m^2 in 230 m^2, z mediano 55 m^2 ter povprečjem 58 m^2. Vzorec prodaj je s stališča velikosti stanovanj reprezentativen za populacijo vseh stanovanj v Sloveniji, kjer mediana za velikost znaša 53,6 m^2 (EMV, 2020). Prodana so bila stanovanja, zgrajena med letoma 1435 in 2019, s povprečjem leta izgradnje v letu 1975 ter mediano 1978. Mediana za leto izgradnje prodanih stanovanj v populaciji znaša 1975 (EMV, 2020). Vzorec prodaj je tako tudi s stališča letnice izgradnje reprezentativen za populacijo vseh stanovanj v Sloveniji.

Ekonomska življenjska doba stanovanj je približno 80–100 let (Polajnar, 2006), kar pomeni, da so v letu 2020 ekonomsko upravičene le stavbe, mlajše od leta 1920. Leto izgradnje zaradi tega popravimo tako, da vsem stavbam, ki so zgrajene pred letom 1900, pripišemo korigirano leto izgradnje 1900, saj morajo biti redno vzdrževane, da so še vedno uporabne. Cenovna območja, torej območja, za katera predpostavljamo enake silnice povpraševanja in ponudbe, so v nadaljevanju predstavljena na sliki 3. Preglednica 3 navaja opisne statistike po cenovnih območjih. Slika 1 prikazuje opisne statistike z okvirji z ročaji za cene po cenovnih območjih.

Preglednica 3: Opisne statistike prodaj stanovanj v Sloveniji po cenovnih območjih za obdobje od 1. 1. 2015 do 31. 12. 2019.

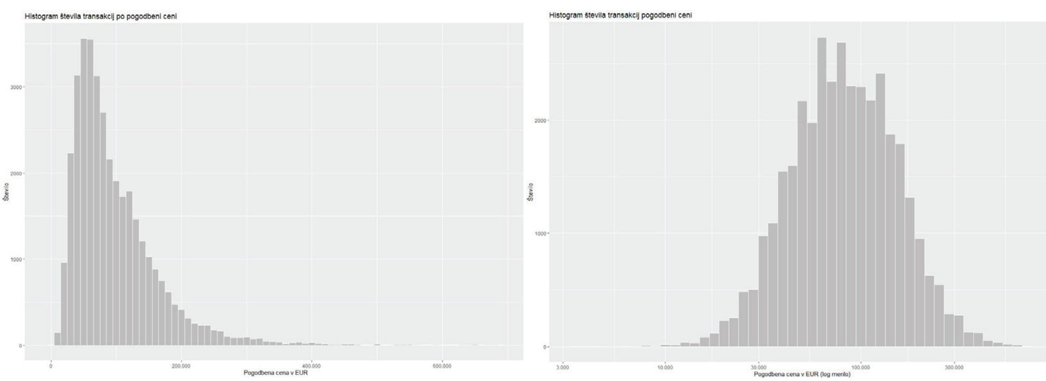
Oznaka cenovnega območja	**Število prodaj**	**Mediana cene [€] (zaokroženo na 1000)**	**Povprečje cene [€] (zaokroženo na 1000)**	**Mediana velikosti [m^2]**	**Mediana leta izgradnje**
Alpe in idrijsko območje	359	52.000	55.000	53,1	1974
Celje	1.382	58.000	62.000	51,8	1971
Dolenjsko območje in Posavje	1.759	55.000	59.000	51,8	1978
Gorenjsko območje	2.016	74.000	83.000	50,6	1977
Koroško območje s Pohorjem	927	50.000	52.000	52,9	1975
Ljubljana	10.204	130.000	147.000	55,7	1977
Maribor	4.376	58.000	64.000	52,0	1971
Nova Gorica	518	85.000	86.000	57,0	1975
Obala in slovenska Istra	3.193	125.000	136.000	55,1	1989
Okolica Celja	2.133	56.700	60.000	54,1	1977
Okolica Maribora	813	55.000	57.000	53,8	1985
Osrednjeslovensko območje brez Ljubljane	3.690	105.000	114.000	56,4	2001
Postojnsko in kočevsko območje	959	53.000	57.000	54,1	1973
Prekmursko območje	526	43.000	52.000	51,7	1977
Slovenske gorice, Haloze in Kozjansko	1.068	49.000	52.000	54,0	1977
Zaledje Obale, Kras in Vipavska dolina	590	70.000	72.000	55,4	1978
Zasavsko območje	792	40.000	42.000	52,0	1969

Vir podatkov: ETN (2020), lastni izračuni.



Slika 1: Okvirji z ročaji za ceno po cenovnih območjih (vir podatkov: ETN (2020), lastni izračuni).

Najvišje cene stanovanj so v cenovnem območju Ljubljana, ki obsega območje Ljubljane znotraj obroča obvozne avtoceste. To je tudi območje z največ stanovanji in posledično največ prodajami v Sloveniji. Po cenah sledita Obala s slovensko Istro ter okolica Ljubljane, ki pa ima v strukturi prodanih stanovanj veliko novejših stanovanj (mediana je leto 2001). Medsebojno so primerljive cene na gorenjskem območju, v Novi Gorici ter zaledju Obale, na Krasu in v Vipavski dolini. Prav tako so medsebojno primerljive cene v Mariboru, Celju, njunih okolicah ter na dolenjskem območju. Ostala območja imajo primerljivo nižje pogodbene cene. Porazdelitev pogodbene cene kot odvisne spremenljivke prikazuje slika 2.



Slika 2: Histogram števila transakcij po pogodbeni ceni: (1) osnovni podatki (levo) in (2) logaritmirani podatki (desno) (vir podatkov: ETN (2020), lastni izračuni).

Porazdelitev pogodbene cene kaže na asimetrijo podatkov, zato podatke prikazujemo tudi v logaritemski skali (slika 2, desno).

3 METODOLOGIJA RAZISKAVE

Za izgradnjo modela množičnega vrednotenja nepremičnin smo uporabili pristop generaliziranih aditivnih modelov (GAM), kjer kot odvisna spremenljivka nastopa pogodbena cena stanovanj (*pog_cena)*, pojasnjevalne spremenljivke pa so lokacija, podana z ravninskima koordinatama centroida stavbe v državnem referenčnem koordinatnem sistemu (*x*, *y*), čas prodaje stanovanja (*time*), korigirano leto izgradnje (*leto_izg_cor*) ter velikost stanovanja (*izmera_pop*). Cena v modelu zaradi porazdelitve cen stanovanj (slika 2) nastopa v logaritmični transformirani obliki. Tudi pojasnjevalne spremenljivke so transformirane, za kar so uporabljeni zlepki.

V raziskavi sta uporabljeni Gaussova in gama porazdelitev odvisne spremenljivke ter generalizirani aditivni modeli z zlepki. Po Wood (2010) poteka izbira parametrov glajenja za potrebe izračuna zlepkov po dveh skupinah kriterijev. V prvi (asimptotične metode) se poskuša čim bolj zmanjšati napaka napovednega modela z optimizacijo kriterijev, kot so Akaikejev informacijski kriterij (AIC), navzkrižna kontrola ali posplošena navzkrižna kontrola (GCV) (Craven in Wahba, 1979). Druga skupina obravnava gladke funkcije kot naključne učinke (Kimeldorf in Wahba, 1970), tako da so parametri glajenja parametri variance, ki jo je mogoče oceniti s cenilko največjega verjetja (angl. *maximum likelihood* oziroma *ML* po Anderssen in Bloomfield, 1974) ali omejeno cenilko največjega verjetja oziroma generaliziranega maksimalnega verjetja (*REML*/*GML*; Wahba, 1985). Izkaže se, da GCV razvije več minimumov ter poda bolj variabilne parametre glajenja (Wood, 2010). Predoločenost modela kaznuje le šibko, pri čemer je minimum glede na variabilnost vzorca pri glajenju nizek. To lahko vodi do predoločenosti modela. REML na drugi strani predoločenost močneje kaznuje, zaradi česar glede na spremenljivost vzorca podaja izrazitejši optimum.

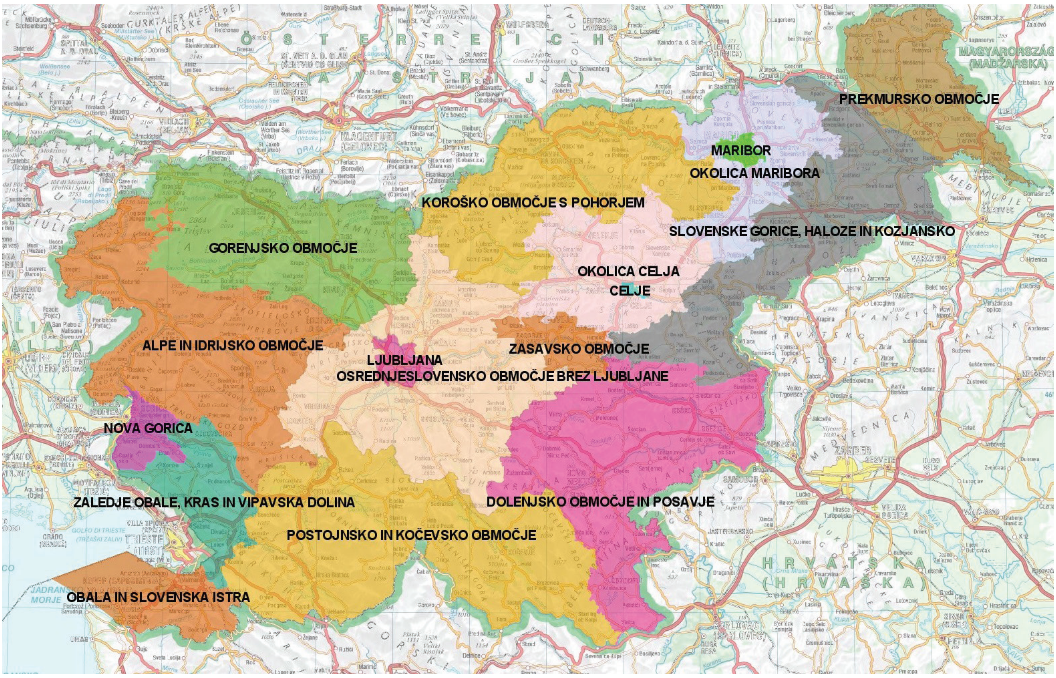
Ekstremnemu (pod)glajenju se je mogoče izogniti z uporabo sintetične mere primernosti, kot je Akaikejev informacijski kriterij AIC (Hurvich, Simonoff in Tsai, 1998), vendar v praksi uporaba nizkih do vmesnih rangov za parametre glajenja zavira prekomerno določenost, zaradi česar AIC ponuja le redke dodatne koristi glede na GCV. Večja odpornost proti predoločenosti, manjša variabilnost parametrov glajenja in zmanjšana tendenca k več minimumom dajejo prednost metodama REML in ML pred metodama GCV in AIC. Te prednosti pa morajo biti tehtane s tem, da sta metodi REML in ML v primerjavi z GCV in AIC manj zanesljivi. Zaradi vsega navedenega je za optimalno določitev posameznega modela ob iteracijah pri iskanju najboljših parametrov uporabljena metoda fREML (angl. *fast stable restricted maximum likelihood*), za primerjavo med končnimi modeli pa se uporablja odstotek pojasnjene deviance oziroma variabilnosti odvisne spremenljivke (Greenacre in Primicerio, 2014) ter AIC. Pojasnjena deviacija predstavlja generalizacijo determinacijskega koeficienta za primer generaliziranih modelov, kot sta GLM, to je generalizirani linearni model, ter GAM, to je generalizirani aditivni model. Služi primerjavi razlik med modeli glede na njihovo sposobnost pojasnjevanja variabilnosti odvisne spremenljivke. Poenostavljena enačba modela se glasi (1):

$$log(pog\_cena) \approx f_{t\_co}(time,\ ime\_co) + f_{xy}(x, y) + f_i(izmera\_pop) + f_l(leto\_izg\_cor) + \varepsilon \qquad (1)$$

Pri tem so:

- f_i in f_l zlepka po vplivu velikosti in letu izgradnje,
- f_{t_co} zlepki za vpliv datuma prodaje po posameznem cenovnem območju ter
- f_{xy} dvodimenzionalni zlepek, ki odraža vpliv lokacije na vrednost stanovanja.

Cenovna območja (slika 3) so oblikovana tako, da se v njih predvidevajo enake silnice ponudbe in povpraševanja, razvite na podlagi večletnega spremljanja nepremičninskega trga v Sloveniji (Ulbl, Štembal in Smodiš, 2016).

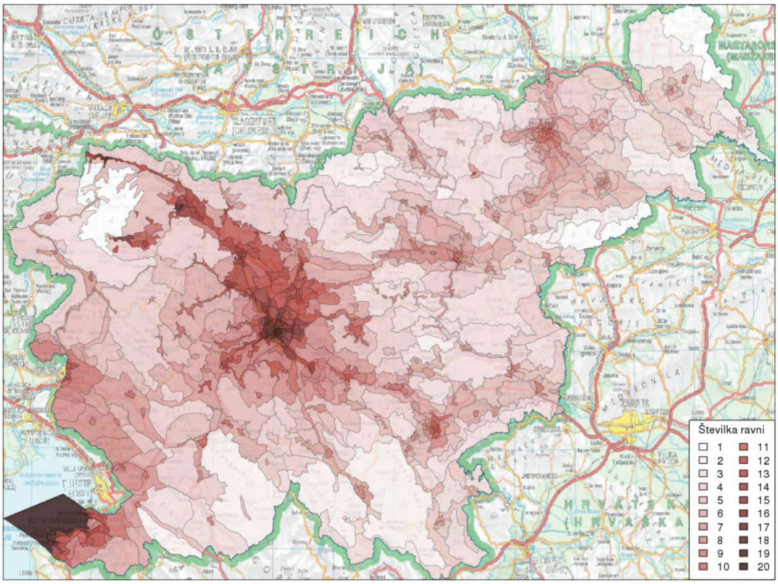


Slika 3: Prikaz cenovnih območij trga stanovanj v Sloveniji (vir podatkov: ETN (2020), lastni prikaz).

Rezultate za trende tako izračunanih modelov bomo za vsako cenovno območje primerjali s trendi, izračunanimi z metodo SPAR, ki jo pri delu uporablja geodetska uprava za določitev vpliva datuma prodaje na ceno stanovanja. Metoda SPAR (angl. *sale price appraisal ratio*) se v sistemih množičnega vrednotenja uporablja tudi na Novi Zelandiji, Švedskem, Danskem ter Nizozemskem (Vries et al., 2009). Bourassa, Hoesli in Sun (2006) so jo predstavili kot metodo za oblikovanje indeksov cen nepremičnin. Pri metodi SPAR se za izračun indeksa cen nepremičnin upošteva kvocient med ceno nepremičnine in predhodno ocenjeno vrednostjo.

Kot navaja €ostat (2013), se metoda SPAR nanaša na vse podatke o kupoprodajnih poslih in je uporabna le tam, kjer so na voljo zanesljive ocenjene vrednosti nepremičnin. Pri tem je na podlagi že oblikovanih modelov vrednotenja prodanim nepremičninam pripisana izračunana vrednost v skladu z veljavnim modelom. Po podatkih evidence modelov vrednotenja (EMV, 2020) je posplošena tržna vrednost za stanovanja, na podlagi katere GURS izračunava trend po metodi SPAR, zmnožek ocenjene vrednosti iz vrednostne tabele (kjer se upošteva vpliv lokacije, velikosti in leta izgradnje), faktorja obnov, faktorja lastnosti, faktorja dodatnih prostorov, faktorja lege ter faktorja oddaljenosti od linijskih objektov gospodarske javne infrastrukture. Vsi podatki o izračunu vrednosti so predstavljeni na portalu Evidenca modelov vrednotenja pod zavihkom opis in kakovost modela, starost in velikost ter kakovost (EMV, 2020).

Pri prikazih vpliva datuma na ceno nepremičnine v modelu, ki vse spremenljivke upošteva hkrati, so za primerjavo dodani tudi prikazi trendov, ki jih geodetska uprava uporablja za časovno prilagajanje transakcij (metoda SPAR z metodo drsečih sredin, pri čemer je kot sredina uporabljeno geometrično povprečje razmerij med ceno in izračunano vrednostjo za obdobje prodaj 120 dni pred in 90 dni po datumu, za katerega se trend računa). Vpliv lokacije smo v modelu upoštevali s prostorskim zlepkom in ga primerjali z vrednostnimi conami, objavljenimi v evidenci modelov vrednotenja (slika 4). Geodetska uprava v okviru množičnega vrednotenja nepremičnin vpliv lokacije namreč upošteva na podlagi vrednostnih con (Ulbl, Štembal in Smodiš, 2016; Ulbl in Smodiš, 2019). To so območja, znotraj katerih imajo nepremičnine z enakimi opisnimi podatki enako posplošeno vrednost. Vsaki vrednostni coni je pripisana vrednostna raven, ki predstavlja vrednost referenčne enote vrednotenja. Pri stanovanjih je to stanovanje v stavbi z od 6 do 50 stanovanji, veliko je 50 m^2, zgrajeno med letoma 1975 in 1983, ni obnovljeno, nima dvigala, stoji v pritličju ali prvem, drugem ali tretjem nadstropju in ne stoji na vplivnem območju linijskih objektov gospodarske javne infrastrukture. Slika 4 prikazuje vrednostne cone, ki so obarvane glede na vrednostne ravni, pripisane posamezni vrednostni coni.



Slika 4: Prikaz vrednostnih con za stanovanja (vir: EMV, 2020).

4 REZULTATI

V tem poglavju podajamo rezultate analize izračunov. Najprej so predstavljeni rezultati ocenjevanja tržnih vrednosti stanovanj po razvitih modelih in ocenjevanje primernosti modelov, sledi predstavitev rezultatov analize vpliva trenutka prodaje na ceno stanovanj kot predviden pomemben dejavnik na višino transakcijske vrednosti.

4.1 Rezultati ocenjevanja modelov

Za izračun ocenjene vrednosti so uporabljeni generalizirani aditivni modeli. Pri tem je odvisna spremenljivka upoštevana z gama ter z Gaussovo porazdelitvijo. V obeh primerih je uporabljena logaritemska transformacija odvisne spremenljivke.

```
Family: gaussian
Link function: log

Formula:
pog_cena ~ s(time, bs = »cr«, by = as.factor(ime_co), k = 6) +
    s(x, y, bs = »tp«, k = 100) + s(izmera_pop, bs = »cr«,
    k = 20) + s(leto_izg_cor, bs = »cr«, k = 10)

Parametric coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 11.331127   0.001791    6328   <2e-16 ***

Signif. Codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                                                                   edf Ref.df        F  p-value
s(time):as.factor(ime_co)ALPE IN IDRIJSKO OBMOCJE                3.262  3.886    2.707  0.04011 *
s(time):as.factor(ime_co)CELJE                                   1.900  2.359   31.980 5.55e-16 ***
s(time):as.factor(ime_co)DOLENJSKO OBMOCJE IN POSAVJE            2.118  2.617   43.267  < 2e-16 ***
s(time):as.factor(ime_co)GORENJSKO OBMOCJE                       3.192  3.833   71.247  < 2e-16 ***
s(time):as.factor(ime_co)KOROSKO OBMOCJE S POHORJEM              1.559  1.921    6.209  0.00241 **
s(time):as.factor(ime_co)LJUBLJANA                               4.977  5.000 1164.922  < 2e-16 ***
s(time):as.factor(ime_co)MARIBOR                                 3.252  3.899   60.458  < 2e-16 ***
s(time):as.factor(ime_co)NOVA GORICA                             3.265  3.909   14.095 4.95e-11 ***
s(time):as.factor(ime_co)OBALA IN SLOVENSKA ISTRA                4.822  4.984  129.699  < 2e-16 ***
s(time):as.factor(ime_co)OKOLICA CELJA                           3.225  3.869   22.343  < 2e-16 ***
s(time):as.factor(ime_co)OKOLICA MARIBORA                        2.040  2.529   10.071 1.17e-05 ***
s(time):as.factor(ime_co)OSREDNJESLOVENSKO OBMOCJE BREZ LJUBLJANE  4.109  4.654  185.696  < 2e-16 ***
s(time):as.factor(ime_co)POSTOJNSKO IN KOCEVSKO OBMOCJE          1.985  2.457   22.831 6.04e-12 ***
s(time):as.factor(ime_co)PREKMURSKO OBMOCJE                      3.196  3.828    7.430 1.00e-05 ***
s(time):as.factor(ime_co)SLOVENSKE GORICE, HALOZE IN KOZJANSKO   2.100  2.603    4.449  0.00671 **
s(time):as.factor(ime_co)ZALEDJE OBALE, KRAS IN VIPAVSKA DOLINA  1.685  2.093   11.977 4.88e-06 ***
s(time):as.factor(ime_co)ZASAVSKO OBMOCJE                        2.298  2.829    7.567 8.82e-05 ***
s(x,y)                                                          95.162 98.549  680.691  < 2e-16 ***
s(izmera_pop)                                                   11.621 13.468 6532.887  < 2e-16 ***
s(leto_izg_cor)                                                  8.211  8.784  845.058  < 2e-16 ***

Signif. Codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.888   Deviance explained = 88.9%
fREML = -4.0398e+05  Scale est. = 4.9836e+08  n = 35305
```

Slika 5: Rezultati modela, pri katerem odvisna spremenljivka nastopa kot porazdeljena po Gaussovi porazdelitvi (vir podatkov: ETN (2020), lastni izračuni).

Model, v katerem odvisna spremenljivka nastopa z lognormalno porazdelitvijo (Gaussova z logaritemsko transformacijo), pojasni skoraj 89 % variabilnosti odvisne spremenljivke. Vse spremenljivke statistično značilno vplivajo na ceno (slika 5).

```
Family: Gamma
Link function: log

Formula:
pog_cena ~ s(time, bs = »cr«, by = as.factor(ime_co), k = 6) +
    s(x, y, bs = »tp«, k = 100) + s(izmera_pop, bs = »cr«,
    k = 20) + s(leto_izg_cor, bs = »cr«, k = 10)

Parametric coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 1.132e+01  9.868e-04   11474   <2e-16 ***

Signif. Codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
Approximate significance of smooth terms:
                                                                edf Ref.df       F  p-value
s(time):as.factor(ime_co)ALPE IN IDRIJSKO OBMOCJE             4.604  4.923   12.88 1.86e-11 ***
s(time):as.factor(ime_co)CELJE                                2.086  2.584   94.01  < 2e-16 ***
s(time):as.factor(ime_co)DOLENJSKO OBMOCJE IN POSAVJE         3.436  4.084  102.39  < 2e-16 ***
s(time):as.factor(ime_co)GORENJSKO OBMOCJE                    2.972  3.602  150.36  < 2e-16 ***
s(time):as.factor(ime_co)KOROSKO OBMOCJE S POHORJEM           1.000  1.000   70.74  < 2e-16 ***
s(time):as.factor(ime_co)LJUBLJANA                            4.853  4.989  954.08  < 2e-16 ***
s(time):as.factor(ime_co)MARIBOR                              3.950  4.538  271.53  < 2e-16 ***
s(time):as.factor(ime_co)NOVA GORICA                          2.658  3.245   33.35  < 2e-16 ***
s(time):as.factor(ime_co)OBALA IN SLOVENSKA ISTRA             4.381  4.822  131.82  < 2e-16 ***
s(time):as.factor(ime_co)OKOLICA CELJA                        4.242  4.743   49.93  < 2e-16 ***
s(time):as.factor(ime_co)OKOLICA MARIBORA                     2.037  2.527   31.78  < 2e-16 ***
s(time):as.factor(ime_co)OSREDNJESLOVENSKO OBMOCJE BREZ LJUBLJANE  4.009  4.584  237.29  < 2e-16 ***
s(time):as.factor(ime_co)POSTOJNSKO IN KOCEVSKO OBMOCJE       2.112  2.607   69.56  < 2e-16 ***
s(time):as.factor(ime_co)PREKMURSKO OBMOCJE                   3.569  4.203   25.03  < 2e-16 ***
s(time):as.factor(ime_co)SLOVENSKE GORICE, HALOZE IN KOZJANSKO     1.000  1.000   34.96 3.39e-09 ***
s(time):as.factor(ime_co)ZALEDJE OBALE, KRAS IN VIPAVSKA DOLINA    1.000  1.000   60.43 7.78e-15 ***
s(time):as.factor(ime_co)ZASAVSKO OBMOCJE                     3.516  4.160   32.34  < 2e-16 ***
s(x,y)                                                       97.674 98.953 1373.64  < 2e-16 ***
s(izmera_pop)                                                13.395 15.303 7220.64  < 2e-16 ***
s(leto_izg_cor)                                               7.950  8.640 1236.00  < 2e-16 ***

Signif. Codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.879   Deviance explained = 91.1%
fREML = -9334.6  Scale est. = 0.033707  n = 35305
```

Slika 6: Rezultati modela, pri katerem odvisna spremenljivka nastopa z gama porazdelitvijo (vir podatkov: ETN (2020), lastni izračuni).

Model, v katerem odvisna spremenljivka nastopa z gama porazdelitvijo, pojasni več kot 91 % odvisne spremenljivke. Vse spremenljivke imajo ocenjene vrednosti regresijskih koeficientov, ki so statistično značilno različne od nič (slika 6). V preglednici 4 so navedeni rezultati primerjave modelov, pri katerih je bila odvisna spremenljivka modelirana po Gaussovi ter po gama porazdelitvi.

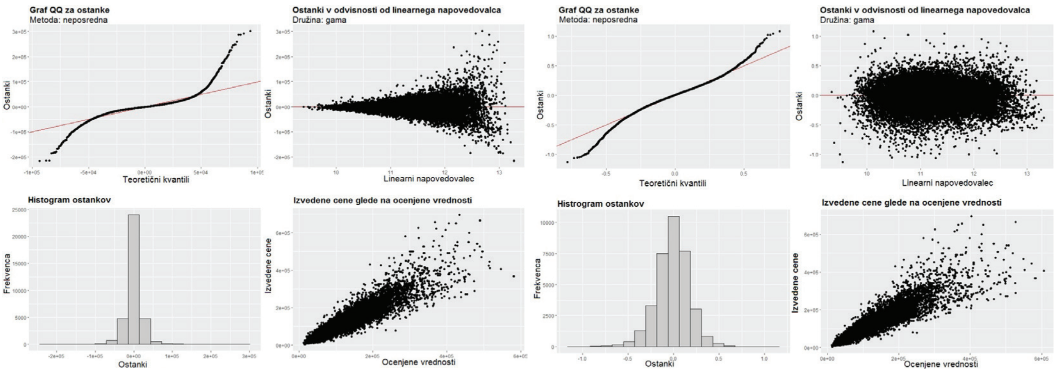
Preglednica 4: Primerjava pojasnjene variabilnosti odvisne spremenljivke in AIC za oba modela.

Model	**Pojasnjena variabilnost odvisne spremenljivke**	**AIC**
Gaussova porazdelitev	88,9 %	807.432,1
gama porazdelitev	91,1 %	780.502,2

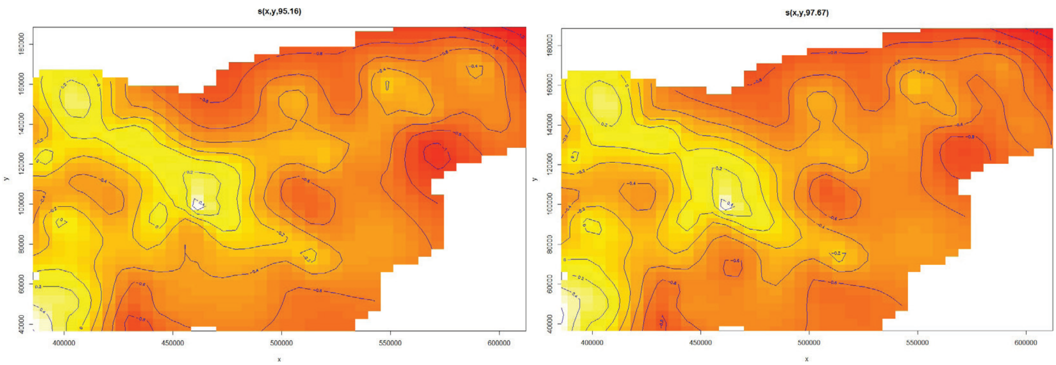
Iz preglednice 4 razberemo, da je model, pri katerem se za odvisno spremenljivko uporabi gama porazdelitev z logaritemsko transformacijo, boljši. Pojasni več variabilnosti odvisne spremenljivke, nižji pa je tudi AIC. Na sliki 7 so prikazani ostanki modelov, pri katerih je bila odvisna spremenljivka modelirana po Gaussovi (4 izrisi zgoraj) ter po gama porazdelitvi (4 izrisi spodaj).

Podobno, kot je navedeno v preglednici 4, v kateri se kot boljši model izkaže model z gama porazdelitvijo, kaže tudi slika ostankov, ki za model z Gaussovo porazdelitvijo odvisne spremenljivke kaže na manj ustrezno porazdelitev ostankov. Ostanki so pri gama porazdelitvi neprimerno bolje porazdeljeni. Pri tem graf QQ za ostanke kaže, da ima tudi model z gama porazdelitvijo odvisne spremenljivke še potencial za izboljšanje.

V nadaljevanju so prikazani rezultati obeh modelov. Prikazani so delni vplivi posamezne spremenljivke na izračunano vrednost. Dodatno je izvedena primerjava z rezultati aktualnega modela množičnega vrednotenja.



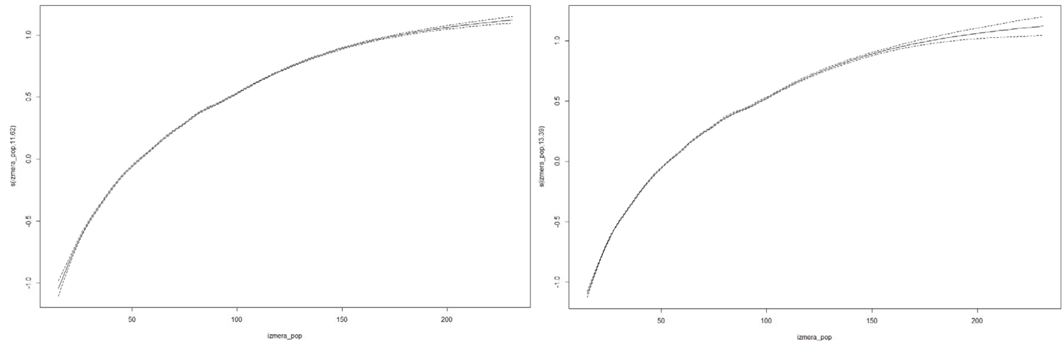
Slika 7: Slika ostankov: porazdelitev odvisne spremenljivke po Gaussovi porazdelitvi (zgoraj levo) in porazdelitev odvisne spremenljivke po gama porazdelitvi (spodaj desno) (vir podatkov: ETN (2020), lastni izračuni).



Slika 8: Parcialni ostanki modela za lokacijo: porazdelitev odvisne spremenljivke po Gaussovi porazdelitvi (levo) in porazdelitev odvisne spremenljivke po gama porazdelitvi (desno) (vir podatkov: ETN (2020), lastni izračuni).

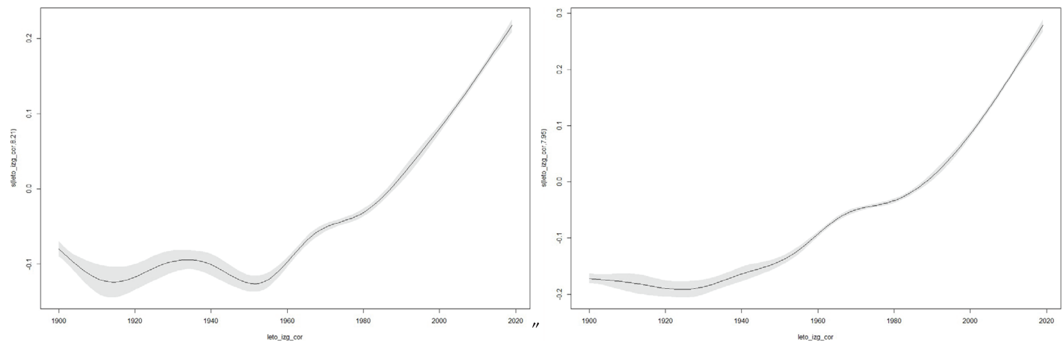
Na sliki 8 so prikazane ocenjene tržne vrednosti stanovanj glede na lokacijo v Sloveniji. Oba modela podata zelo podobne rezultate. Model, ki upošteva porazdelitev odvisne spremenljivke po gama porazdelitvi, kaže na nekaj nižjo ocenjeno vrednost čisto na severovzhodu Slovenije, nekaj razlike je tudi na Koroškem (sever) ter na jugovzhodu (Haloze). Najnižje cene in posledično ocenjene tržne vrednosti so v Prekmurju (rdeča barva) in Halozah, najvišje pa v Ljubljani in na Obali. Visoke cene opazimo tudi na Gorenjskem, nekaj nižje v Novi Gorici. Maribor in Novo mesto imata približno enake cene oziroma vrednosti. Nekaj nižje cene so v Celju in njegovi okolici ter Slovenj Gradcu. Vse to ustreza odnosu med cenami, objavljenimi v polletnem poročilu o slovenskem nepremičninskem trgu (GURS, 2019). Ta rezultat lahko dodatno primerjamo z vrednostnimi conami, objavljenimi v evidenci modelov vrednotenja (slika 4), ki odražajo vpliv lokacije na ceno nepremičnine. Slika 9 prikazuje delni vpliv velikosti na ceno stanovanja. Osenčeni del predstavlja 95-odstotne intervale zaupanja za srednjo vrednost.

Opazimo lahko (slika 9), da bi velikost stanovanja v modelu lahko upoštevali z logaritemsko transformacijo. Oba modela podata zelo podoben rezultat za vpliv velikosti. Opazna je večja variabilnost za večja stanovanja pri gama porazdelitvi odvisne spremenljivke.



Slika 9: Delni ostanki modela za velikost stanovanja: porazdelitev odvisne spremenljivke po Gaussovi porazdelitvi (levo) in porazdelitev odvisne spremenljivke po gama porazdelitvi (desno) (vir podatkov: ETN (2020), lastni izračuni).

Slika 10 prikazuje delni vpliv leta izgradnje na ceno stanovanj.

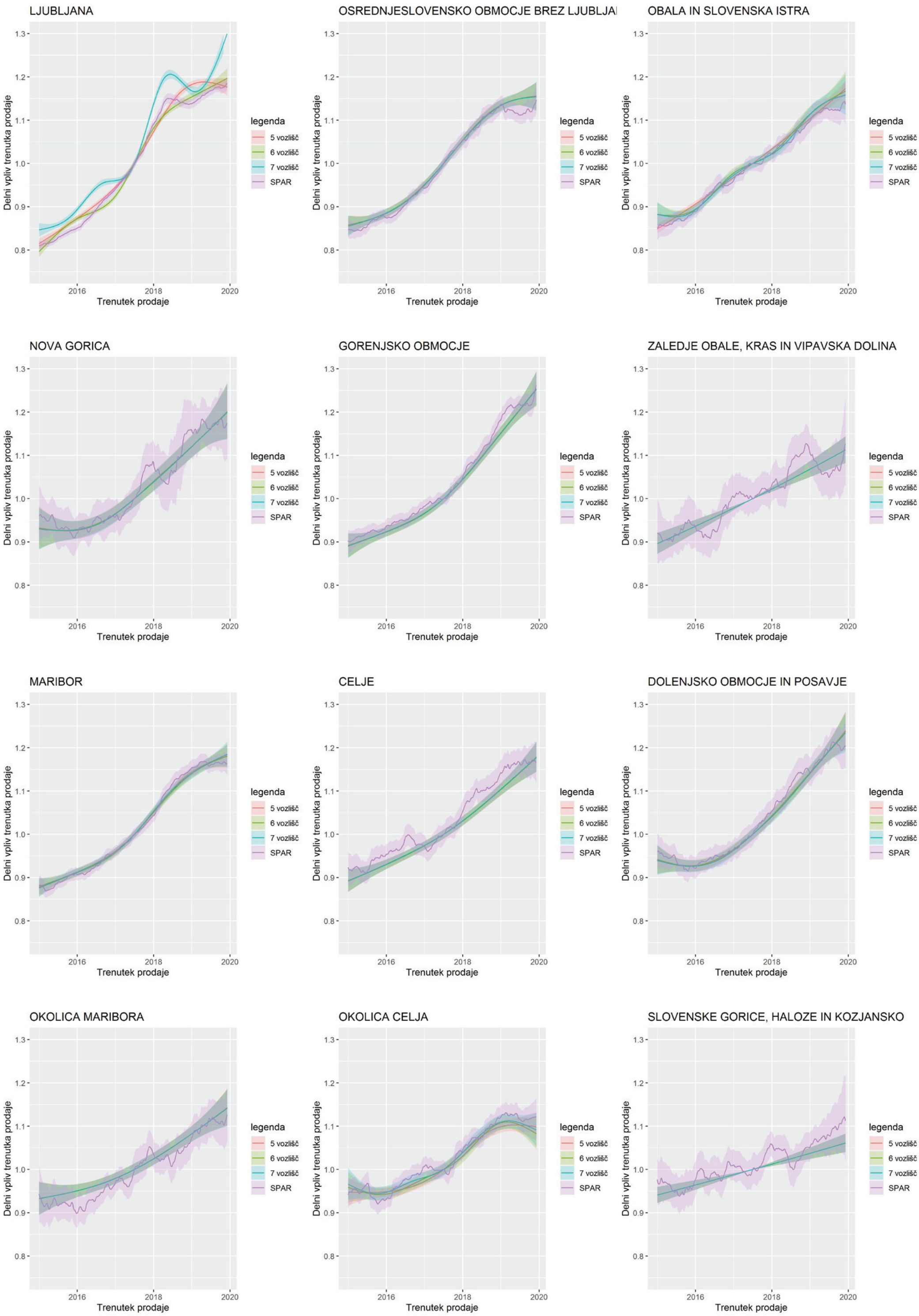


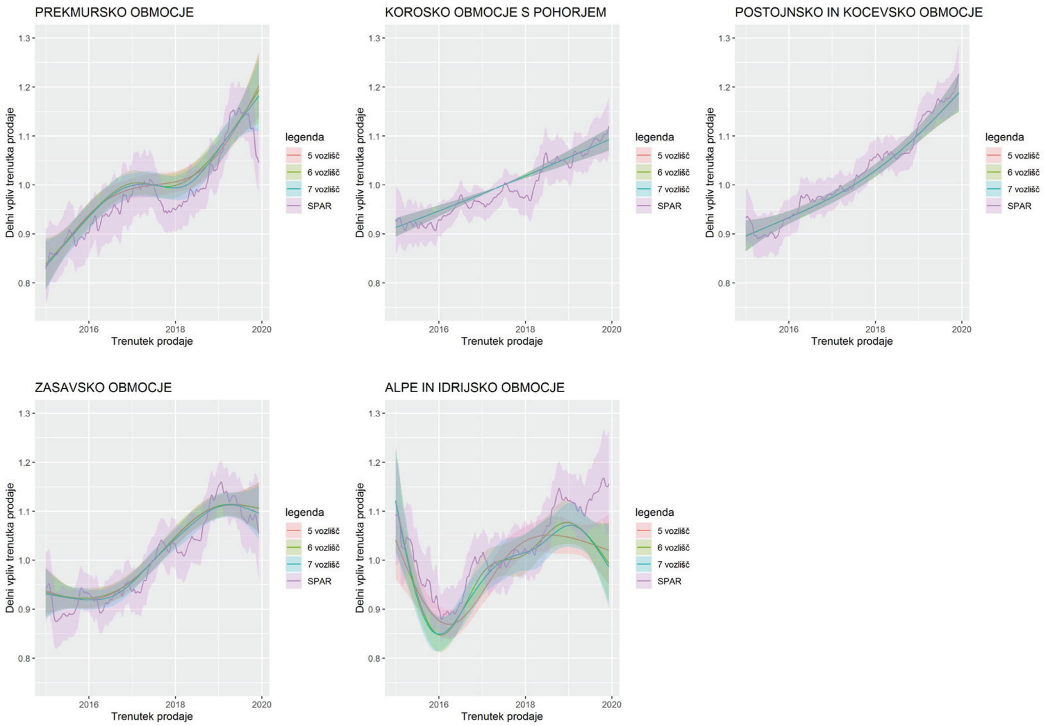
Slika 10: Delni ostanki modela za popravljeno leto izgradnje: porazdelitev odvisne spremenljivke po Gaussovi porazdelitvi (levo) in porazdelitev odvisne spremenljivke po gama porazdelitvi (desno) (vir podatkov: ETN (2020), lastni izračuni).

Najnižje so cene za stanovanja, zgrajena približno leta 1925. Starejša stanovanja imajo nekaj višjo ceno. Cena stanovanj z letnico izgradnje od leta 1925 do približno leta 1955 skoraj linearno narašča, potem je rast cene glede na leto izgradnje nekaj strmejša. Stanovanja, zgrajena med letoma 1970 in 1985, imajo skoraj enake cene. To je tudi obdobje, v katerem je zgrajenih največ stanovanj v Sloveniji (EMV, 2020). Rast cen stanovanj, zgrajenih po letu 1985, je glede na leto izgradnje zelo strma. V tridesetih letih doseže 30 % višjo vrednost. Največjo variabilnost v podatkih je mogoče opaziti za stanovanja, starejša od leta 1955. Cena teh stanovanj je zelo odvisna od vzdrževanja, zaradi česar bi bilo v prihodnje v model smiselno vključiti podatke o vzdrževanju stanovanja.

4.2 Delni vpliv trenutka prodaje na ceno stanovanj

Delni vpliv trenutka prodaje iz modela je za vsako cenovno območje primerjan s trendom, izračunanim po metodi drsečih sredin na podlagi razmerja po metodi SPAR. Pri tem je kot mera za izračun sredine uporabljeno geometrično povprečje. Upoštevani so podatki za razmerja med ceno in izračunano vrednostjo z datumi do 120 dni pred dnevom in 90 dni za dnevom, na katerega je računana sredina. Za potrebe ugotavljanja ustreznega števila vozlišč v zlepkih je bilo sestavljenih več modelov z različnim številom vozlišč (3, 5, 6, 7 in 10). V nadaljevanju (slika 11) so prikazani trendi po cenovnih območjih, primerjaje za 5, 6 in 7 vozlišč ter za trend po metodi SPAR.


LJUBLJANA
OSREDNJESLOVENSKO OBMOCJE BREZ LJUBLJA
OBALA IN SLOVENSKA ISTRA
NOVA GORICA
GORENJSKO OBMOCJE
ZALEDJE OBALE, KRAS IN VIPAVSKA DOLINA
MARIBOR
CELJE
DOLENJSKO OBMOCJE IN POSAVJE
OKOLICA MARIBORA
OKOLICA CELJA
SLOVENSKE GORICE, HALOZE IN KOZJANSKO
Delni vpliv trenutka prodaje
Trenutek prodaje
legenda
5 vozlišč
6 vozlišč
7 vozlišč
SPAR
0.8
0.9
1.0
1.1
1.2
1.3
2016
2018
2020



Slika 11: Trendi cen stanovanj po cenovnih območjih (vir podatkov: ETN (2020), lastni izračuni).

Med modeli z različnim številom vozlišč za vpliv trenutka prodaje v rezultatih ni bistvenih razlik. Največje razlike so se pokazale le v cenovnem območju Ljubljana, in sicer je to cenovno območje z največjim številom podatkov. Izkaže se, da je najbolj smiseln model s šestimi vozlišči.

V vseh cenovnih območjih se izkaže kot smiselna uporaba modela, pri katerem se trenutek prodaje upošteva hkrati z ostalimi spremenljivkami. Trend po metodi SPAR bolj niha, na trgu pa se vrednosti nepremičnin v kratkem časovnem intervalu ne spreminjajo tako hitro. Nihanje je posledica sezonskih trendov ter predvsem majhnega števila podatkov po območjih. Majhno število podatkov ima za posledico veliko občutljivost trenda za vsa odstopanja v podatkih. V nekem trenutku se lahko proda več stanovanj v boljšem stanju, z boljšo opremo, zaradi česar dosežejo višjo ceno, v naslednjem trenutku pa so prodana stanovanja v slabšem stanju, zaradi česar so cene nižje. Ker kakovost stanovanj, vključno z informacijo o prodaji stanovanj z opremo, v podatkovnih zbirkah ni na voljo, v modelu ni upoštevana. Posledično ni upoštevan niti njen vpliv na ceno. Takšne kratkoročne vplive metoda SPAR zazna in jih prikazuje, medtem ko zlepek z manj vozlišči takšnih nihanj ne zazna.

5 SKLEPNE UGOTOVITVE

V prispevku je predstavljen inovativen pristop k modeliranju tržne vrednosti stanovanj. Upoštevani so bili lokacija, velikost, leto izgradnje ter trenutek prodaje glede na lokacijo nepremičnine.

Prispevek se osredotoča na ugotavljanje, ali je mogoče hkrati ugotoviti in upoštevati vse navedene vplive. Geodetska uprava RS pri svojem delu umerjanje modela za zdaj izvaja ciklično. Na podlagi veljavnega modela in cen nepremičnin se za vsako cenovno območje izračuna trend cen nepremičnin. Nato se vse cene popravijo na podlagi faktorja časovne prilagoditve. Temu sledi izračun parametrov modela, predvsem velikosti in leta izgradnje. Na podlagi novih modelov se preveri vpliv lokacije, ki je v modelu opredeljen z vrednostnimi conami in ustreznimi vrednostnimi ravnmi, po potrebi se model popravi. Sledi ponovni izračun trenda. Ta cikel se ponavlja, dokler rezultat ni zadovoljiv. Pri tem se opazuje napaka modela.

Pri pristopu, prikazanem v tem prispevku, se hkrati upoštevajo vplivi naslednjih spremenljivk: lokacije, trenutka prodaje po cenovnih območjih, velikosti in leta izgradnje. Takšen pristop je bistveno bolj ekonomičen in omogoča kakovostnejši nadzor nad rezultati. Izkaže se, da je upoštevanje odvisne spremenljivke, porazdeljene po gama porazdelitvi, boljše od upoštevanja lognormalne porazdelitve. To kažejo tako rezultati izračunov kot tudi grafični prikaz ostankov. Ostanki sicer kažejo, da tudi gama porazdelitev ni optimalna. Tako bi bila v prihodnje smiselna uporaba generaliziranih aditivnih modelov za lokacijo, merilo in obliko (Ulbl, Štembal in Smodiš, 2016).

V prispevku smo predstavili tudi rezultate razvitega modela z aktualnim modelom množičnega vrednotenja v Sloveniji. Izkaže se, da so rezultati vpliva lokacije med modeloma podobni. Prav tako je vpliv trenutka prodaje med modeloma primerljiv za vsa cenovna območja. Analizirano je bilo tudi število ustreznih lomov v zlepku za vpliv trenutka prodaje. Kot optimalno število se je izkazalo šest vozlišč.

Z modelom, pri katerem se upoštevajo vsi navedeni vplivi na tržno vrednost stanovanj, bi lahko ustrezno izboljšali model množičnega vrednotenja v Sloveniji, saj se obravnavane spremenljivke upoštevajo hkrati. Rezultat cikličnega načina, kot ga izvaja GURS, je namreč odvisen od rezultata predhodnih ciklov in subjektivnega mnenja, na podlagi katerega je upoštevan vpliv lokacije v okviru vrednostnih con. Opisani postopek je torej inovativen pristop k določanju enovitega modela na ravni celotne države. Njegova bistvena prednost je hkratno upoštevanje vpliva obravnavanih spremenljivk, upoštevanje lokacije kot zvezne spremenljivke ter zvezno upoštevanje leta izgradnje brez predhodnih predpostavk o ustrezni krivulji vpliva. Velika prednost predlaganega pristopa je zagotovo tudi spremljanje porazdelitve odvisne spremenljivke.

Literatura in viri:

Glej literaturo na strani 62.

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Ulbl M., Verbič M., Lisec A., Pahor M. (2021). Predlog za izboljšavo množičnega vrednotenja nepremičnin v Sloveniji na podlagi pristopa generaliziranih aditivnih modelov. Proposal of real estate mass valuation in Slovenia based on generalised additive modelling approach. Geodetski vestnik, 65 (1), 46-81. DOI: https://doi.org/10.15292/geodetski-vestnik.2021.01.46-81

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