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Residential Property Prices in Croatia

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Abstract

This paper presents the house price index (HPI) based on the data of the Tax Administration of the Republic of Croatia, constructed in cooperation between the Croatian Bureau of Statistics (CBS) and the Croatian National Bank (CNB). The paper also shows how developed econometric models and the Tax Administration database may be used for the (mass) valuation of residential property.

Keywords:
residential property prices, hedonic regression, time dummy index, generalised additive models, two-dimensional spline

JEL:
R30, R32

Note:
The time series constructed in this paper constitute a working version of the price index and may therefore slightly differ from official indices published on the CBS website. This paper also for the first time publishes information on the total number and value of all available residential property transactions in the Republic of Croatia, based on Croatian Tax Administration data. The CBS will regularly publish these data with the HPI.

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Contents

1 Introduction

The monitoring of residential property prices is crucial to the economy, residential property being an important component of household property and overall household wealth. Due to the effect of household wealth on household consumption, residential property prices have a direct impact on aggregate economic activity. Apart from their impact on households, these prices play an important role in the context of financial stability: residential property is typically pledged as collateral for corporate and household borrowing and, as such, influences the amount of credit risk assumed by banks. A growth in residential property prices boosts the collateral value, easing lending conditions and increasing both loan demand and loan supply. And vice versa, a drop in residential property prices decreases the collateral value, adversely affecting the resilience of borrowers and increasing the probability of default and contingent losses in the financial sector. This, in turn, worsens economic conditions and increases a creditor's credit risk.

It is therefore in the interest of all residential property market participants and economic policy makers for residential property price developments to be able to be monitored in a timely and reliable manner. Important in this context is an EU regulation that recognises the importance of monitoring residential property prices and analyses the modalities of incorporating them in general consumer price indices.[1]

The CBS and the CNB in 2015 constructed a *house price index* (HPI) for Croatia, which is methodologically fully harmonised with the mentioned EU regulation and the accompanying Eurostat methodological manual (Eurostat, 2013; Eurostat, 2017). Due to the considerable heterogeneity commonly associated with residential property markets, the monitoring of residential property prices requires a quality adjustment. For that reason it is recommended that *hedonic regressions*[2] be used as a methodological framework for the compilation of real estate price indices. The HPI is constructed based on the comprehensive database of the Ministry of Finance Tax Administration, which comprises all residential property transactions in the Republic of Croatia registered according to the Residential Property Transaction Form. The HPI is the first residential property price index in the Republic of Croatia compiled observing high standards both in the choice of methodology (hedonic regressions) and of transaction data (a relevant comprehensive database of residential property *selling* prices).

Residential property prices in Croatia used to be monitored by two indices: the CNB's *hedonic real estate price index* (HREPI)[3] and the *real estate price index* (REPI) constructed by the web portal *Centar nekretnina*.

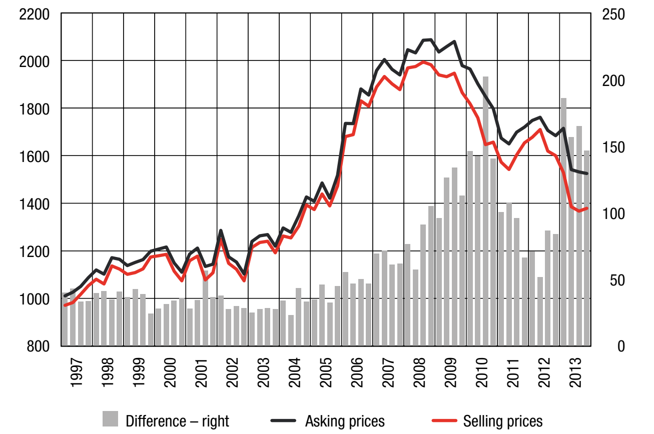
1 Commission Regulation (EU) No 93/2013 of 1 February 2014 laying down detailed rules for the implementation of Council Regulation (EC) No 2494/95 concerning harmonised indices of consumer prices, as regards establishing owner-occupied housing price indices. Council Regulation (EC) No 2494/95 was repealed and replaced by Regulation (EU) 2016/792 of the European Parliament and of the Council.

2 For the examples of hedonic real estate price indices see Kagie and van Wezel (2006), Gouriéroux and Laferrère (2009), Hansen (2006), Sobrino (2014), Hülagü et al (2016). Important theoretical papers include, inter alia, Rosen (1974) and Griliches (1971).

3 This index was based on realised residential property prices collected by *Burza nekretnina*. This database was in 2007 (at the time the index was first constructed) the only available source of data on sufficiently long house price time series. The HREPI was constructed and regularly updated by CNB analysts (for details see Kunovac et al., 2008), but its construction was discontinued in the second quarter of 2015 due to a marked decline in the quality of input transaction data.

The methodological framework of the HPI, based on hedonic regressions, is similar to that of the HREPI. However, the database used for the construction of the HPI is much more comprehensive and more reliably reflects the dynamics of residential property selling (actual/realised) prices in Croatia. As concerns the REPI, this index, unlike the other two, is not constructed according to hedonic methods and so probably insufficiently accounts for the heterogeneity of the residential property market. In addition, as it is based on the data on *residential property asking prices*, it is a *priori* unclear as to what extent it can represent the dynamics of residential property selling prices. Nevertheless, such an index, based on asking prices and methods that do not include a *quality adjustment* for the residential property market, can still credibly represent selling price developments if two important assumptions are met: the dynamics of residential property asking and selling prices should be very similar, and the characteristics of residential property used for the construction of price indices should not exhibit a significant heterogeneity. As regards the first problem, Kunovac et al. (2008) demonstrate that hedonic price indices for the Republic of Croatia based on the asking and selling prices of *Burza nekretnina* (an association of real estate agencies) were in the period before the 2008 crisis indeed very similar, while the difference between them increased significantly in the following period, as clearly illustrated by Figure 1, based on the example of the Zagreb residential property market. This is an indication that price indices based on asking prices might be strongly biased.

Figure 1 Comparison of average residential property asking and selling prices per square meter in Zagreb



Note: The prices are obtained from Burza nekretnina and expressed in euro.
Source: CNB.

This paper has two basic goals. The first is to provide a detailed description of the construction of the HPI and the characteristics of the Tax Administration database used in the process. Given that the monitoring of residential property prices is important for all market participants, for experts and for general public, one can expect that the number of users of these statistics will be large. This is why it is important to document clearly the basic characteristics of the index and make its interpretation as user-friendly as possible. To this aim, the paper first describes the methodological details related to the construction of the house price index and then the index construction process.

The other goal of the paper is to suggest how the developed hedonic econometric models and Tax Administration database can be used for the (mass) *valuation of residential property*. Specifically, the constructed hedonic models enable, among other things, the valuation of the specific characteristics of residential property, such as location and age, providing a natural methodological framework for the price assessment of the residential property with a known combination of these characteristics. The hedonic assessments of residential property prices may primarily be useful for the so-called *comparative method* of residential property valuation.[4] Additionally, in view of the significance of the location of residential property for its price, the basic

4 See Articles 23 and 24 of the Real Estate Valuation Act (Official Gazette78/2015).

specifications of the residential property price model used in the first part of the paper were extended and very precise indicators of the location of residential property – longitude and latitude coordinates – were included in the model. Kunovac et al (2008) show how residential property prices can be successfully assessed by standard hedonic models in which the location, as in the compilation of the HPI, is represented by location dummy variables showing, e.g. the municipality, town, city. The implied assumption is that the contributions of all residential property within one area are proportionally similar. In the domestic literature, Slišković and Tica (2016) criticise this approach, claiming that the location approximation represented by dummy variables only could be deficient. They were the first to define the hedonic model for the domestic residential property market, using spatial variables derived from the microlocation of specific residential property (geographical coordinates data): its distance from the city centre, etc. The authors' basic findings are that prices decline in proportion to the distance of a residential property from the defined city centre and that important information on developments in residential property market prices cannot be obtained if the available data on the residential property's microlocation are not used.[5]

This paper builds on the existing literature on the use of microlocations in hedonic models for the Republic of Croatia. First, using the *General Additive Model (GAM)*, as in Wood et al. (2015) and Hill and Scholz (2017), we employ two-dimensional splines to define the function to estimate the price of a random microlocation in the City of Zagreb as an approximation of selling prices in its surroundings. In the process we explicitly test whether the precision of hedonic models is increased if data on the microlocation are added, and then we analyse the usefulness of such an approach in the valuation of residential property. The main finding in this part of the analysis is that the use of microlocation can indeed be useful for the valuation of residential property, especially when residential property prices change relatively strongly within a narrow geographic area. However, the residential property price model that includes microlocations for the market of the City of Zagreb based on Tax Administration data did not prove to be more precise in assessing the total value of housing stock than the model that approximates the location only by dummy variables. These findings confirm that models for the assessment of residential property market developments should be selected bearing in mind the specific purpose of the model being defined. Most importantly, if the model is used for determining the price of specific residential property, the results show that the available data on its microlocation can be included in the model in a useful way, which is in line with the existing comparative method of estimating residential property prices.

The paper is structured as follows – the second chapter provides a detailed description of hedonic models, that is, of the common methodological framework applied in the construction of real estate price indices. This chapter is technical in nature and is not directly related to the Croatian residential property market. The construction of the HPI for Croatia is specifically dealt with in the third chapter. The fourth chapter analyses the exploitability of the microlocation for the construction of real estate price indices and the residential property valuation process, while the fifth chapter presents the conclusion.

2 Methodology

This chapter presents the main characteristics and difficulties of measuring residential property market dynamics, placing a special emphasis on the description of a basic methodological tool that enables the treatment of the marked heterogeneity of the residential property market: hedonic regressions.

5 On page 41, the authors conclude as follows: "In the context of implications of this research, it is more than obvious that its results indicate the need to improve the current practice of calculating the mean by the econometric approach in the residential property valuation, whether it regards the tax base or the collateral of a financial institution. The common practice of calculating the mean by neighbourhoods or by years results in a one-dimensional analysis of market condition, constantly depriving analysts and decision makers of an important information segment, offering them only partially useful information, taken out of the common, econometrically assessable context."

2.1 Problems related to measuring residential property market prices

Real estate price indices are often constructed applying a measure of averaging the selling prices per square meter: arithmetic mean or median. This is a common strategy for calculating price indices, due to several reasons. First, an average price index is easy to construct and interpret. Second, the requirements regarding data are minimal: the only data necessary are those on the residential property's selling price and floor area. Average price indices are often constructed due to the (un)availability of a more comprehensive database structure, inclusive of specific residential property characteristics. However, these indices suffer from serious deficiencies. Given that residential property units are markedly heterogeneous, that is, exhibit very different characteristics, the available sample of residential property sold sometimes does not adequately represent the whole market, as for example, in the cases when an above-average number of luxury or well-located flats are sold in a certain period. Such an unrepresentative sample causes a bias in an average price index, which then overestimates the real level of residential property prices. Such an index can also underestimate the actual level of residential property prices if a large number of dwellings are sold in a certain period, for example, from a publicly subsidised residential construction programme. If the structure of residential property sold changes over time, such a bias from period to period results in an excessive short-term volatility of the calculated index.

In contrast with the monitoring of prices of most other goods, a task performed by statistical offices, the monitoring of residential property prices is quite challenging. The main reason is obvious: as a rule, residential property is not sold very often, so that the price of a specific residential property cannot be monitored continuously as the prices of many other products. Additionally, the constant quality of residential property is difficult to maintain. For example, even if the same N residential property is sold every quarter over several years, there is no guarantee that the product quality, a necessary precondition for a consistent price index, will remain the same. For example, its quality may change due to the simple reason that the residential property value diminishes because of use. On the other hand, if the residential property is renovated or invested in in some other way its value may grow. In addition, a city district may become more attractive and therefore more expensive, so that the value of a specific residential property in such a neighbourhood may increase although the residential property itself has not been altered.

Accordingly, the construction of a real estate price index is quite a demanding process, which should take into account the differences in the quality of a specific residential property. Standard average price indices could be adjusted to mitigate this problem by stratification, a strategy that divides the available residential property sample into relatively homogeneous subsamples – strata. However, when it comes to the residential property market it is relatively difficult to achieve homogeneity. For example, if the total sample of residential property for a city is stratified into five residential property types, three size classes (small, large and medium-sized), two age classes (newly-constructed and old) and five city neighbourhoods, a special index for $5 \times 3 \times 2 \times 5 = 150$ strata should be calculated. Due to a large number of indices that need to be calculated, this strategy is impractical, unsuccessful and very often results in the construction of unreliable indices. If the sample used for the calculation of a price index is relatively small, it will be further stratified into 150 groups, some of which will contain only several residential property units (or none at all), and the final result will be pointless.

The issue of heterogeneity of residential property is successfully addressed in the microeconomic hedonic demand theory (Rosen, 1974), empirically introduced by hedonic regressions. The main assumption of hedonic models is that the buyer, being attracted by the specific characteristics (attributes) of a specific residential property, approaches it as a group of characteristics. Since it is the characteristics that determine how a buyer will value a residential property, the prices of the individual characteristics have to be determined. Yet there is no market for individual characteristics, and the price of a given characteristic has to be estimated from available data about transactions completed and the characteristics that the properties in question actually possess. Hedonic regressions establish the relationship between the prices and characteristics of residential property, enabling the calculation of the prices of specific characteristics, the so-called *implicit prices*. These implicit prices can be used for various purposes, the most important being the construction of a hedonic real estate price index and its application in residential property price assessment. In addition to their primary purpose in this paper, the defined models may also be used to analyse buyers' preferences in the residential property market.

2.2 Hedonic real estate price indices

The paper goes on to define various types of hedonic real estate price indices. This part of the paper, rather than dealing with the specificities of the Croatian residential property market, aims to present the measurement of residential property prices – its general concept and related problems.

Before the specification of individual types of indices, some common symbols will be introduced. Let us assume that we have a database on residential property sold containing data on the transactions during $T+1$ periods (e.g. quarters). In every period $t \in \{0,...,T\}$ N_t of residential property sold are available. Let us assume that for the residential property $i \in \{1,...,N_t\}$ sold in the period t data are available for the selling price (P_i^t) and its qualitative and location characteristics $(X_{ij}^t, j = 0,...,J)$.[6] The basic hedonic model then connects the price of residential property with its characteristics in the period t:

$$\ln(P_i^t) = \sum_{j=0}^{J} \alpha_j^t X_{ij}^t + u_i^t. \qquad (1)$$

The most frequently applied model is the semi-log model shown here, but in some cases the model is specified in levels.[7] The coefficient α_j^t is the implicit price of the characteristic j in the period t, which is assessed by the ordinary least squares method and labelled as $\hat{\alpha}_j^t$.[8] The coefficients $\hat{\alpha}_j^t$, show, for example, how much value is assigned to the fact that a flat has gas heating, that it is a basement flat or that it is located in the centre. Let us also note that a regressor included in the model is a constant (e.g. $X_{i0}^t = 1$) and that we assume that random errors of the model u_i^t are independent and identically distributed with expectation 0.

Although all basic hedonic price models are based on the same econometric model (linear regression), the associated real estate price indices can be calculated according to various strategies. Each type of hedonic indices has its advantages and disadvantages, so that the final choice of the adequate index depends on its purpose, the availability of data, the character of the residential property market, etc. For example, depending on the character of the market, the implicit prices of specific characteristics can be assessed according to the whole sample or they can be constructed using only the data from a more recent period. Furthermore, some types of indices, once constructed, need to be regularly revised, which is often not a common practice of statistical offices. This has led to the development of index variants that need not be revised, but such a strategy causes another kind of problems.

The following subchapters present the time dummy hedonic index, its rolling window version and the imputation hedonic index. This part of the paper for the most part relies on very informative Eurostat manuals: *Handbook on Residential Property Price Indices* (HRPPI) and *Technical Manual on Owner-Occupied Housing and House Price Indices* (TMOOHHPI).

6 The characteristics X_{ij}^t can be continuous or discrete variables. Continuous variables can be given in levels or logarithmically transformed. Especially important among discrete variables are dummy variables that assume only values of 0 or 1.

7 In the technical sense, logarithmic transformation compresses and equalises the price variance, mitigating the problem of unequal variances in residuals, the so-called heteroscedasticity of error. In addition, the logarithmic transformation of prices provides for a direct and very simple calculation of a price index, directly from regression parameters. The application of the model in price levels $P_i^t = \sum_{j=0}^{J} \alpha_j^t X_{ij}^t + u_i^t$ can be considered if separate data on the land parcel and the floor area are available.

8 Similarly, $\hat{P}_i^t$ will mark the estimated residential property price with the characteristics $(X_{ij}^t, j = 0,...,J)$, as follows: $\hat{P}_i^t = \exp\left(\sum_{j=0}^{J} \hat{\alpha}_j^t X_{ij}^t\right)$. It should be noted that such an approximation of prices is not equal to the conditional expectation of prices $E(P_i^t | (X_{i0}^t, X_{i1}^t, \ldots, X_{iJ}^t))$. Specifically, if u is a random variable from the normal distribution with expectation 0 and variance $(\sigma^2 > 0)$ $(u \sim N(0, \sigma^2))$, the expectation of log-normal random variable $v = \exp(u)$ is $E(v) = \exp(\sigma^2/2)$, which is strictly higher than 1. The consequence is that from (1) follows $E(P_i^t | (X_{i0}^t, X_{i1}^t, \ldots, X_{iJ}^t)) = \exp\left(\sum_{j=0}^{J} \alpha_j^t X_{ij}^t\right) \cdot E(v) > \exp\left(\sum_{j=0}^{J} \alpha_j^t X_{ij}^t\right)$. In addition, $\exp(\hat{\alpha}_j^t)$ is a biased estimator of $\exp(\alpha_j^t)$ as (again due to the characteristics of the log-normal distribution) $E(\exp(\hat{\alpha}_j^t)) = \exp(\alpha_j^t + \frac{1}{2} V(\hat{\alpha}_j^t))$, with $V(\hat{\alpha}_j^t)$ being the variance of the OLS estimator $\hat{\alpha}_j^t$. The bias introduced in price approximation is usually small and often neglected in practice (see Van Dalen and Bode, 2004).

2.2.1 Time dummy hedonic index

In order to calculate the time dummy hedonic index for the period from 0 to T dummy variables are introduced as regressors into model (1) for each period except the initial one. The extended hedonic model is now:

$$\ln(P_i^t) = \sum_{k=1}^{T} \delta_k D_{ik}^t + \sum_{j=0}^{J} \alpha_j X_{ij}^t + u_i^t, \tag{2}$$

with the estimation performed on the whole sample. The introduced dummy variable D_{ik}^t will equal 1 only if $k=t$ (otherwise it is 0), i.e. regressor D_{ik}^t will equal 1 for all residential property sold in the period k, and 0 for the residential property sold in other periods. It should be noted the OLS assessment of model (2) results in the implicit prices of specific attributes of the residential property – $\hat{\alpha}_j$. In contrast with model (1), the implicit prices of attributes are now constant *(time-invariant)* for the whole observed period. In other words, the total change in residential property prices over the quarter is contained in coefficients $\hat{\delta}_k$. Indeed, if we compare the prices of the residential property with an arbitrary combination of characteristics $\mathbf{X}_i = (X_{i0}, X_{i1}, \ldots, X_{iJ})$ sold in the periods 0 and t,, where $t>0$, we can see that:

$$\frac{P_t}{P_0} = \frac{\hat{P}_i^t(\mathbf{X}_i)}{\hat{P}_i^0(\mathbf{X}_i)} = \frac{\exp\left(\hat{\delta}_t + \sum_{j=0}^{J} \hat{\alpha}_j X_{ij}\right)}{\exp\left(\sum_{j=0}^{J} \hat{\alpha}_j X_{ij}\right)} = \exp(\hat{\delta}_t). \tag{3}$$

Now, assuming that $P_0 = 100$, it is easy to obtain from (3) the value of the index for other periods as $P_t = 100 \cdot \exp(\hat{\delta}_t)$. The hedonic price index calculated in this manner is called the time dummy index.[9]

An index constructed in this way has some positive characteristics, which are especially evident when the residential property database for its calculation is relatively small. In addition, the index is very easy to calculate once the hedonic model is defined. The first step is to assess hedonic regression with time dummy variables, whose coefficients then show the value of the base real estate price index. Notwithstanding its simplicity, statistical offices are reluctant to use this index as an official variant of the real estate price index because the whole index needs to be revised every time new data are obtained for a new period. These revisions are required due to the way the index is constructed; all the coefficients of the associated regression, including those associated with time dummy variables, are calculated from all the previous data on residential property transactions. Therefore, with the arrival of new data, all estimates based on the OLS method, including coefficients with time dummy variables, have to be changed. This means that all past values of the index also change. However, in the technical sense, revisions need not be bad procedures, due to the fact that with the arrival of new data, revisions de facto increase the accuracy of the real estate price index.[10] Nevertheless, statistical offices reluctantly use price indices that require regular revisions. The basic time dummy index can therefore be adjusted to avoid revisions, as shown below.

2.2.2 Rolling time dummy hedonic index

The standard time dummy index can be calculated in a version that need not be regularly revised. For example, special hedonic time dummy regressions can be defined for each two successive periods in the sample:

$$\ln(P_i^t) = \delta_s D_{is}^t + \sum_{j=0}^{J} \alpha_j^s X_{ij}^t + u_i^t, \tag{4}$$

where $s \in \{1, \ldots, T\}$ and where for each period s the assessment is performed on the sample $\{s-1, s\}$. The dummy variable D_{is}^t assumes the value 1 if the residential property is sold in the period s, and 0 if it is sold in the period $s-1$. Accordingly, a total of T models are estimated: the first on the data for the periods 0 and 1 and the second on the data for the periods 1 and 2, and so on.

9 It should be noted that, in line with the argumentation from the previous note, the estimator $\exp(\hat{\delta}_t)$ is also biased. For more details about this issue and a possible correction of such a bias, see Hill (2013).

10 The estimator with a lower standard error of estimated parameters is more precise.

These regressions and coefficients with time dummy variables enable the calculation of the price of residential property with an arbitrary combination of characteristics $\mathbf{X}_i = (X_{i0}, X_{i1}, \ldots, X_{iJ})$ between the neighbouring periods s and $s-1$ as follows:

$$\frac{P_s}{P_{s-1}} = \frac{\hat{P}_i^s(\mathbf{X}_i)}{\hat{P}_i^{s-1}(\mathbf{X}_i)} = \exp(\hat{\delta}_s). \tag{5}$$

Naturally, the real estate price index for all periods is easily obtained by the concatenation of the rates of change from particular models. The index thus obtained is called the rolling time dummy index.

If we want to estimate the hedonic model on a larger sample, e.g. for the n periods, special hedonic time dummy models can be estimated on the moving sample $\{s-n+1, s-n+2, \ldots, s-1, s\}$ with the length n, in which by a period being added at the end of the sample $(s+1)$ the data for the period at the beginning $(s-n+1)$ would be removed. The estimated model is similar to model (4), except that in addition to D_{is}^t it also includes additional time dummy variables $D_{i,s-1}^t, \ldots, D_{i,s-n+2}^t$. This again enables the construction of the real estate price index for all periods by concatenation, with the rate of change of prices between the neighbouring periods now calculated as follows:

$$\frac{P_s}{P_{s-1}} = \frac{\hat{P}_i^s(\mathbf{X}_i)}{\hat{P}_i^{s-1}(\mathbf{X}_i)} = \frac{\exp(\hat{\delta}_s)}{\exp(\hat{\delta}_{s-1})}. \tag{6}$$

As seen from (6), the calculation of the index from each model requires only estimated coefficients with time dummy variables for the last two periods in the moving sample.[11]

The advantage of an index based on rolling windows is that it does not require the same regular revisions as the time dummy model constructed based on all available data. In addition, in contrast with the standard model, the parameters of hedonic regressions, i.e. the implicit prices of specific residential property characteristics, are now estimated on a narrower set of data. This can be an advantage or disadvantage, depending on the context. For example, if there are significant changes in the structure of the residential property market, in the sense that some neighbourhoods become more attractive than others, it is advisable to calculate indices based on more recent data. This is because an index that is calculated on the whole sample may become biased because it cannot capture short-term fluctuations caused by changes in buyers' preferences. On the other hand, if relatively few transactions are available for the calculation of the index in a certain period, the use of a moving sample (instead of the whole sample) may introduce unnecessary volatility into the final index. Cases in which the database of available residential property is relatively small are resolved by the application of a moving sample that includes several periods. The conclusion is that the final variant of the index should be chosen depending on the available data and users' demands.

2.2.3 Hedonic imputation index

In contrast with the construction of time dummy indices, the construction of imputation real estate price indices requires that for each period a special hedonic model be developed. Therefore, for each period $t \in \{0, 1, \ldots, T\}$ we estimate the model (1) and get different implicit prices $\hat{\alpha}_j^t$. Using these estimated parameters, we can then assess (impute) the value of the residential property with an arbitrary combination of characteristics in various periods. Let us assume that we have the residential property with the characteristics $\mathbf{X}_i^t = (X_{i0}^t, X_{i1}^t, \ldots, X_{iJ}^t)$ sold in the period t at the price P_i^t. Although the same property was probably not sold in the period $t+1$ too, its value in that period can be assessed using the estimated hedonic model:

$$\hat{P}_i^{t+1}(\mathbf{X}_i^t) = \exp\left(\sum_{j=0}^{J} \hat{\alpha}_j^{t+1} X_{ij}^t\right). \tag{7}$$

We can compare this value with the selling price of the residential property in the period t (P_i^t) in order to assess the change in its price between two periods. Such a comparison of residential property prices is called

11 On the first moving sample $\{0,1,\ldots, n-1\}$ the real estate price index is constructed as in subchapter 2.2.1, using the estimated coefficients with time dummy variables for all periods, and not only for the last two.

single imputation (because the price is imputed only in one period). Residential property prices can also be imputed for the period t and the value $\hat{P}_i^t(\mathrm{X}_i^t)$ can be compared with the value from (7). This procedure is labelled *double imputation*. This method of calculation of price changes, provides, as a rule, a more accurate result than single imputation and it is, according to Hill and Melser (2008), more stable when the problem of the omitted variable bias is present in the model.

If we now restrict our analysis to double imputation only , for each residential property from the period t (a total of N_t we can in a a similar way calculate imputed values in the periods t and $t+1$ and obtain the total change of prices in these two periods applying the geometric mean:[12]

$$\frac{P_{t+1}}{P_t} = \prod_{i=1}^{N_t} \left(\frac{\hat{P}_i^{i+1}(\mathrm{X}_i^t)}{\hat{P}_i^t(\mathrm{X}_i^t)} \right)^{\frac{1}{N_t}} \tag{8}$$

By means of the rates of change, it is easy to obtain the Laspeyres-type real estate price index. Then, the equation on the right reads:

$$\frac{P_{t+1}}{P_t} = \prod_{i=1}^{N_t} \left(\frac{\exp\left(\sum_{j=0}^{J} \hat{\alpha}_j^{t+1} X_{ij}^t\right)}{\exp\left(\sum_{j=0}^{J} \hat{\alpha}_j^t X_{ij}^t\right)} \right)^{\frac{1}{N_t}} = \frac{\exp\left(\sum_{j=0}^{J} \hat{\alpha}_j^{t+1} \frac{1}{N_t} \sum_{i=1}^{N_t} X_{ij}^t\right)}{\exp\left(\sum_{j=0}^{J} \hat{\alpha}_j^t \frac{1}{N_t} \sum_{i=1}^{N_t} X_{ij}^t\right)} = \frac{\hat{P}_i^{t+1}(\bar{\mathrm{X}}^t)}{\hat{P}_i^t(\bar{\mathrm{X}}^t)} \tag{9}$$

where $\bar{\mathrm{X}}^t = \frac{1}{N_t}\sum_{i=1}^{N_t} \mathrm{X}_i^t$ is the average value of the regressor in the period t, that is $\bar{\mathrm{X}}^t$ represents the residential property sold with average characteristics in that period. Consequently, it makes no difference whether indices constructed from the geometric mean of the ratio of imputed values are observed or the ratio of prices of residential property with average characteristics.

The equation (8) uses the characteristics of residential property sold in the period t; however, residential property sold in the later period $(t + 1)$ can be used instead, so the change in prices can be calculated as follows:

$$\frac{P_{t+1}}{P_t} = \left(\frac{\hat{P}_i^{t+1}(\bar{\mathrm{X}}^t)}{\hat{P}_i^t(\bar{\mathrm{X}}^t)} \cdot \frac{\hat{P}_i^{t+1}(\bar{\mathrm{X}}^{t+1})}{\hat{P}_i^t(\bar{\mathrm{X}}^{t+1})} \right)^{\frac{1}{2}}. \tag{11}$$

The index achieved by the growth rates of change from (10) is called the Paasche-type price index.

Finally, as it is not clear whether it is better to use the characteristics of sold residential property from the period t or from $t+1$ for the construction of the index, the Fisher-type index can be calculated as the geometric mean of the Laspeyres and Paasche-type index:

$$\frac{P_{t+1}}{P_t} = \left(\frac{\hat{P}_i^{t+1}(\bar{\mathrm{X}}^t)}{\hat{P}_i^t(\bar{\mathrm{X}}^t)} \cdot \frac{\hat{P}_i^{t+1}(\bar{\mathrm{X}}^{t+1})}{\hat{P}_i^t(\bar{\mathrm{X}}^{t+1})} \right)^{\frac{1}{2}}. \tag{11}$$

An advantage of imputation indices is that estimated implicit prices, calculated separately for each period, reflect well possible changes in buyers' preferences. A potential disadvantage of this method is that that the database of sold residential property should be larger than the databases for other two versions of the time dummy index. Specifically, as regression models are estimated here based only on data from one period, a larger number of sold residential property units is needed for a sufficiently precise estimation of regression parameters.

The Eurostat manuals HRPPI and TMOOHHPI recommend the use of hedonic methods for the construction of real estate price indices, but the final choice of the index version is left to national institutions responsible for the construction of price indices. Hill et al (2017) present a good overview of hedonic models used by the statistical offices of EU member states. The authors use the data for two non-EU cities (Sydney and Tokyo) to construct various hedonic models and give some conclusions. The main conclusion is that indices obtained by various hedonic models used by EU member states' statistical offices are, as a rule, very

12 If the model is estimated in price levels, and not in log levels, the arithmetic mean is used instead of the geometric mean. In this case, Laspeyres, Paasche and Fisher-type indices are derived in the same way as in (9), (10) and (11). For details see Eurostat's HRPPI.

similar. Also, Laspeyres-type or Paasche-type imputation indices exhibited stronger deviations on analysed data sets than other indices. The authors recommend that a time dummy index based on a moving sample that includes four or five quarters is used in cases in which the residential property database for the calculation of the hedonic index is small.

2.2.4 Index aggregation

Real estate price indices usually employ stratified samples, with the available residential property group divided into relatively homogeneous parts – strata. Separate real estate price indices are then constructed on each stratum. These *elementary indices* are then aggregated to obtain higher-level indices, such as an index of newly-constructed residential property or an index of all property prices.

Elementary indices can be concatenated by various methods. Eurostat recommends the one-quarter overlap method[13] for the aggregation of price indices to higher levels. According to this method, index values in the current quarter are linked to the fourth quarter in the previous year using weights from the previous year. More precisely, let $I^i_{t,q}$ mark the value of the real estate price index in the q quarter of the t year in the stratum i, and w^i_{t-1} mark the associated weight for the i stratum, with the number of strata equalling N.[14] The weights are calculated according to the shares in the value of residential property sold in a stratum in the previous year. Indices $I^1_{t,q},\ldots,I^N_{t,q}$ are then aggregated into a higher-level index $I_{t,q}$ by means of the following formula:

$$I_{t,q}=\left(\sum_{i=1}^{N} w^i_{t-1}\cdot\frac{I^i_{t,q}}{I^i_{t-1,4}}\right)\cdot I_{t-1,4} \quad (12)$$

[15,16]

It should be noted that the weights w^i_{t-1} can be calculated in several ways. Let us assume that we have two strata, with the total values of transactions during a quarter in the year $t-1$ marked with x_1,x_2,x_3 and x_4 for the first stratum, and with y_1,y_2,y_3 i y_4 for the second stratum. In addition, the appropriate price indices in the year $t-1$ are marked with $I^1_{t-1,1},I^1_{t-1,2},I^1_{t-1,3}$ and $I^1_{t-1,4}$ for the first stratum, and with $I^2_{t-1,1},I^2_{t-1,2},I^2_{t-1,3}$ and $I^2_{t-1,4}$ for the second stratum. Then weights can be calculated from the formulas $w^1_{t-1}=\frac{x}{x+y}$ and $w^2_{t-1}=\frac{y}{x+y}$, with x and y obtained by one of the following three methods:

1. $$\begin{aligned} x &= x_1+x_2+x_3+x_4 \\ y &= y_1+y_2+y_3+y_4 \end{aligned}$$
2. $$\begin{aligned} x &= (x_1+x_2+x_3+x_4)\cdot\frac{I^1_{t-1,4}}{\frac{1}{4}(I^1_{t-1,1}+I^1_{t-1,2}+I^1_{t-1,3}+I^1_{t-1,4})} \\ y &= (y_1+y_2+y_3+y_4)\cdot\frac{I^2_{t-1,4}}{\frac{1}{4}(I^2_{t-1,1}+I^2_{t-1,2}+I^2_{t-1,3}+I^2_{t-1,4})} \end{aligned}$$
3. $$\begin{aligned} x &= x_1\cdot\frac{I^1_{t-1,4}}{I^1_{t-1,1}}+x_2\cdot\frac{I^1_{t-1,4}}{I^1_{t-1,2}}+x_3\cdot\frac{I^1_{t-1,4}}{I^1_{t-1,3}}+x_4 \\ y &= y_1\cdot\frac{I^2_{t-1,4}}{I^2_{t-1,1}}+y_2\cdot\frac{I^2_{t-1,4}}{I^2_{t-1,2}}+y_3\cdot\frac{I^2_{t-1,4}}{I^2_{t-1,3}}+y_4 \end{aligned}.$$

The first method of weight calculation does not take into account the change of prices during the year,

13 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Short-term_business_statistics_and_(annual)_chain_linking

14 Weights are non-negative numbers normalised in such a way that their sum equals 1, as follows:

$$w^1_{t-1}+w^2_{t-1}+\cdots+w^N_{t-1}=1$$

15 For the first year ($t=0$) the weights are taken as a share in the residential property sold in that year and the formula (12) is reduced to $I_{0,q}=\sum_{i=1}^{N} w^i_0 I^i_{0,q}$. .

16 In Eurostat's documents this formula is termed the Laspeyres-type formula. The name may be explained by the fact that the Laspeyres-type index may be written in a different way (q^i_0 are base period quantities, p^i_0 and p^i_t are the prices from the base period or the arbitrary period t for the commodity i), as follows:

$$\frac{\sum_i q^i_0\cdot p^i_t}{\sum_j q^j_0\cdot p^j_0}=\sum_i\frac{q^i_0\cdot p^i_0}{\sum_j q^j_0\cdot p^j_0}\cdot\frac{p^i_t}{p^i_0}=\sum_i w^i_0\cdot\frac{p^i_t}{p^i_0}$$

where

$$w^i_0=\frac{q^i_0\cdot p^i_0}{\sum_j q^j_0\cdot p^j_0}$$

that is, w^i_0 represents the share in the total spending on the commodity in the base period. The formula (12) is not precisely a Laspeyres-type formula because its weights are taken as the shares in the total spending in the whole year t–1, and not only in the base period, that is, the fourth quarter of the same year.

while the other two methods are in line with the guidelines of Regulation (EU) of the European Parliament and of the Council 2016/792 stating that weights are to be adjusted in such a way as to reflect prices in the fourth quarter.

3 Construction of the house price index (HPI) for the Republic of Croatia

This chapter describes in detail the process of construction of the HPI, analyses the available database for the index and presents the final time series of constructed indices. As the final specification of the index is to a large extent determined by the characteristics of the available database, this issue is given special consideration.

The house price index (HPI) is based on a database that comprises all available data on residential property transactions in Croatia, registered and submitted by the Tax Administration of the Ministry of Finance. These data were originally available for the period from the fourth quarter of 2007 to the third quarter of 2015 so that indices were constructed for that period and for the first time officially released by the CBS at the beginning of 2016.[17] The indices were subsequently extended backwards to the beginning of 2002 as the data of the Tax Administration for that period became available.

The Tax Administration provided a database for the construction of 12 various indices by combining the *age of the residential property* and its location in a certain region. Specifically, Commission Regulation (EU) No 93/2013 obliges statistical bureaus to produce (if possible), in addition to the index for the whole country (total index), special indices for the existing and for new residential property. In addition, due to the regional heterogeneity of the Croatian residential property market, in addition to the index for the whole of Croatia, special indices were constructed for three relatively homogeneous regions: the City of Zagreb, the Adriatic Coast and Other (rest of Croatia).

Because some attributes in the database were unavailable, the indices could not be constructed in an equivalent way for the whole period – from 2002 onwards. There are three typical periods with separate econometric specifications of the indices for which they are constructed:

- 1st period: 1st quarter of 2002 – 4th quarter of 2007;
- 2nd period: 4th quarter of 2007 – 1st quarter of 2012;
- 3rd period: 1st quarter of 2012 – onwards.[18]

The main deficiency of the database in the first period is a very weak representation of the attribute *construction year*. That is why separate indices for the existing and for new residential property could not be constructed there. The second important characteristic of the database is that its quality improved over time as some attributes that had been available only sporadically over time became available in the period from 2012 onwards. These attributes were included in the models in the third period. Indices constructed for three periods were finally combined into a single HPI for the whole period from 2002 onwards. Table 1 shows the availability of constructed indices per period together with the selected type of the hedonic model of each index. The paper further shows the characteristics of the database and the applied models.

Table 1 Availability of house price indices by characteristic period

Index\period	Q1 2002 – Q4 2007	Q4 2007 – Q1 2012	As of Q1 2012 onwards
City of Zagreb – new City of Zagreb – existing	–	✓ (TD)	✓ (RW)

17 Although in the first release the CNB index referred to the periods until the third quarter of 2015, the results shown here will include the fourth quarter of 2015. The official index that includes more recent periods is available at the CBS website.

18 Two neighbouring periods share a common quarter so that indices constructed on two parts of the sample could be combined into one index.

Index\period	Q1 2002 – Q4 2007	Q4 2007 – Q1 2012	As of Q1 2012 onwards
City of Zagreb – total	✓ (TD)	✓ (AG)	✓ (AG)
Adriatic Coast – new Adriatic Coast – existing	–	✓ (TD)	✓ (RW)
Adriatic Coast – total	✓ (TD)	✓ (AG)	✓ (AG)
Other – new Other – existing	–	✓ (TD)	✓ (RW)
Other – total	✓ (TD)	✓ (AG)	✓ (AG)
Croatia – new Croatia – existing	–	✓ (AG)	✓ (AG)
Croatia – total	✓ (AG)	✓ (AG)	✓ (AG)

Note: The method of construction of each index in a specific period is shown in the brackets. TD stands for the index obtained by the time dummy model, RW marks the model obtained by the time dummy model on a moving sample and AG index obtained by the aggregation of lower-level subindices. Indices available at the CBS website are bolded.

3.1 Construction of the HPI

The construction of the HPI included the preparation of data and the testing of various hedonic models for the purpose of choosing an optimal final econometric specification. The preparation of data for the econometric analysis was conducted in several steps. The first step involved selecting only those transactions from the database by which acquirers, that is, buyers, are natural persons purchasing residential property (houses and flats).[19] In the second step the database was cleaned of incorrect and *unrealistic* inputs and numerous corrections were introduced manually. The third step included the construction of the variables included in the econometric analysis. After the phase of data preparation, a large number of hedonic models were tested and final specifications were selected, based on the recommendations from Eurostat manuals and taking into account the specific characteristics of the available database.

3.1.1 Basic characteristics of the Tax Administration database

The minimum required characteristics for the construction of reliable real estate price indices by means of hedonic models include the following: *the location of residential property, the time of sale, the year of construction, the type of residential property* (house or flat), *the floor area* and *the price*. Most difficulties were caused by *the year of construction* and *the type of residential property*. As the Tax Administration database also contains, in addition to standard formatted data, textual descriptions of residential property, this information was used for making corrections to these two variables. However, the presence of the attribute *the year of construction* posed a more difficult problem in earlier transactions (before 2012) and it was satisfactory in transactions carried out later (between 80% and 90%).[20] Once the year of construction was imputed, the residential property was designated as new if its age was less than or equal to five years.[21] The attribute *the type of residential property* was treated in a similar way. Specifically, the Tax Administration database lacks information on the type of residential property for the period prior to 2011, so that it was reconstructed from the textual description. The correct identification of houses and flats is important for several reasons. A trivial reason is that the identification of specific types of residential property enables the analysis only of residential property, excluding business premises or garages. In addition, the price per square meter of houses is generally lower than that of flats and it is therefore important to distinguish between the two, especially when a common hedonic model is used both for houses and flats.

19 In addition to used transactions, the database also contains the transactions of acquirers-legal persons by which they purchased business premises, garages or parking spots.

20 The availability of information on the year of construction is further complicated by the fact that until the end of 2014 it was not possible to establish whether an entry refers the year of construction or the year of remodelling. This was, to a large extent, amended by the information obtained from the textual description of the residential property.

21 In the cases when the year of construction was not available (and could not be imputed from the description of residential property), such residential property was considered as existing.

Figure 2 Croatia divided into three regions (City of Zagreb, Adriatic Coast and Other)

Note: The City of Zagreb is marked red, the Adriatic Coast blue and Other green.
Source: CNB.

Eurostat's HRPPI emphasises the importance of correctly controlling the location in the construction of the real estate price index. This problem was solved on two levels: the territory of the Republic of Croatia was divided into three strata/regions (the City of Zagreb, the Adriatic Coast and Other) and additional location variables were included in the models. The Adriatic Coast region is defined as consisting of 139 municipalities/cities, marked blue in Figure 2. The region Other (rest of Croatia), marked green, comprises all residential property that is not from the City of Zagreb (marked red) and the Adriatic Coast.

As regards the attribute *the floor area*, it should be noted that the Tax Administration database does not contain separate data on the land parcel area and the floor area of the building, but only data on the total area. This may present a problem for houses purchased with a large land parcel, because the price per square meter of the residential property is in such cases unrealistically small. In the process of eliminating outliers, such residential property is often taken out of consideration.

In addition to the mentioned main characteristics of the residential property, the database contains some additional characteristics, but their representation is satisfactory only as of 2012 onwards.

3.1.2 Hedonic models for the HPI for the Republic of Croatia

As stated in the introduction to this chapter, since the Tax Administration database has improved over time, house price indices were constructed according to the described typical time segments and integrated into single indices for the whole observed period.

In view of the relatively small number of residential property units sold in Croatia and the relative advantages and disadvantages of specific hedonic models, time dummy models on a moving sample were chosen for the construction of the indices in the most recent period (from 2012 onwards). The advantages of these models are, among others, that they need not be revised, that they use data from more than one period (which is important for small datasets) and that, which is especially important for our database, the set of variables in each iteration of the calculation of the index need not be the same. This is because, due to the limited number of usable variables in our dataset, satisfactory price indices are obtained only if sufficiently detailed location variables are used.[22] However, this increases the complexity of our models. For example, some specifications require that the model include several hundred location dummy variables whose presence changes over time. Some smaller municipalities and cities are not present in each sample, but larger and more important ones are.[23]

Standard time dummy models were estimated for the period prior to 2012. An advantage of the indices obtained from these models is that they are estimated on a large number of data, that is, with a great precision. The already mentioned problem of the need to revise time dummy indices when new results come in is not relevant here because the residential property data from that period are not used for the calculation of the index value for the period after 2012.[24]

In contrast with indices for other regions, the real estate price index for the City of Zagreb was obtained only from the data on flats; the houses sold in Zagreb were excluded from the analysis. This is not too a restrictive choice: the Zagreb market of flats is the most developed market segment in Croatia and includes most of the transactions carried out in Zagreb. Houses, in addition to being considerably less represented among the residential property estate sold in Zagreb, are characterised by a significant heterogeneity (which cannot be explained by variables included in our hedonic models), which introduces a large amount of noise into our indices. Finally, as already mentioned, transactions of houses are not recorded using separate data on the land parcel area and the floor area of the building, the database containing only data on the total area. This problem was to a certain extent resolved for the other two regions: the Adriatic Coast and Other. The models pertaining to these two regions regularly included an additional dummy variable that assumed the value 1 for houses and 0 for flats, which enabled control for the value of the house floor area (and that of house lots) per square meter being underestimated.

3.1.3 Detection and elimination of outliers

An important step in the process of index construction was the detection of outliers in the available database. The outliers were eliminated automatically, in a two-phase procedure. In the first phase, based on the estimated empirical density function, we eliminated 5% of the cheapest and 5% of the most expensive residential property per square meter. If the lower limit achieved in this manner was unrealistically low, a further

22 Location variables were introduced to the model as dummy variables that identify certain locations. The City of Zagreb was divided into 11 areas in accordance with the locations of Tax Administration offices: Sesvete, Trnje, Medveščak, Susedgrad, Dubrava, Novi Zagreb, Trešnjevka, Črnomerec, Peščenica, Maksimir and Centar. Due to the higher heterogeneity of the Adriatic Coast and Other, more detailed location variables were used for these regions. These regions were divided according to their belonging to a specific city or municipality. As there are 127 cities and 428 municipalities in Croatia (according to the Ministry of Public Administration data), the number of dummy variables defined in this way can be very large.

23 This problem could have been avoided if the model had been evaluated using only the data for more important and larger municipalities and cities. However, in that case a large part of the Tax Administration data would have had to be discarded, which we tried to avoid, bearing in mind the relatively small number of transactions. An alternative strategy would be to group cities and municipalities into larger categories that are represented in each period. However, it is not quite clear how to define the criteria and perform the regrouping.

24 The results are very similar in terms of quality if time dummy regression is replaced by time dummy regression on a moving sample for the period from the first quarter of 2002 to the fourth quarter of 2007, and for the period from the fourth quarter of 2007 to the first quarter of 2012.

requirement was that the price per square meter of residential property should be higher than the predetermined limit.[25] In addition to ensuring the homogeneity of the data set used for the calculation of the index, this enabled us to clean the database from incorrect entries of key variables: the residential property price and floor area. The first phase, which involved the elimination of outliers, was followed by the estimation of preliminary hedonic regressions and the analysis of the residuals of these models. The second phase of the elimination of outliers consisted of the elimination of the transactions in which studentised residuals were in absolute terms higher than 2.[26] It should be noted that the procedure of eliminating outliers described here is rather conservative as it discards a large number of transactions from the dataset. However, due to the large heterogeneity of data, such strict criteria are necessary to ensure an acceptable level of volatility in the final house price indices. This was the only way to isolate important signals about residential property prices, which is required for monitoring the aggregated dynamics at the residential property market, from the available Tax Administration data.

As the Tax Administration delivered the database for two separate periods with their demonstrated specificities (2002 – 2007, and from 2008 onwards), each of the two segments will be analysed below and their results will be shown separately.

3.2 HPI for the period from 2002 to the fourth quarter of 2007

3.2.1 Data preparation

The Tax Administration database for the period from 2002 to 2007 was inferior in quality to the database for the later period. This primarily relates to the poor representation of key attributes, *the year of construction* and the *type of residential property*, as well as to the lack of additional residential property features comprised by the database in the later period. On the other hand, the representation of other key variables, e.g. those on the type of residential property purchaser, location, time of sale, floor area and price, was very high.

The presence of the attribute *the year of construction* in the database averaged about 23% and was considerably higher at the beginning of the sample (e.g. around 50% in the first quarter of 2002) than at the end (e.g. around 12% in the first quarter of 2007). Since the age of residential property is one of the main characteristics used in the construction of a real estate price index, the missing figure on the construction year was imputed using the information on the residential property for which the construction year was available. More precisely, for the residential properties from the period from 2002 to 2007 that lack construction year data, we completed, that is, imputed the data on the pertaining address from the total available database if that was possible.[27] This procedure increased the share of residential property with the available figure on the construction year to an average of 35%. Figure 3 shows the presence of the construction year attribute over the quarter before and after imputing.

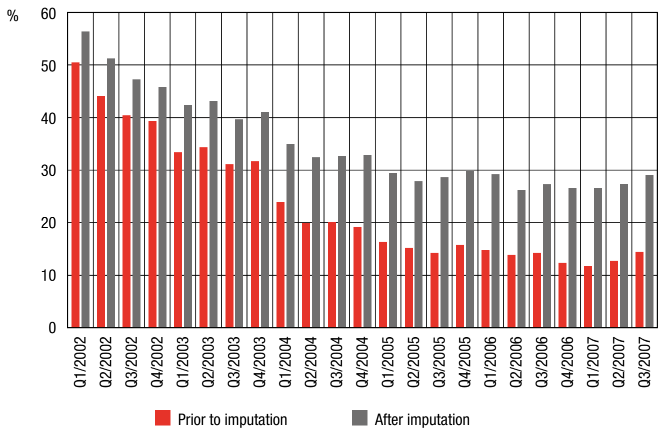
The problem with the other key variable was successfully resolved by retrieving the type of real property from its textual description. The share of real property identified as houses or flats in total real property is about 80%; the remaining real property comprises business premises, garages or real property without descriptions.

25 The predefined lower limit for the residential property purchased until the end of 2007 in Zagreb was 3 000 kuna per square meter, 2 000 kuna per square meter for the residential property purchased in the Adriatic Coast region, and 1 000 kuna per square meter for the residential property purchased in the Other region. This limit was in the later period increased to 4 000 kuna per square meter for all new residential property, as for the existing property in Zagreb. Finally, in the same period, the lower limit for all existing residential property on the Adriatic Coast was 3 000 kuna per square meter, and in the Other region it was 2 000 kuna per square meter.

26 About 95% of studentised residuals should be within the interval [–2,2] (see for example TMOOHHPI).

27 If the database contained two residential property units with the same address and different construction years, they were not used for the introduction of the missing data.

Figure 3 Share of residential property with the construction year attribute in the period from Q1 2002 to Q3 2007



Source: CNB.

3.2.2 Index construction

Due to the very small number of residential property units with an established year of construction (even after the imputing), the number of residential property units identified as newly-constructed is also (unrealistically) small and, as such, insufficient for the construction of credible real estate price indices. This is why only three aggregate house price indices were constructed for the period from 2002 to 2007: for the City of Zagreb, the Adriatic Coast and Other. Hence, no separate indices for the existing and for new residential property are constructed for this period.

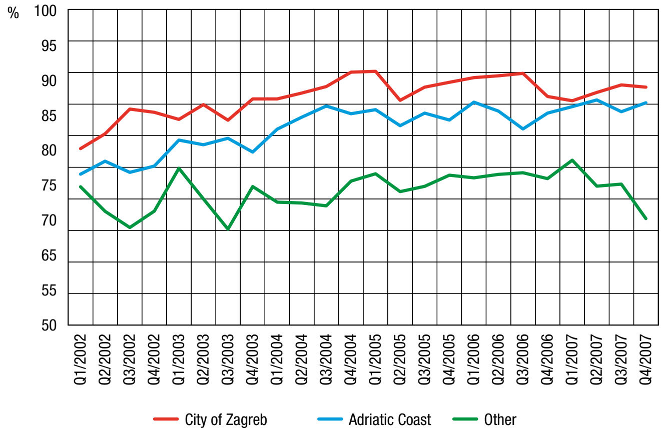
All logarithm models show the price as the linear function of the constant, the logarithm of the floor area, the time of sale and location dummy variables.[28] In addition, the models included two additional dummy variables: one identified new residential property and the other residential property in the form of houses (for the regions Adriatic Coast and Other).

The standard time dummy hedonic model was estimated for three strata, after which three time dummy indices were constructed and then aggregated into an overall index for the whole of Croatia. The determination coefficient R^2, which measures the efficiency of our specifications in explaining the variation in residential property prices, is the highest for the City of Zagreb, as the most homogenous stratum, and amounts to 0.89. The determination coefficient for the Adriatic Coast region is 0.80, and that for the very heterogeneous region Other stands at 0.78. The share of transactions used for the final construction of the index (transactions after the second phase of eliminating outliers), in total transactions is, as expected, the largest for the City of Zagreb and the smallest for the stratum Other. For the City of Zagreb the share was, on average, 83%, for the Adriatic Coast 75% and for the Other 59% if the number of transactions is taken into account. If the values of transactions are taken into account, these values were, on average, higher, amounting to 86% for the City of Zagreb, 81% for the Adriatic Coast and 71% for the Other (Figure 4). [29]

28 Location dummy variables refer to the municipalities/cities in the regions Adriatic Coast and Other, and the regions specified in accordance with the location of Tax Administration offices in the City of Zagreb.

29 Tables 4, 5 and 6 in the Appendix show the number of residential property units and their values by regions during the quarter. The data shown relate to initial transactions and transactions after the first and second phases of the elimination of outliers.

Figure 4 Share of transactions after the second phase of elimination of outliers in initial transactions according to the value of residential property in the period from Q1 2002 to Q4 2007



Source: CNB.

3.3 HPI for the period from the fourth quarter of 2007

3.3.1 Data preparation

In addition to the key characteristics of residential property for this period, the database also contains data on some additional characteristics that may be used in hedonic regressions, e.g., data on whether a flat is served by an elevator, whether it is a basement or an attic flat and whether it is connected to the electricity, gas, water or sewage system.[30] Also available are data on the degree of completeness of the residential property (completed or *Rohbau*) and its condition (luxury, requires renovation or in good condition).[31] Tables 7 – 12 in the Appendix show the number of initial transactions, their total value and the presence of the mentioned additional characteristics by strata during the quarter. These tables display some important characteristics of the Croatian residential property market that had an impact on the choice of the final econometric specification of the model. Specifically, due to the outbreak of the financial crisis, the number of transactions decreased considerably over time for all regions.[32] This is why priority was given to models that in the econometric assessment take into account the residential property sold in several periods. Also, the availability of qualitative characteristics becomes satisfactory no sooner than in 2012. Prior to that period, data for most of the attributes in the available database were only sporadic and were therefore considered unreliable.

3.3.2 Index construction

House price indices were constructed for the period from the fourth quarter of 2007 to the fourth quarter of 2015. The combination of the location and age of the residential property resulted in the construction of six basic house price indices (City of Zagreb – new, City of Zagreb – existing, Adriatic Coast – new; Adriatic Coast – existing; Other – new and Other – existing). In a similar way as before, for all six strata, the logarithmically transformed price is shown as the linear function of the constant, the logarithm of the floor area, the time of sale, location and various qualitative characteristics of the residential property. The location, as already mentioned, is characterised by a large number of location dummy variables.

30 The database does not contain separate entries for attics and basements, this information was comprised by one variable.

31 The entry of data on additional characteristics was not obligatory for Tax Administration employees. An additional problem as regards these data is that only the entry "yes" is available if a characteristic is present, whereas the entry "no" did not exist prior to the second quarter of 2015, so that an empty entry can mean both "no" and (not entered) "yes". In cases when it could not be concluded based on the description of the residential property whether it had a certain characteristic or not, the empty entry was interpreted as "no".

32 This decrease is especially significant for some strata. For example, the number of new residential property units sold in Zagreb in the first half of 2015 accounts only for about 15% of the number of property units sold in the first half of 2008.

As we considered that potentially valuable information contained in additional explanatory variables should be included into final models, special econometric models were specified for the period from 2012 onwards and the period before it. The standard time dummy hedonic model was estimated without additional qualitative variables for the period ending with the first quarter of 2012, and for the period from 2012 onwards the time dummy hedonic model was estimated on a moving sample of four quarters with additional qualitative variables. Two models share the first quarter of 2012 so that indices constructed on two parts of the sample could be combined into one index. Table 2 presents a list of additional variables included into six models for the period from 2012 onwards.

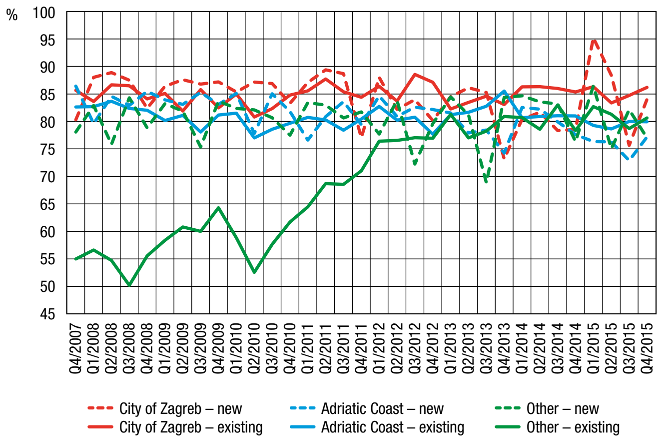
Table 2 Additional variables included in hedonic models from 2012 onwards

	City of Zagreb – new	City of Zagreb – existing	Adriatic Coast – new	Adriatic Coast – existing	Other – new	Other – existing
Elevator		✓	✓	✓	✓	✓
Basement or attic		✓	✓	✓		✓
Electricity		✓	✓	✓	✓	✓
Water			✓			✓
Gas	✓	✓	✓	✓	✓	✓
Sewage system		✓	✓	✓	✓	✓
Degree of completeness: completed			✓	✓	✓	✓
Degree of completeness: Rohbau			✓			✓
Condition: luxury	✓					
Condition: requires renovation		✓		✓		✓
Condition: good		✓	✓	✓	✓	✓

Tables 13, 14 and 15 in the Appendix show that our specifications account for most of the variations in residential property prices – the determination coefficient R^2 averages 0.88 for all specifications.[33] This statistic is directly influenced by the previously described method of detection (and elimination) of outliers, during which a lot of residential property whose inclusion would have a negative effect on R^2 are removed from the analysis. However, even when a more lenient criterion is applied for the detection of outliers, R^2 statistics do not fall below 0.7. The tables also display the number and value of residential property not removed in one of the two phases of outliers' elimination. From two more homogeneous areas (City of Zagreb and Adriatic Coast) between 10% and 25% of transactions were removed in this manner, while in the very heterogeneous area Other 64% of the data was removed in some periods. The situation is similar if the value of residential property is observed instead of the number of residential property units. Figure 5 shows the share of the value of residential property used to construct the index in the initial value of residential property. The figure shows that in the phase of elimination of outliers for the City of Zagreb the least of the residential property was removed, while the stratum Other – existing was the most problematic (especially in the period prior to 2012) so that a large portion of residential property was removed.

33 It should be emphasised that the values of R^2 statistics are very similar to the values of R^2 statistics adjusted for the number of parameters, which is why they are not shown here. This finding shows that a large number of location dummy variables used in the specifications does not compromise the quality of the models.

Figure 5 Share of transactions after the second phase of the elimination of outliers in initial transactions according to the value of residential property in the period from Q4 2007 to Q4 2015

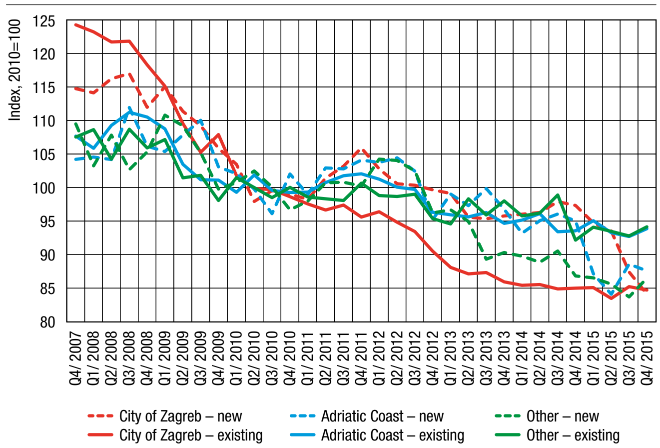


Source: CNB.

3.4 Results – the HPI constructed and residential property market preferences

Figure 6 shows indices obtained directly from the estimated coefficients of hedonic models for the period from the fourth quarter of 2007 to the fourth quarter of 2015. In general, residential property prices in Croatia were on decline in the observed period. A comparison of average prices in 2008 and those in 2015 shows that the largest decrease was in the City of Zagreb (–30% for the existing and –22% for new residential property), then on the Adriatic Coast (–14% for the existing and –19% for new residential property) and finally in the region Other (–12% for the existing and –18% for new residential property). In addition, the indices for the most homogeneous market, flats in the City of Zagreb, were the least volatile.

Figure 6 House price indices for the period from Q4 2007 to Q4 2015

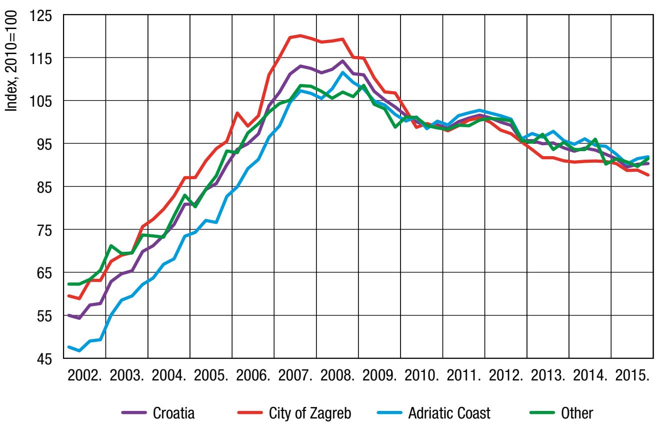


Source: CNB.

The aggregation of the basic six indices according to formula (12), with the weights adjusted to reflect prices in the fourth quarter, resulted in six new indices. The aggregation with regard to the age of the residential property resulted in the construction of indices for new and existing residential property, while the aggregation with regard to the region resulted in the construction of indices for the City of Zagreb, the Adriatic Coast and Other. Finally, taking into account all the available residential property sold in the Republic of Croatia, the aggregation resulted in a construction of the house price index for the whole country.[34]

Four indices were constructed for the earlier period (2002-2007): three indices that correspond with these regions were obtained directly from the time dummy model, and the index of all residential property prices was obtained by their aggregation. The mentioned indices were merged with the corresponding indices in the later period and are presented in Figure 7, which shows that all residential property prices increased sharply in the period from 2002 to 2008 and started to fall afterwards. A comparison of average prices in 2002 and those in 2008 shows that average residential property prices doubled in that period, with prices on the Adriatic Coast exhibiting the highest growth (+125%). In the City of Zagreb growth was slightly more moderate in that period (+93%), while in the region Other it was +68%.[35] Residential property prices peaked in 2008, and started to decline afterwards, in parallel with the economic slowdown in Croatia, continuing the downward trend until the end of the observed period. Residential property prices decreased by a total of 20% from 2008 to 2015 and grew by 61% in the whole analysed period (2002 to 2015)[36]

Figure 7 The house price indices constructed for the period from Q1 2002 to Q4 2015



Source: CNB.

In order to compare the constructed HPI with the indices that were previously used to monitor residential property prices in Croatia, we show them together in Figure 8. In addition to HPI, this figure shows the hedonic real estate price index (HREPI) and the real estate price index (REPI). The HREPI was published by the CNB and the REPI by the online real estate agency Centar nekretnina. Several conclusions can be drawn based on this figure. First, all the indices point to an increase in residential property prices in the period until 2008 and a decrease in the following period. Second, the dynamics of the two hedonic indices, the HPI and the HREPI, is similar during most of the observed period. These two indices started to diverge considerably in 2012 in parallel with the significant deterioration of the quality of input data on transactions from which the

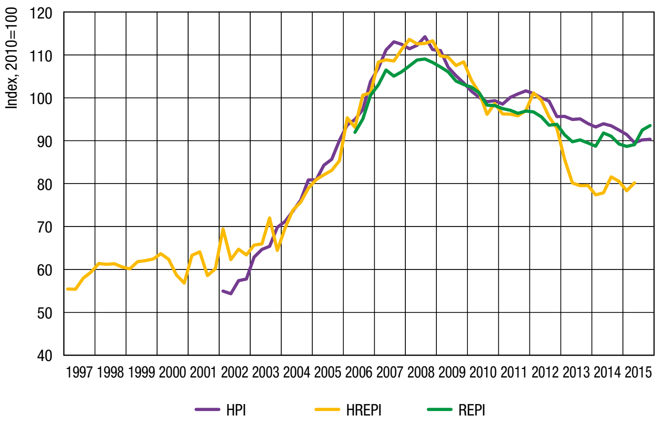
34 Constructed indices for the new and existing residential property (together with the index for all residential property) are shown in the Appendix in Figure 14.

35 Figure 15 in the Appendix shows the annual rates of change in the indices in order to get a better insight into their dynamics.

36 In the period from 2002 to 2012 residential property prices on the Adriatic Coast recorded above-average growth (90%), while in other regions prices increased more moderately (45% in Zagreb and 43% in the region Other).

HREPI was constructed, so that it ceased publication.[37] It seems that in this final period the REPI, although based on residential property asking prices, better follows the dynamics of the HPI than the HREPI.

Figure 8 Comparison of the HPI with alternative residential property indices



Source: CNB.

The estimated hedonic models, as already noted, can also be used for the analysis of customer preferences. In this case the most relevant is the preference regarding the residential property location, i.e. how much buyers are prepared to pay for the residential property with the same characteristics at different locations. Due to the large number of models estimated here, only the results for the period in which time dummy models were used will be shown. Figure 9 shows results of the estimated models for the regions Adriatic Coast and Other for the period from the first quarter of 2002 to the fourth quarter of 2007. Different shades of blue and green show the values with location dummy variables, with darker shades representing cities/municipalities with a higher implicit location price.[38] The locations with the highest prices on the Adriatic Coast were Dubrovnik and the surroundings, Split, some islands in central Dalmatia, Opatija, Krk and western Istria. The cheapest locations in this region were in the area around Opuzen, in the Zadar hinterland and in Karlobag and Senj. As regards the Other region, the most expensive locations were in large cities (Osijek, Slavonski Brod, Varaždin, Bjelovar, Koprivnica), then in the Zagreb surroundings and in the Istria hinterland, while cheaper locations were mostly in rural municipalities. The results for the City of Zagreb are shown separately in Figure 10. The most expensive Zagreb neighbourhood is Medveščak, followed by Trnje and Maksimir, while Sesvete is the cheapest neighbourhood.[39] Figures 17 and 18 in the Appendix in a similar way show the results for the period from the fourth quarter of 2007 to the first quarter of 2012. In the observed period, the number of existing residential property units sold was considerably larger than the number of new residential property units, so that a large number of municipalities/cities remained uncoloured for the strata the Adriatic Coast – new and Other – new. A comparison of results presented in Figure 10 and Figure 19 in the Appendix shows that buyers' preferences as regards location do not change significantly over time. As regards the City of Zagreb, some changes can be noted in the order of neighbourhoods according to price[40], but Medveščak, Trnje, Maksimir, Trešnjevka and Centar are always the most expensive neighbourhoods, whereas Dubrava, Susedgrad and Sesvete are the cheapest.

37 A comparison of the HPI and HREPI subindices for the City of Zagreb and the Adriatic Coast is shown in Figure 16 in the Appendix.

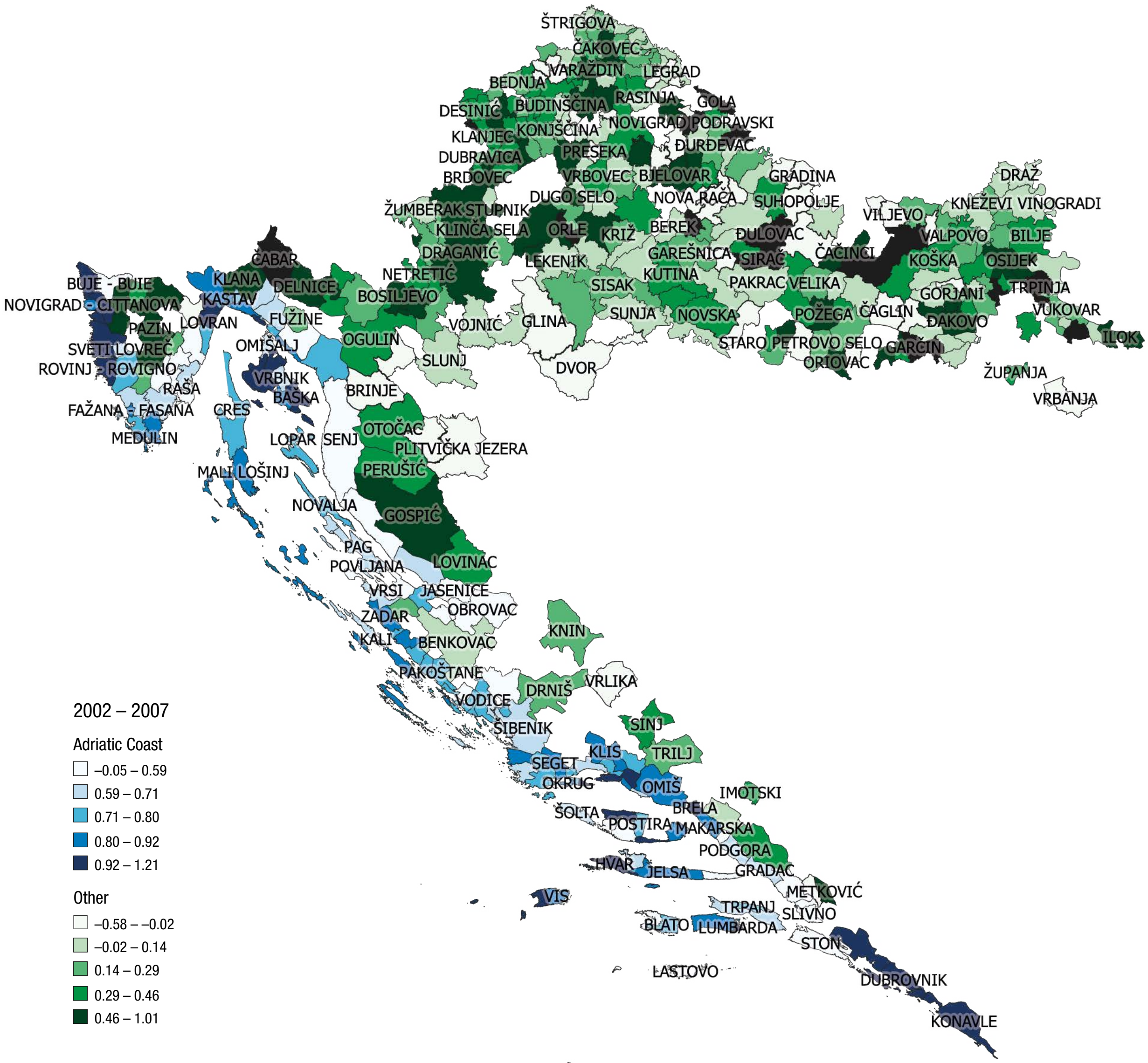
38 For the municipalities/cities in which only one residential property unit was sold on the observed sample, the appropriate location dummy variable was removed from model specifications, but the residential property itself was left in the sample. The estimated coefficients with location dummy variables are interpreted as a deviation from such residential property or (if there are no such municipalities/cities) as a deviation from one (randomly selected) municipality or city.

39 The results for the City of Zagreb are similar to the results obtained in Kunovac et al., 2008.

40 The prices for the neighbourhoods of the City of Zagreb are shown as deviations from the prices in Trnje.

In addition to the presented differences in the prices of residential property depending on the location, also shown is the spatial distribution of the residential property sold. Figures 20, 21 and 22 in the Appendix show the number of residential property units sold by municipalities/cities in the period 2002-2007.[41] These figures show that in the observed period only a few residential property units were sold in the observed period, so that the results shown in Figure 9 should be interpreted taking into account the number of residential property units from which the estimate was derived. For example, the results show that in the municipality of Čačinci in western Slavonia residential property prices were extremely high in this period, but that only three residential property units were sold in this municipality.

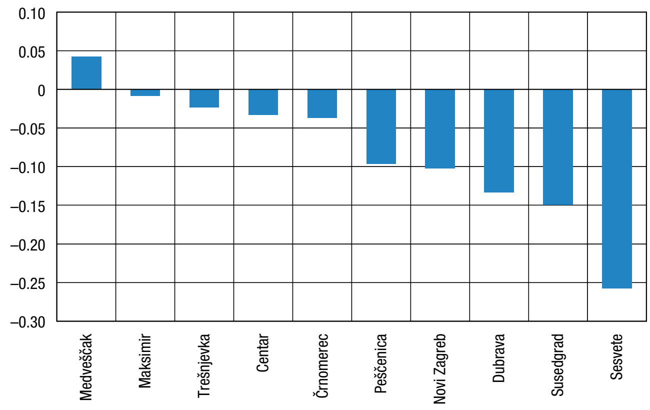
Figure 9 Coefficients with location dummy variables for the regions Adriatic Coast and Other in the period from 2002 to 2007



Source: CNB.

41 Taken in the consideration here is the residential property used in the construction of the time dummy index, i.e. this is the number of residential property units following the second phase of the evaluation of outliers.

Figure 10 Coefficients with location dummy variables for the City of Zagreb in the period from 2002 to 2007



Note: These values are interpreted as deviations from the prices for the Trnje neighbourhood.
Source: CNB.

4 Residential property prices and microlocation – the application in the mass valuation and the compilation of the real estate price index

The introduction showed how the estimated models can be used, not only for the construction of a real estate price index but also for the mass valuation of residential property.[42] If the characteristics of a residential property are known (floor area, age, location, etc.), the estimated regression coefficients (i.e. the implicit prices of specific characteristics) enable its direct valuation (see Kunovac et al., 2008).

Further in the text we will analyse potential improvements to such valuations by including into the hedonic models a very precise location of the residential property, its longitude and latitude coordinates. If we label them x_{1i}^t and x_{2i}^t and for the sake of simplicity limit ourselves to the time dummy model (2), its modified version is now represented by the following equation:

$$\ln(P_i^t) = \sum_{k=1}^{T} \delta_k D_{ik}^t + \sum_{j=0}^{J'} \alpha_j X_{ij}^t + s(x_{1i}^t, x_{2i}^t) + u_i^t \qquad (13)$$

assuming that in the order of variables in (2) qualitative characteristics $(j = 0, \ldots, J')$ come first and are followed by location characteristics $(j = J' + 1, \ldots, J)$, which were here eliminated from the model.[43] Therefore, the difference between model (2) and model (13) is that in model (2) the location of residential property is represented by location dummy variables, whereas in model (13) it is represented by the function of geographical coordinates, with the function s being a smooth function by which the residential property price at a random location can be approximated based on the value of the residential property sold in its close vicinity. In our analysis the function s will be a two-dimensional spline, as in Wood (2003), whereas the estimation of model (13) was made according to Wood et al. (2015). The basic idea of two-dimensional splines is as follows: for the given N ordered pairs (y_i, x_i),where $\mathrm{x}_i \in \mathbb{R}^2$, we want to estimate the smooth function $s(\mathrm{x})$, which reads

$$y_i = s(\mathrm{x}_i) + \varepsilon_i,$$

42 The mass valuation of the residential property is envisaged by the Real Estate Valuation Act (Official Gazette, 78/2015).

43 Such models belong to the class of models termed generalized additive models. More details on these models could be found, for example, in Hastie and Tibshirani (1986) and Wood (2017).

with ε_i being a random error. If the problem is given as the minimisation problem

$$\min_s \sum_{i=1}^{N} (y_i - s(\mathrm{x}_i))^2 + \lambda \cdot J(s), \tag{14}$$

with

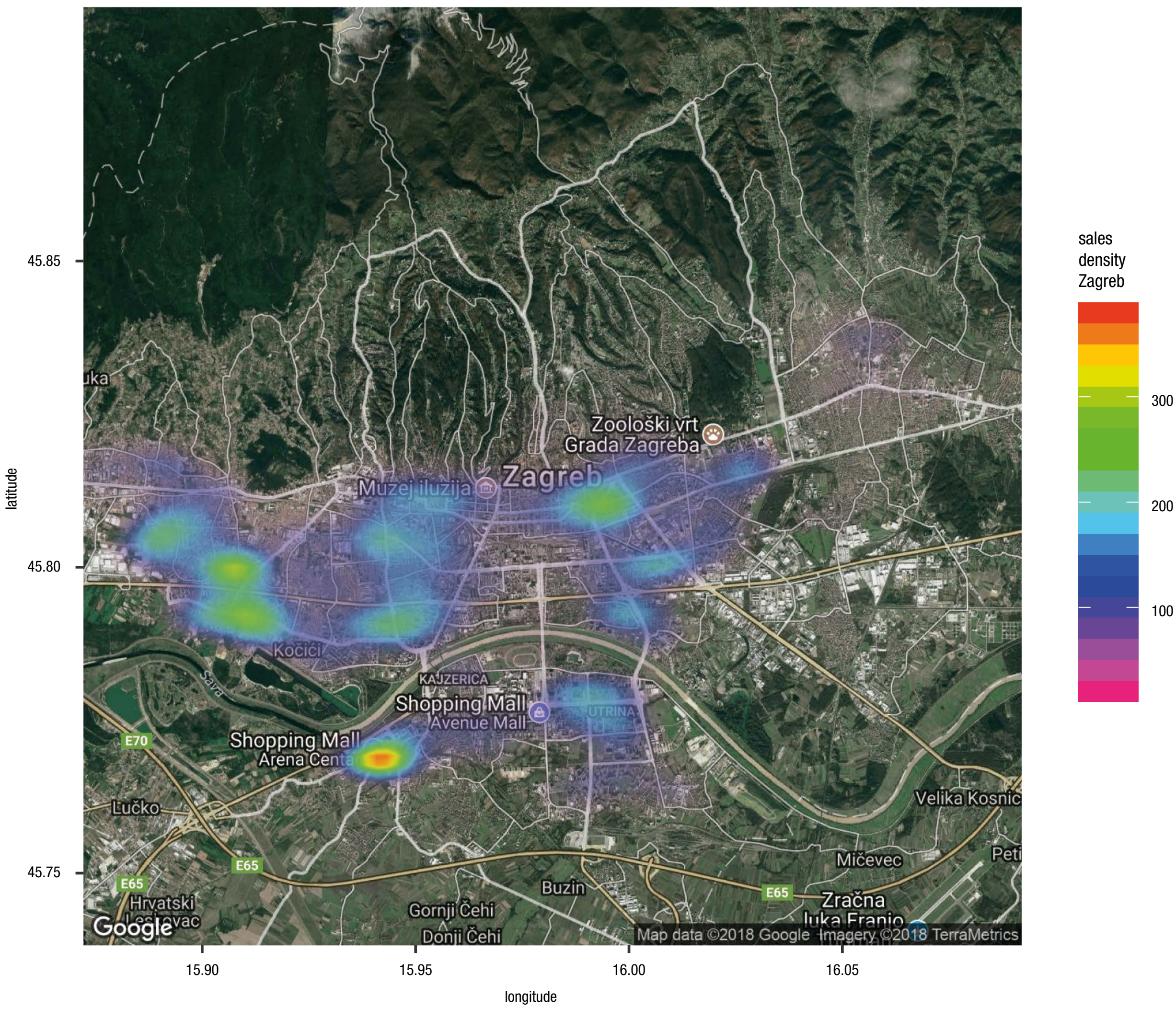
$$J(s) = \iint_{\mathbb{R}^2} \left[\left(\frac{\partial^2 s(\mathrm{x})}{\partial x_1^2} \right)^2 + 2 \left(\frac{\partial^2 s(\mathrm{x})}{\partial x_1 \partial x_2} \right)^2 + \left(\frac{\partial^2 s(\mathrm{x})}{\partial x_2^2} \right)^2 \right] dx_1 dx_2$$

representing the measure of the smoothness of the function $s(\mathrm{x})$, the solution to this problem is *thin plate spline*. The smoothness of the function $s(\mathrm{x})$ is contolled by the parameter λ, for $\lambda \rightarrow 0$ $s(\mathrm{x})$ approaching the interpolation function, while for $\lambda \rightarrow \infty$ $s(\mathrm{x})$ approaching a plane in space. For large sets of data, the problem solution (14) can be demanding in terms of calculation. Wood (2003) therefore introduces the so-called *thin plate regression spline* as a lower rank approximation, which has good characteristics.

In the application of this methodological framework, the residential property address (from the Tax Administration database) should be used in order for data on the geographical coordinates to be isolated first.[44] As this process proves more successful for large cities than for smaller communities, this part of the analysis takes into account only the residential property from the City of Zagreb, where the largest number of residential property units are sold. In the period from the fourth quarter of 2007 to the end of 2015, 41,809 residential property units were sold, and the geographical coordinates were successfully acquired for 40,188 of them. Figure 11 shows their spatial distribution: in the market of the City of Zagreb there were several focal areas with a large number of residential property units sold.

44 The process of transforming the physical address of the residential property to its geographical coordinate is called geocoding. The geocoding tools were used for the purposes of the analysis: Google geocoding API and Nominatim API.

Figure 11 Spatial distribution of the residential property sold in the City of Zagreb in the period from Q4 2007 to Q4 2015



Source: CNB.

This was followed by the estimate of the generalised additive model GAM (13) for the residential property from the City of Zagreb for the period from 4th quarter 2007 to the end of 2015. For the sake of comparison, in addition to the GAM model, the same dataset was used to estimate a model that instead of the geographical coordinates uses location dummy variables (termed LM). Due to the mentioned problems in the database before 2012, the only qualitative characteristic included in these models is a dummy variable that identifies new residential property. It should also be noted that for the sake of comparability of these two models only the first step of the common procedure was applied for the elimination of outliers, with the result that all residential property units with the price per square meter lower than HRK 4,000 or higher than HRK 23,000 were removed from the analysis.

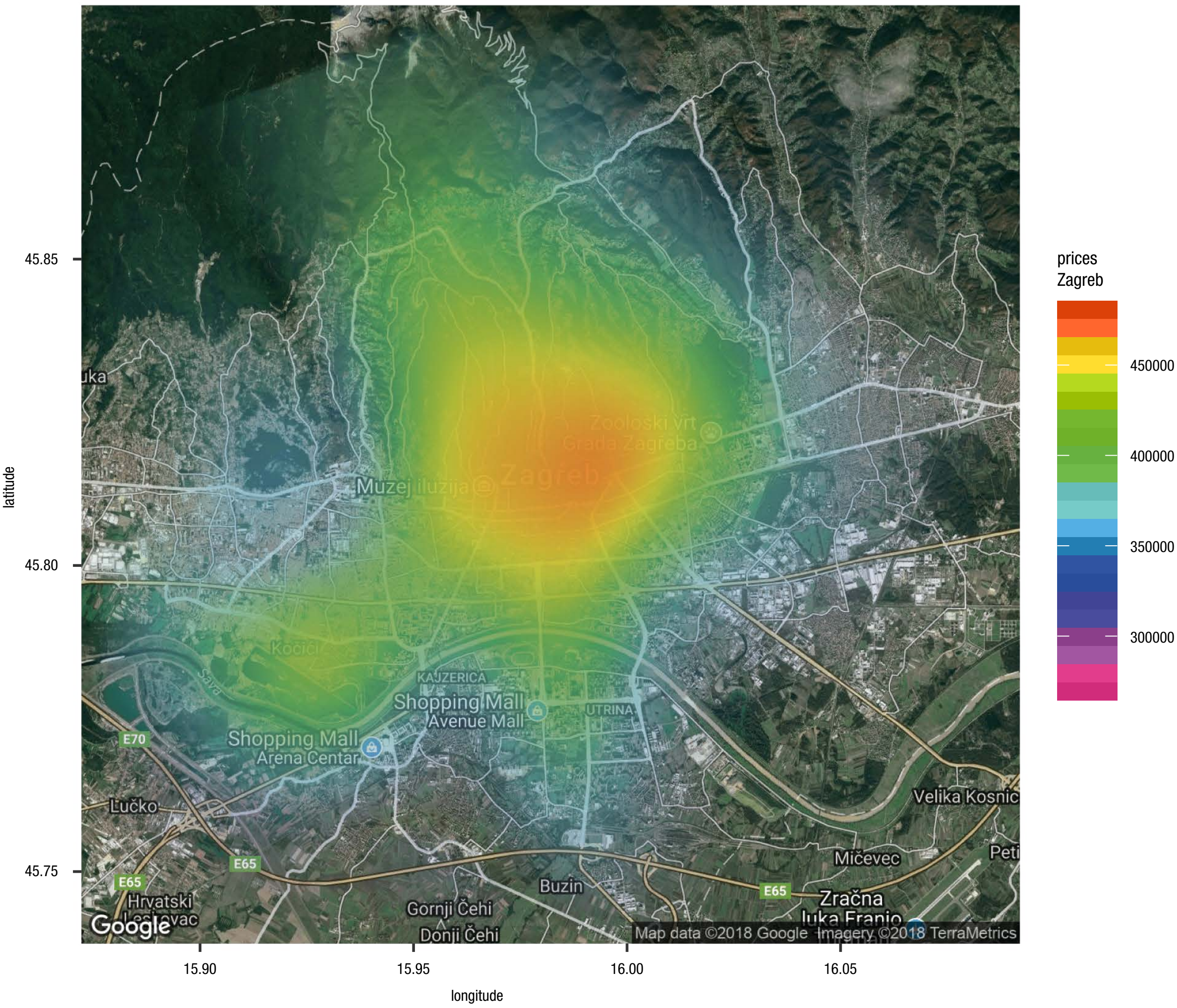
Using the results of the GAM model, we can (in a similar way as for the LM model) obtain the estimated value of a flat in Zagreb with a random floor area and at a random location. For example, the estimated value of a flat (which is not new) of 50 square meters (a median floor area of all flats sold) in the fourth quarter 2015 was shown in Figure 12. It can be observed that the estimated plane is smooth (no leaps) and that the City of Zagreb has two prominent centres of high prices, which means that, as far as the observed specification is concerned we cannot say, for example, that the price decreases proportionally to the distance from the city centre.

The adjusted determination coefficient R^2 is almost equal for both estimated models (0.8574 for the LM model and 0.858 for the GAM model). The result shows that the location City of Zagreb is on average properly described by the location dummy variables. However, the lower level (neighbourhoods) gives rise to further conclusions. Table 3 shows the average deviation of the fit of the two models from the realised values, calculated according to the following formula:

$$\sqrt{\frac{1}{N}\cdot\sum_{i=1}^{N}(y_i-\hat{y}_i)^2}$$

for each neighbourhood.[45] It can be observed that the values differ significantly across neighbourhoods, which makes it much easier to estimate the value of a flat in Sesvete, for example, than of a flat in the Centre.[46] In addition, each of the two models is marginally better for a particular neighbourhood. Trešnjevka is interesting as a large neighbourhood that encompasses one of the two centres of high prices shown in Figure 12. Hence, the GAM model gives slightly better results than the LM model. As was demonstrated for the whole City of Zagreb, Figure 13 shows the estimated value of a flat of 50 square meters in Trešnjevka. The prices, as can be observed, are the highest in the north-east (close to the city centre), then in the south-west, while they are the lowest in the north-west. As the LM model associates the same price with all flats in Trešnjevka, Figure 13 shows that a regular estimate of residential property price in this neighbourhood can give biased results.

Figure 12 Estimated value of a flat of 50 square meters in the City of Zagreb in the fourth quarter of 2015



Source: CNB.

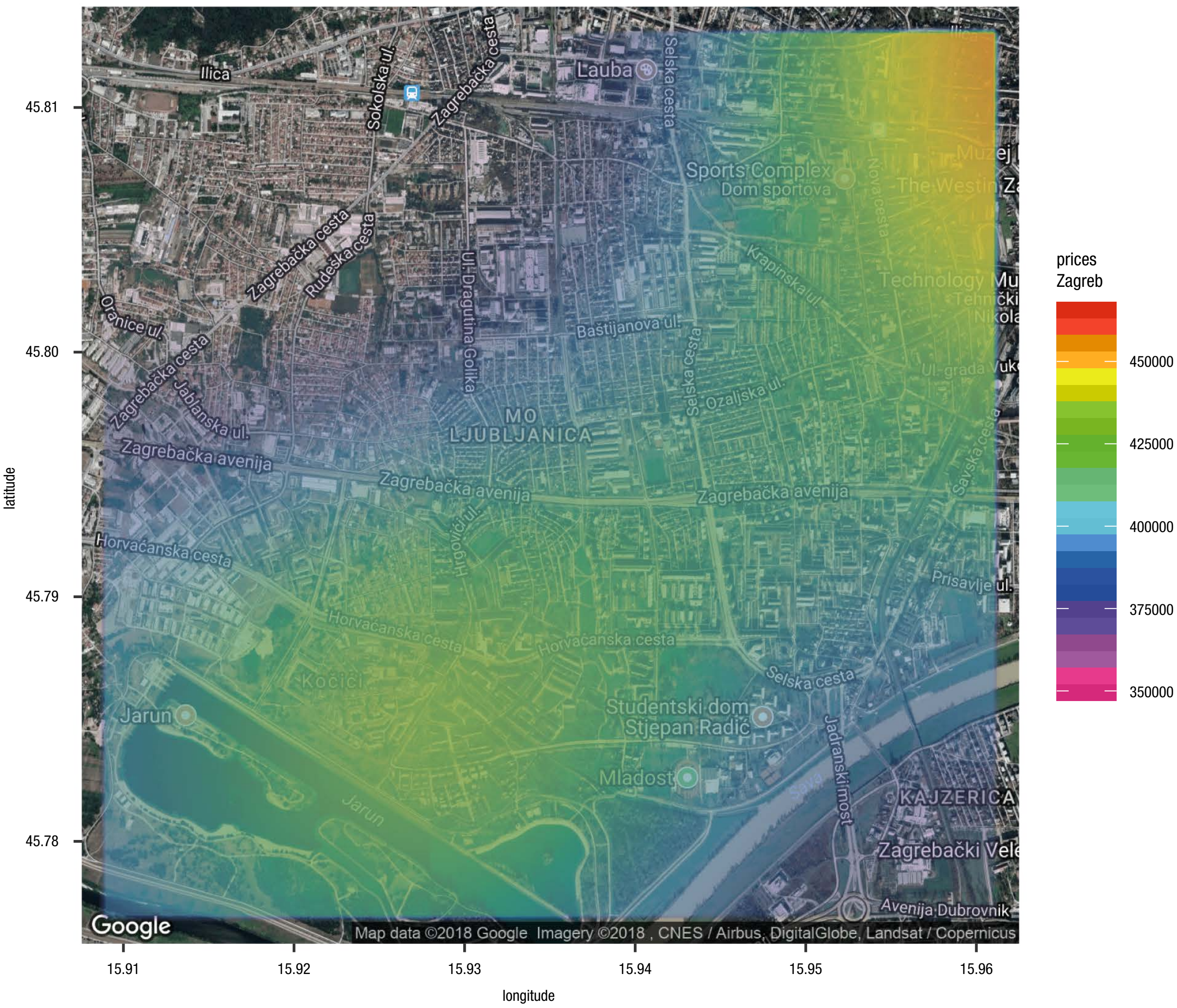
45 The values y_i and $\hat{y}_i$ are given in logarithms.

46 Presumably because the residential property in the Centre is much more heterogeneous than that in Sesvete.

Table 3 Root mean-square deviation for two models

	LM	GAM
Centar	0.344	0.347
Črnomerec	0.315	0.309
Dubrava	0.238	0.236
Maksimir	0.288	0.294
Medveščak	0.307	0.310
Novi Zagreb	0.219	0.211
Peščenica	0.259	0.248
Sesvete	0.179	0.210
Susedgrad	0.225	0.227
Trešnjevka	0.237	0.233
Trnje	0.241	0.240

Figure 13 Estimated value of a flat of 50 square meters in Trešnjevka in the fourth quarter of 2015



Source: CNB.

5 Conclusion

This paper shows the process of construction of a house price index (HPI) based on the data of the Tax Administration of the Republic of Croatia. The paper also suggests how developed econometric models and data on the geolocation of the residential property may be used for the (mass) valuation of residential property. The main finding is that, despite its deficiencies, the Tax Administration database can be used to construct relevant real estate price indices, which convincingly sum up trends in these prices in the last fifteen years. The analysis also shows that it makes sense to analyse the usefulness of models that include into the analysis the microlocation of the residential property as an alternative to or an improvement on existing hedonic models and commonly applied standard comparative models for the determination of residential property prices.

Appendix

Table 4 Number and value of transactions for the City of Zagreb in the period from 2002 to Q4 2007

Quarter	Initial transactions		Transactions after the first phase of outlier elimination		Transactions after the second phase of outlier elimination	
	Number	Value	Number	Value	Number	Value
1 2002	894	237810562	609	191653398	571	185350186
2 2002	1091	312566071	813	257324766	782	251006826
3 2002	1044	334725257	884	289475468	845	281888617
4 2002	1129	381498567	964	331358378	903	319333466
1 2003	1326	476537373	1134	408815200	1061	393499554
2 2003	1314	478013536	1158	423868057	1076	406024811
3 2003	1108	403558832	965	347864644	889	332689889
4 2003	1698	687446763	1524	613657312	1409	590003666
1 2004	1537	612955496	1377	544206954	1288	526050444
2 2004	1574	614609925	1415	552056247	1316	533238349
3 2004	1440	588300723	1296	522690431	1260	516435336
4 2004	1794	760806677	1614	693263132	1568	685304231
1 2005	1497	666347571	1347	608202574	1309	600938864
2 2005	1610	743654281	1448	646412157	1401	636684121
3 2005	1657	783494397	1491	690655491	1472	687008735
4 2005	2103	1063324422	1893	948813406	1866	940662192
1 2006	2023	1025968042	1821	927501065	1756	915224072
2 2006	2141	1100451126	1927	991678788	1891	984712478
3 2006	1847	958798402	1663	866349732	1652	861768760
4 2006	2218	1218819868	1996	1074001795	1885	1050713363
1 2007	2303	1252676298	2064	1101625734	1880	1071445050
2 2007	2283	1273920685	2055	1144439144	1893	1106342902
3 2007	2086	1137162149	1878	1049138157	1702	1001237912
4 2007	2438	1429760968	2126	1279390207	2013	1253913280

Table 5 Number and value of transactions for the region Adriatic Coast in the period from 2002 to Q4 2007

Quarter	Initial transactions		Transactions after the first phase of outlier elimination		Transactions after the second phase of outlier elimination	
	Number	Value	Number	Value	Number	Value
1 2002	827	170957132	525	128917412	507	126372564
2 2002	1088	234106833	718	181148563	699	177856679
3 2002	1304	277690957	829	213720289	792	206085249
4 2002	950	211552953	619	163209030	596	159078189
1 2003	1312	353268765	934	285885344	897	280158680
2 2003	1434	379182270	1004	308224968	947	297954176
3 2003	1493	378726898	1057	312434411	993	301439461
4 2003	1632	469217363	1180	378545447	1096	363237321
1 2004	1706	523761332	1322	438879157	1231	424377058

Quarter	Initial transactions		Transactions after the first phase of outlier elimination		Transactions after the second phase of outlier elimination	
	Number	Value	Number	Value	Number	Value
2 2004	2141	666377635	1709	571214326	1595	552745723
3 2004	2407	798508911	2008	689255917	1926	676328903
4 2004	1986	701753967	1677	601414885	1599	585756507
1 2005	1613	591798919	1367	510243171	1302	497750715
2 2005	2083	724504938	1745	617816277	1622	591182441
3 2005	2324	871732562	1992	750098336	1882	728573766
4 2005	1795	757596103	1568	644308808	1493	624944656
1 2006	1924	797919072	1682	697562241	1599	680732008
2 2006	2165	915423462	1878	800924424	1773	768089329
3 2006	2177	986368471	1926	839236815	1820	799708145
4 2006	2034	974117213	1800	857143103	1680	814109022
1 2007	1930	943431481	1674	828848283	1561	798228565
2 2007	2355	1200671445	2076	1062803880	1971	1028532199
3 2007	2426	1266766015	2145	1103217925	2018	1061413215
4 2007	2278	1247842729	2035	1096340409	1926	1063248899

Table 6 Number and value of transactions for the region Other in the period from 2002 to Q4 2007

Quarter	Initial transactions		Transactions after the first phase of outlier elimination		Transactions after the second phase of outlier elimination	
	Number	Value	Number	Value	Number	Value
1 2002	768	93582300	431	68820157	417	67309195
2 2002	899	111026278	523	77706443	505	75536404
3 2002	978	129322177	544	87743072	516	84641864
4 2002	683	86415140	387	61381342	367	58804105
1 2003	921	148418785	627	113075088	609	111083639
2 2003	1032	152522155	629	110555873	602	106761910
3 2003	1143	164239141	659	113759769	603	107097788
4 2003	1267	187488245	771	139561907	718	134898626
1 2004	1606	222414475	931	161638965	864	154493002
2 2004	2291	320256653	1323	228710224	1256	222118501
3 2004	2259	328166230	1310	232228587	1248	226075870
4 2004	2232	353554154	1403	264312017	1334	257438646
1 2005	1883	303832393	1224	232727335	1166	224755534
2 2005	2648	421615344	1611	308604540	1556	299942393
3 2005	2545	423190641	1567	314428738	1501	304686282
4 2005	2173	398522747	1430	303281409	1359	293919442
1 2006	2244	449398102	1515	337317537	1468	329577996
2 2006	2624	504782592	1696	380766061	1628	372864350
3 2006	2826	595205696	1836	460203741	1733	441328734
4 2006	2565	552865066	1691	419074291	1604	404765737
1 2007	2645	580643022	1748	459373209	1647	442069301
2 2007	2739	604041678	1782	458506767	1665	434899849
3 2007	2581	570589460	1663	431397717	1565	412732565
4 2007	2529	586496758	1514	415532145	1397	392156974

Table 7 Data on initial transactions for the stratum City of Zagreb – new in the period from Q4 2007 to Q4 2015

Quarter	Number	Value	Elevator	Attic/basement	Electricity	Water	Gas	Sewage system	Completed	Incomplete (Rohbau)	Luxury	Renovated	Good condition
4 2007	1054	607839712	0	0	0	0	0	0	0	0	0	0	0
1 2008	906	525647037	0	0	0	0	0	0	0	0	0	0	0
2 2008	1010	624477442	0	0	0	0	0	0	0	0	0	0	0
3 2008	911	562051295	0	0	2	2	1	2	2	0	0	0	1
4 2008	897	556525574	0	0	0	0	0	0	0	0	0	0	0
1 2009	666	456778329	0	0	1	1	1	1	1	0	0	0	1
2 2009	963	636723586	0	0	3	3	2	3	3	0	0	0	2
3 2009	779	509010449	0	0	2	2	0	2	1	0	0	0	1
4 2009	817	512221803	0	0	2	2	2	2	2	0	0	0	2
1 2010	662	398939903	0	0	2	2	2	2	2	0	0	0	0
2 2010	755	443214857	2	0	9	9	6	9	8	1	1	0	6
3 2010	628	372624103	0	0	3	3	3	3	3	0	0	0	2
4 2010	767	462389632	0	1	4	4	3	4	4	0	0	0	4
1 2011	643	377728143	2	0	21	21	19	21	21	0	0	0	13
2 2011	643	384585138	4	1	100	100	92	100	96	5	0	0	29
3 2011	462	272540717	14	1	105	105	94	104	104	4	0	0	56
4 2011	321	238503117	68	3	126	126	103	126	120	7	2	2	99
1 2012	342	217410173	198	16	329	329	309	328	308	22	8	7	308
2 2012	345	212409662	184	10	325	325	292	323	300	22	11	3	302
3 2012	263	159455721	159	10	247	247	202	245	230	16	8	4	227
4 2012	270	174685981	156	3	253	253	224	252	246	4	10	4	234
1 2013	266	176080367	159	1	235	237	194	236	220	10	17	2	208
2 2013	298	167979499	169	3	242	242	183	242	199	16	3	2	211
3 2013	239	130790415	124	0	170	169	125	170	156	4	0	0	155
4 2013	198	118295072	94	0	136	136	104	136	126	5	2	1	129
1 2014	132	75534106	56	0	92	92	75	92	90	1	2	2	86
2 2014	165	101920860	68	0	97	97	74	97	91	5	2	2	90
3 2014	151	91591491	57	1	92	92	70	92	86	3	2	2	85
4 2014	179	114420361	54	0	100	100	74	100	90	9	1	2	93
1 2015	17	11148844	5	0	10	10	7	10	8	2	0	0	10
2 2015	81	58766289	47	2	74	74	70	74	73	1	17	0	57
3 2015	88	48166574	48	4	84	84	78	84	82	2	4	1	79
4 2015	177	104572171	136	1	172	172	164	169	167	6	5	2	166

Note: In addition to the number and value of initial transactions during each of the quarters the table shows the presence of some additional characteristics.

Table 8 Data on initial transactions for the stratum City of Zagreb – existing in the period from Q4 2007 to Q4 2015

Quarter	Number	Value	Elevator	Attic/basement	Electricity	Water	Gas	Sewage system	Completed	Incomplete (Rohbau)	Luxury	Renovated	Good condition
4 2007	1384	821921256	0	0	1	1	0	1	0	0	0	0	0
1 2008	1139	656671361	0	0	0	0	0	0	0	0	0	0	0
2 2008	1186	666039509	0	0	1	1	1	1	1	0	0	0	0
3 2008	1049	588141521	0	0	2	2	2	2	2	0	0	1	0
4 2008	1160	661569277	0	0	1	1	1	1	1	0	0	0	1
1 2009	802	408907574	0	0	3	3	2	3	3	0	0	0	1
2 2009	785	434488576	0	1	6	6	4	6	6	0	0	1	1
3 2009	680	360323544	0	0	3	3	2	3	3	0	0	0	1
4 2009	838	442895786	0	0	2	2	1	2	2	0	0	1	0
1 2010	768	385004718	0	0	3	3	0	3	2	1	0	0	1
2 2010	861	464534642	0	0	5	5	1	5	5	0	0	1	2
3 2010	688	346857213	0	1	6	6	3	6	3	0	0	2	0
4 2010	807	383115346	0	0	13	13	5	13	12	0	0	3	2
1 2011	734	348385770	0	5	61	61	25	61	60	0	0	4	3
2 2011	753	368371606	8	9	161	161	75	160	146	0	0	24	5
3 2011	687	326162352	5	9	180	180	93	180	171	2	0	34	17
4 2011	831	386370764	64	19	281	280	166	281	269	5	0	119	107
1 2012	758	343899910	230	27	662	661	419	658	637	4	0	346	302
2 2012	683	324826462	239	34	601	599	374	597	577	5	0	312	283
3 2012	590	266483739	173	53	522	522	325	517	500	5	0	284	237
4 2012	659	296511819	198	30	575	575	367	572	559	0	0	300	258
1 2013	575	265461294	146	25	490	489	330	487	464	3	0	274	207
2 2013	741	330009520	201	14	564	562	361	558	525	8	0	324	235
3 2013	520	218503045	128	8	339	341	218	338	329	4	1	201	139
4 2013	743	344626805	192	17	461	459	305	459	442	4	0	267	190
1 2014	557	261292357	130	15	335	335	221	332	310	3	0	213	123
2 2014	609	283145014	144	17	372	370	236	367	356	3	0	198	171
3 2014	628	287820978	151	6	396	393	264	393	383	2	0	227	174
4 2014	710	318739120	139	12	407	406	262	407	399	4	0	228	179
1 2015	593	271720595	70	8	193	193	122	193	190	4	0	104	89
2 2015	806	378337163	129	17	365	365	240	364	364	6	1	232	137
3 2015	715	336364601	167	11	389	387	250	384	384	5	0	240	149
4 2015	675	311613814	173	19	424	423	295	420	422	4	0	234	191

Table 9 Data on initial transactions for the stratum Adriatic Coast – new in the period from Q4 2007 to Q4 2015

Quarter	Number	Value	Elevator	Attic/basement	Electricity	Water	Gas	Sewage system	Completed	Incomplete (Rohbau)	Luxury	Renovated	Good condition
4 2007	640	371235628	0	0	2	2	0	0	2	0	0	0	2
1 2008	474	273658105	0	0	2	2	0	2	1	0	0	0	1
2 2008	528	288185312	0	1	3	3	0	3	4	0	0	0	4
3 2008	541	322221004	0	0	6	5	0	2	4	2	0	1	4
4 2008	677	418442677	1	0	6	6	0	3	8	0	0	0	5
1 2009	398	243888849	0	0	19	19	0	14	16	3	0	0	15
2 2009	431	261309751	0	0	21	21	2	18	17	11	1	0	14
3 2009	496	314906981	0	0	34	34	0	31	32	6	1	1	15
4 2009	402	240075824	1	0	27	27	0	26	26	5	0	0	9
1 2010	307	177827193	2	0	39	39	0	35	35	6	0	1	24
2 2010	366	213712309	1	1	13	13	1	12	13	4	0	0	8
3 2010	529	279333657	0	1	27	27	2	21	24	3	0	1	24
4 2010	482	309025022	0	2	26	26	0	19	25	3	0	0	20
1 2011	353	233207132	1	1	27	27	0	16	26	0	0	0	25
2 2011	420	269768292	1	0	26	25	2	18	28	4	0	0	27
3 2011	488	295532149	4	4	55	55	5	31	52	5	0	2	50
4 2011	503	341093825	8	5	175	175	15	123	168	11	5	5	164
1 2012	470	352924579	41	6	356	357	27	216	329	34	5	11	327
2 2012	554	394919998	26	14	425	426	42	278	399	28	7	6	402
3 2012	485	339715351	11	10	361	359	23	221	338	25	8	9	336
4 2012	498	324400556	31	5	339	338	62	215	308	32	4	12	312
1 2013	362	243436196	11	6	269	268	40	164	256	26	6	6	241
2 2013	455	298218340	10	8	336	332	20	208	317	27	3	5	311
3 2013	427	303409300	9	9	325	321	26	200	293	34	6	3	294
4 2013	458	319833738	10	4	320	319	69	210	311	22	5	3	285
1 2014	310	209402431	17	8	221	222	24	157	210	21	6	5	207
2 2014	449	313265023	57	3	343	342	94	231	328	24	11	4	317
3 2014	389	321647572	21	5	290	290	17	188	272	21	7	6	270
4 2014	654	519648754	66	12	473	474	126	342	448	53	23	5	443
1 2015	84	55182027	2	4	74	74	6	38	70	6	0	4	72
2 2015	203	130552464	25	15	186	180	17	116	172	28	5	18	176
3 2015	242	177454300	40	17	228	227	24	155	220	9	5	4	219
4 2015	277	199719888	54	14	260	255	46	192	251	15	15	2	248

Table 10 Data on initial transactions for the stratum Adriatic Coast – existing in the period from Q4 2007 to Q4 2015

Quarter	Number	Value	Elevator	Attic/basement	Electricity	Water	Gas	Sewage system	Completed	Incomplete (Rohbau)	Luxury	Renovated	Good condition
4 2007	1638	876607101	0	1	3	3	0	2	3	0	0	1	2
1 2008	1436	751521645	0	0	1	1	0	0	1	0	0	0	1
2 2008	1454	781952321	0	0	0	0	0	0	0	0	0	0	0
3 2008	1339	705777733	0	0	1	1	0	0	0	0	0	1	0
4 2008	1334	729032323	2	0	17	17	0	15	16	0	0	0	15
1 2009	832	440798649	0	0	50	50	0	46	48	0	0	6	34
2 2009	1117	574988928	1	0	38	38	0	37	36	0	0	1	31
3 2009	1172	606396819	0	0	45	44	1	37	44	1	0	8	30
4 2009	1028	540921905	0	0	46	46	0	42	42	2	0	3	35
1 2010	926	458459212	0	1	56	56	0	49	52	1	0	7	45
2 2010	1159	569542983	0	0	55	55	0	46	48	0	0	6	47
3 2010	1314	652659386	4	0	72	72	0	61	66	0	0	11	55
4 2010	1210	615920663	1	2	43	42	1	36	39	2	0	19	23
1 2011	1090	554949449	0	1	34	34	0	27	26	4	1	13	15
2 2011	1345	699819710	3	6	51	51	0	37	40	6	0	28	28
3 2011	1433	709942961	1	4	97	93	5	49	83	11	1	46	56
4 2011	1233	653035760	23	14	277	274	18	214	243	10	2	128	155
1 2012	1016	550733760	78	35	690	685	79	552	587	21	2	333	364
2 2012	1045	555654986	49	26	708	697	86	543	637	29	1	316	384
3 2012	1085	590233907	41	19	767	756	78	593	678	28	0	335	411
4 2012	1038	553202966	31	23	734	720	76	573	647	28	1	350	353
1 2013	921	466937883	36	26	652	641	83	497	577	21	1	300	340
2 2013	1241	683873673	45	39	922	909	109	703	808	35	2	365	512
3 2013	1021	505698125	45	25	708	694	75	513	619	24	1	320	379
4 2013	1016	562300068	29	36	693	685	81	541	623	44	0	336	357
1 2014	811	468338987	69	31	555	547	79	417	498	17	0	275	298
2 2014	1071	602306814	58	19	708	696	74	518	660	22	2	334	420
3 2014	1098	597610810	69	24	754	748	82	559	691	24	1	360	415
4 2014	1307	751648067	79	32	841	828	120	658	778	34	2	389	484
1 2015	984	597385225	86	41	828	815	76	642	799	31	3	366	463
2 2015	1252	775434623	143	42	1103	1095	111	843	1087	29	5	474	634
3 2015	1205	655768595	83	36	1007	988	96	723	1008	33	1	434	606
4 2015	1301	754306221	134	42	1105	1089	82	813	1084	43	2	519	605

Table 11 Data on initial transactions for the stratum Other – new in the period from Q4 2007 to Q4 2015

Quarter	Number	Value	Elevator	Attic or basement	Electricity	Water	Gas	Sewage system	Completed	Incomplete (Rohbau)	Luxury	Renovated	Good condition
4 2007	377	143872140	0	0	0	0	0	0	0	0	0	0	0
1 2008	362	136171727	0	0	0	0	0	0	0	0	0	0	0
2 2008	296	119015642	0	0	0	0	0	0	0	0	0	0	0
3 2008	294	117653826	0	0	1	1	1	1	1	0	1	0	0
4 2008	386	144870962	0	0	0	0	0	0	0	1	0	0	0
1 2009	361	143878581	1	0	2	2	2	2	0	1	0	0	1
2 2009	353	134840653	0	0	1	1	0	1	0	1	0	0	0
3 2009	383	157679772	0	1	2	2	1	2	2	0	0	0	2
4 2009	459	177619535	0	0	6	6	6	6	7	0	0	0	6
1 2010	338	135076384	1	0	2	2	2	2	1	1	0	1	1
2 2010	334	130084365	0	1	1	1	1	1	1	0	0	1	1
3 2010	264	108000822	1	0	5	5	4	5	5	0	0	0	4
4 2010	294	108738632	0	0	6	6	4	6	6	0	0	0	6
1 2011	316	115147065	0	0	10	10	5	10	8	2	0	1	9
2 2011	358	147986174	1	0	18	18	14	18	16	3	0	1	14
3 2011	374	142693145	4	1	40	39	21	39	40	2	1	0	37
4 2011	275	112457433	23	4	88	86	75	85	82	9	7	2	76
1 2012	307	134219550	51	7	257	253	221	246	233	21	17	1	225
2 2012	221	103303335	45	8	198	197	182	195	188	10	12	3	166
3 2012	171	71499795	14	2	138	138	115	135	125	13	4	5	128
4 2012	223	95522889	35	4	202	202	169	200	194	4	6	4	185
1 2013	119	51196030	19	3	93	93	90	92	80	10	4	3	78
2 2013	169	75836341	34	4	139	139	129	132	126	13	3	1	132
3 2013	148	55967322	10	2	120	121	86	118	110	10	1	2	112
4 2013	174	77481600	28	1	154	153	130	149	139	10	10	2	138
1 2014	92	43274038	29	0	82	83	76	81	78	5	3	0	78
2 2014	104	47494577	27	5	91	91	81	85	88	7	3	1	81
3 2014	97	45503715	32	4	81	81	71	76	74	11	3	1	72
4 2014	203	100191227	42	5	181	182	163	171	158	19	8	3	161
1 2015	26	11629166	2	1	22	22	18	21	19	2	0	1	19
2 2015	53	22701275	18	5	49	49	42	47	46	3	5	3	41
3 2015	81	34765079	28	17	71	70	56	69	68	3	3	5	63
4 2015	93	50938887	45	7	90	90	88	87	86	4	18	3	69

Table 12 Data on initial transactions for the stratum Other – existing from Q4 2007 to Q4 2015

Quarter	Number	Value	Elevator	Attic or basement	Electricity	Water	Gas	Sewage system	Completed	Incomplete (Rohbau)	Luxury	Renovated	Good condition
4 2007	2152	442624618	0	0	4	4	1	3	4	0	0	0	4
1 2008	1906	392661725	0	0	1	1	0	1	0	1	0	2	0
2 2008	2138	433064263	0	0	1	1	0	0	0	0	0	1	0
3 2008	2061	409144772	0	0	0	0	0	0	0	0	0	0	0
4 2008	2042	405623938	0	0	5	5	2	5	3	0	0	1	3
1 2009	1324	275524033	0	0	2	1	0	1	1	1	0	1	1
2 2009	1519	280343751	0	0	3	3	0	2	3	0	0	3	1
3 2009	1370	261062514	0	0	4	4	1	3	6	1	0	3	3
4 2009	1339	270039487	1	0	4	4	3	3	3	1	0	0	3
1 2010	1066	221507553	0	0	10	9	4	9	10	0	0	4	9
2 2010	1323	236697789	1	0	10	10	5	7	8	0	0	4	3
3 2010	1422	268932614	1	0	16	16	3	10	12	1	0	8	7
4 2010	1388	260642798	1	1	26	22	4	18	20	1	0	10	12
1 2011	1210	242658000	1	2	51	46	12	38	50	4	0	29	25
2 2011	1401	276261021	3	1	77	63	14	51	59	5	0	33	36
3 2011	1287	262859546	5	4	104	90	44	72	103	9	1	60	47
4 2011	1028	219030207	10	6	200	185	71	150	193	8	0	98	124
1 2012	850	210286189	46	14	629	606	279	532	538	28	0	301	342
2 2012	754	190432283	26	11	596	562	263	484	502	20	1	320	268
3 2012	717	176875632	37	9	532	497	225	438	443	21	1	254	274
4 2012	691	165125356	36	5	515	489	217	426	417	21	1	254	242
1 2013	579	140365097	24	11	427	412	197	347	325	23	0	220	187
2 2013	743	175941664	43	6	540	516	234	439	436	12	0	292	242
3 2013	634	145330980	28	13	492	467	204	414	399	22	0	243	252
4 2013	580	156019027	27	7	495	486	219	429	424	17	0	236	241
1 2014	498	137427796	27	6	430	419	199	373	375	13	1	221	198
2 2014	489	128012066	25	9	431	417	210	383	379	15	0	224	207
3 2014	544	143036521	25	7	452	443	206	392	374	12	0	229	209
4 2014	612	154666550	26	8	528	519	263	456	464	11	1	246	261
1 2015	477	128857844	21	15	387	379	191	340	367	16	0	178	204
2 2015	581	147943603	48	10	422	413	196	378	420	5	1	200	227
3 2015	638	168747921	37	24	441	434	220	379	432	16	1	195	249
4 2015	589	162456364	47	7	436	435	234	391	425	17	1	215	229

Table 13 Number and value of transactions after the second phase of elimination of outliers for the City of Zagreb in the period from Q4 2007 to Q4 2015 and the accompanying R^2 coefficients

Quarter	City of Zagreb – new			City of Zagreb – existing		
	Number	Value	R^2	Number	Value	R^2
4 2007	799	488039645		1076	704036765	
1 2008	724	462704187		865	549040772	
2 2008	850	555075336		937	577097086	
3 2008	765	491725286		848	508585184	
4 2008	714	458514595		929	556366649	
1 2009	566	394561243		599	347963108	
2 2009	840	557709540		619	355860506	
3 2009	671	441786340		549	309168923	
4 2009	701	446507085		647	365283300	
1 2010	553	340563631		599	327262285	
2 2010	661	386254090		684	375376409	
3 2010	549	323742361		561	285556719	
4 2010	666	385151637		653	324802492	
1 2011	564	328887750		587	298000673	
2 2011	576	343760136		621	323082656	
3 2011	415	241670261		545	278487614	
4 2011	285	183721097		652	326026255	
1 2012	305	191326534	0.94	601	297098590	0.90
2 2012	283	174608289		551	271799419	
3 2012	223	133890862		489	236001366	
4 2012	225	140049365	0.89	540	258287599	0.90
1 2013	229	148794419	0.88	459	218336675	0.90
2 2013	263	144648682	0.91	588	275470720	0.90
3 2013	208	111519997	0.92	422	184858672	0.90
4 2013	155	86578059	0.94	632	286251439	0.89
1 2014	109	60705858	0.94	488	225475588	0.89
2 2014	133	83220811	0.94	525	244434091	0.89
3 2014	123	71762800	0.93	542	247529897	0.88
4 2014	146	89860218	0.94	596	272051849	0.88
1 2015	15	10614102	0.87	502	234558114	0.88
2 2015	73	51946323	0.88	678	315395809	0.89
3 2015	69	36438196	0.90	616	284970654	0.89
4 2015	151	87850861	0.92	579	268610668	0.90

Note: If the residential property from a quarter participated in several models, the table shows the number and value of transactions for only one quarter.

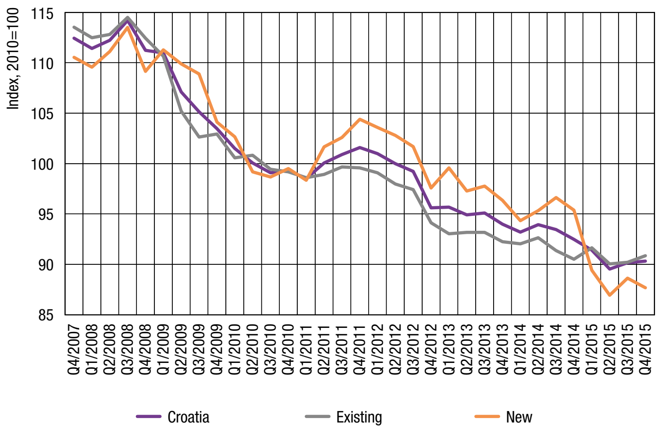
Table 14 Number and value of transactions after the second phase of elimination of outliers for the region Adriatic Coast in the period from Q4 2007 to Q4 2015 and the accompanying R^2 coefficients

Quarter	Adriatic Coast – new			Adriatic Coast – existing		
	Number	Value	R^2	Number	Value	R^2
4 2007	551	320797087		1323	724445239	
1 2008	374	217852034		1116	621477066	
2 2008	448	243698199		1163	654058101	
3 2008	459	267205877		1060	581377971	
4 2008	584	357610280		1054	598066300	
1 2009	332	204685184		647	353318250	
2 2009	351	217157564		872	466329537	
3 2009	422	268605844		918	473444097	
4 2009	339	199485038		812	439002879	
1 2010	265	151282768		731	373679607	
2 2010	300	166299386		902	438607372	
3 2010	462	237513193		1030	512726666	
4 2010	415	252730084		941	490618877	
1 2011	298	178636889		864	448060584	
2 2011	364	218106700		1070	561793806	
3 2011	424	247006471		1102	556694516	
4 2011	437	270892824		977	525142385	
1 2012	406	298632761	0.85	820	455542929	0.82
2 2012	475	319540977		840	445769658	
3 2012	417	280540813		867	476754674	
4 2012	434	266509079	0.82	821	429648074	0.85
1 2013	312	198486916	0.83	710	379360195	0.85
2 2013	381	232327553	0.84	1008	558371235	0.84
3 2013	358	237988486	0.84	824	418582815	0.85
4 2013	381	237473358	0.84	838	480925205	0.88
1 2014	269	172838006	0.83	674	377858209	0.88
2 2014	388	257549923	0.84	894	487204528	0.87
3 2014	340	257104178	0.85	932	484185144	0.87
4 2014	557	403312203	0.85	1097	608925239	0.85
1 2015	67	42129993	0.86	826	473485266	0.87
2 2015	166	99582823	0.85	1043	609880599	0.87
3 2015	209	129307563	0.84	1002	524578841	0.87
4 2015	231	154137796	0.84	1092	603055957	0.87

Table 15 Number and value of transactions after the second phase of elimination of outliers for the region Other in the period from Q4 2007 to Q4 2015 and the accompanying R^2 coefficients

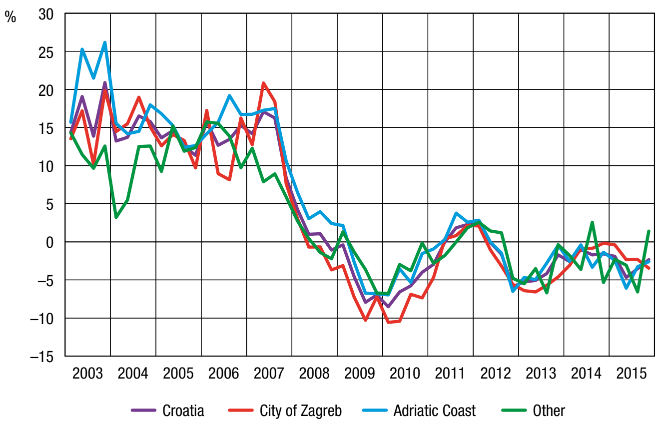
Quarter	Other – new			Other – existing		
	Number	Value	R^2	Number	Value	R^2
4 2007	278	112309343		885	243346899	
1 2008	283	112893284		766	222279491	
2 2008	212	90263766		863	236933921	
3 2008	237	99164080		756	205396564	
4 2008	295	114229068		807	225378864	
1 2009	271	119738916		545	160859324	
2 2009	251	110387590		643	170432600	
3 2009	273	118775061		562	156653183	
4 2009	349	148628044		625	173594710	
1 2010	257	111245084		490	130352013	
2 2010	245	106795537		472	124413650	
3 2010	192	87128660		627	155023487	
4 2010	215	84277283		649	160845382	
1 2011	244	96045049		636	156431600	
2 2011	286	122773628		770	189744600	
3 2011	256	115077434		688	180210056	
4 2011	210	91918050		599	155568687	
1 2012	222	104283832	0.88	572	160646163	0.86
2 2012	175	86598530		483	145745709	
3 2012	117	51667417		488	136239639	
4 2012	180	76024038	0.88	468	127051214	0.86
1 2013	96	43234426	0.87	402	114051848	0.86
2 2013	135	61577989	0.87	479	135477297	0.85
3 2013	85	38531282	0.88	454	113679942	0.87
4 2013	142	65358828	0.89	428	126194924	0.87
1 2014	77	36629945	0.90	365	110882976	0.87
2 2014	85	39686129	0.89	349	100572966	0.87
3 2014	79	37836539	0.90	400	118694030	0.85
4 2014	163	76471933	0.91	458	121154315	0.86
1 2015	21	10054433	0.91	358	106543703	0.85
2 2015	39	17037719	0.89	432	120288371	0.86
3 2015	66	28554617	0.87	474	132830848	0.84
4 2015	79	39218139	0.89	462	131011783	0.83

Figure 14 House price indices for new, existing and all residential property in the period from Q4 2007 to Q4 2015



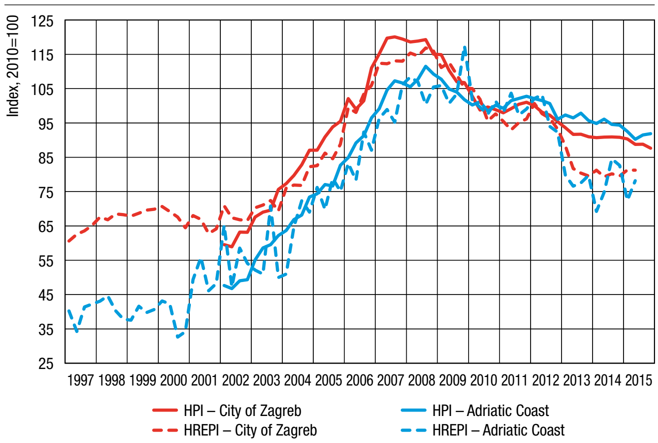
Source: CNB.

Figure 15 House price indices for the period from Q1 2002 to Q4 2015 (annual rates)



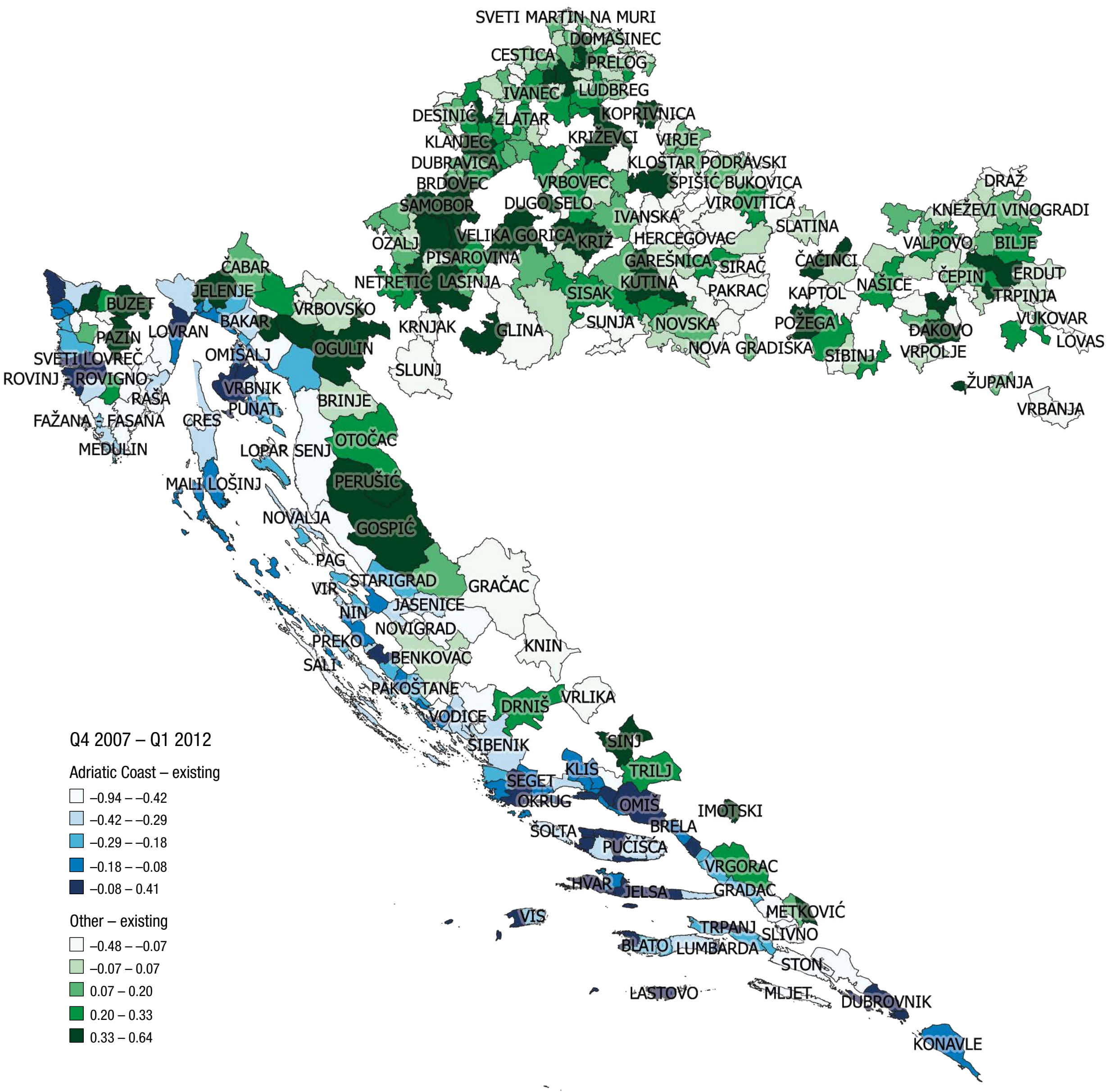
Source: CNB.

Figure 16 Comparison of HPI and HREPI for the City of Zagreb and Adriatic Coast



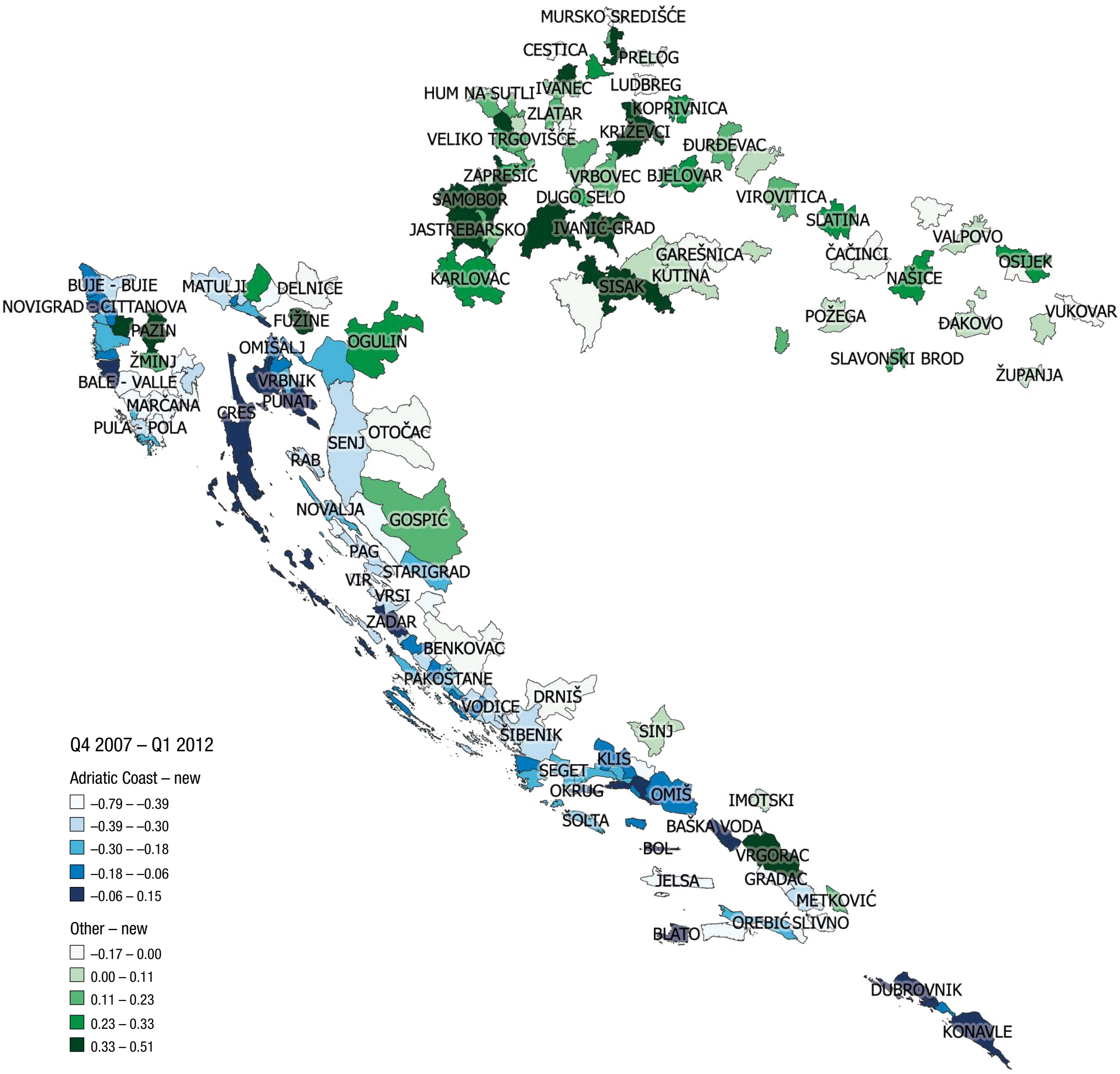
Source: CNB.

Figure 17 Coefficients with location dummy variables for the strata Adriatic Coast – existing and Other – existing for the period from Q4 2007 to Q1 2012



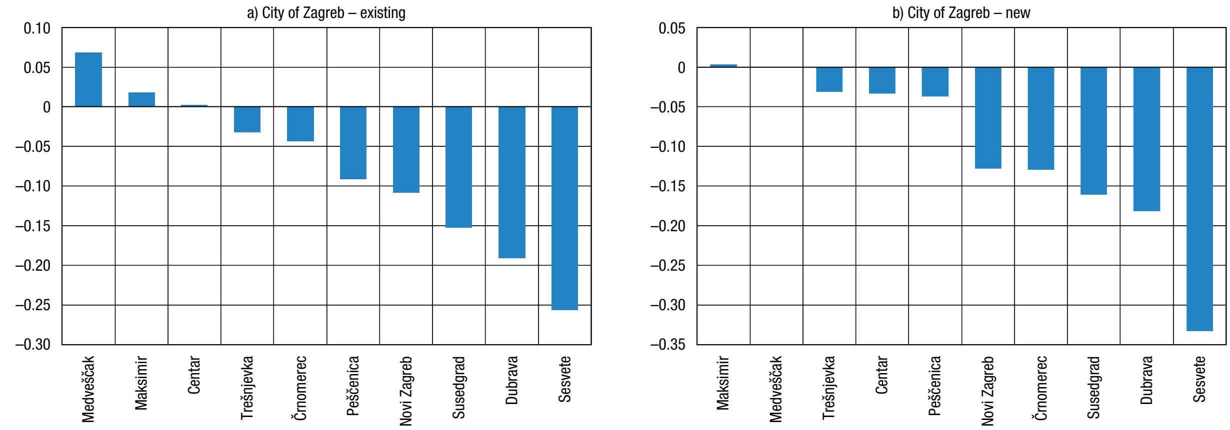
Source: CNB.

Figure 18 Coefficients with location dummy variables for the strata Adriatic Coast– new and Other – new for the period from Q4 2007 to Q1 2012



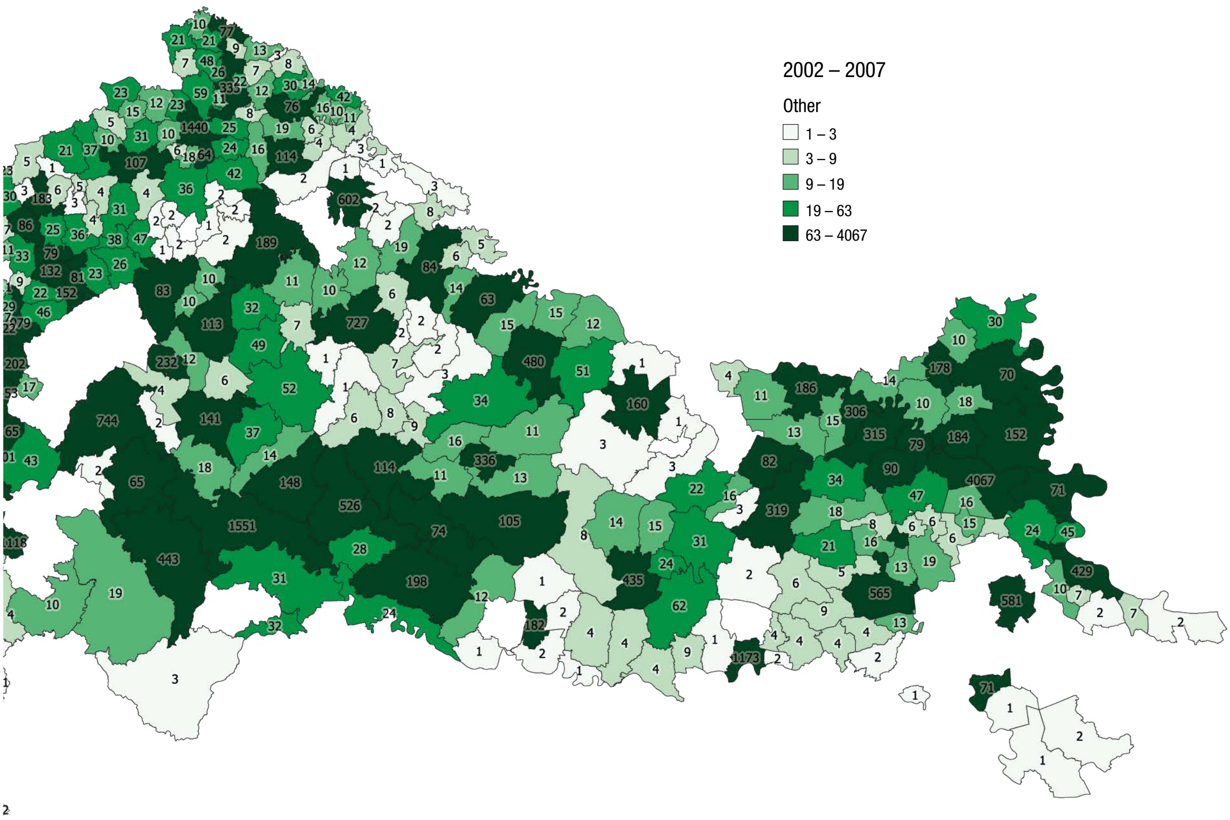
Source: CNB.

Figure 19 Coefficients with location dummy variables for the City of Zagreb for the period from Q4 2007 to Q1 2012



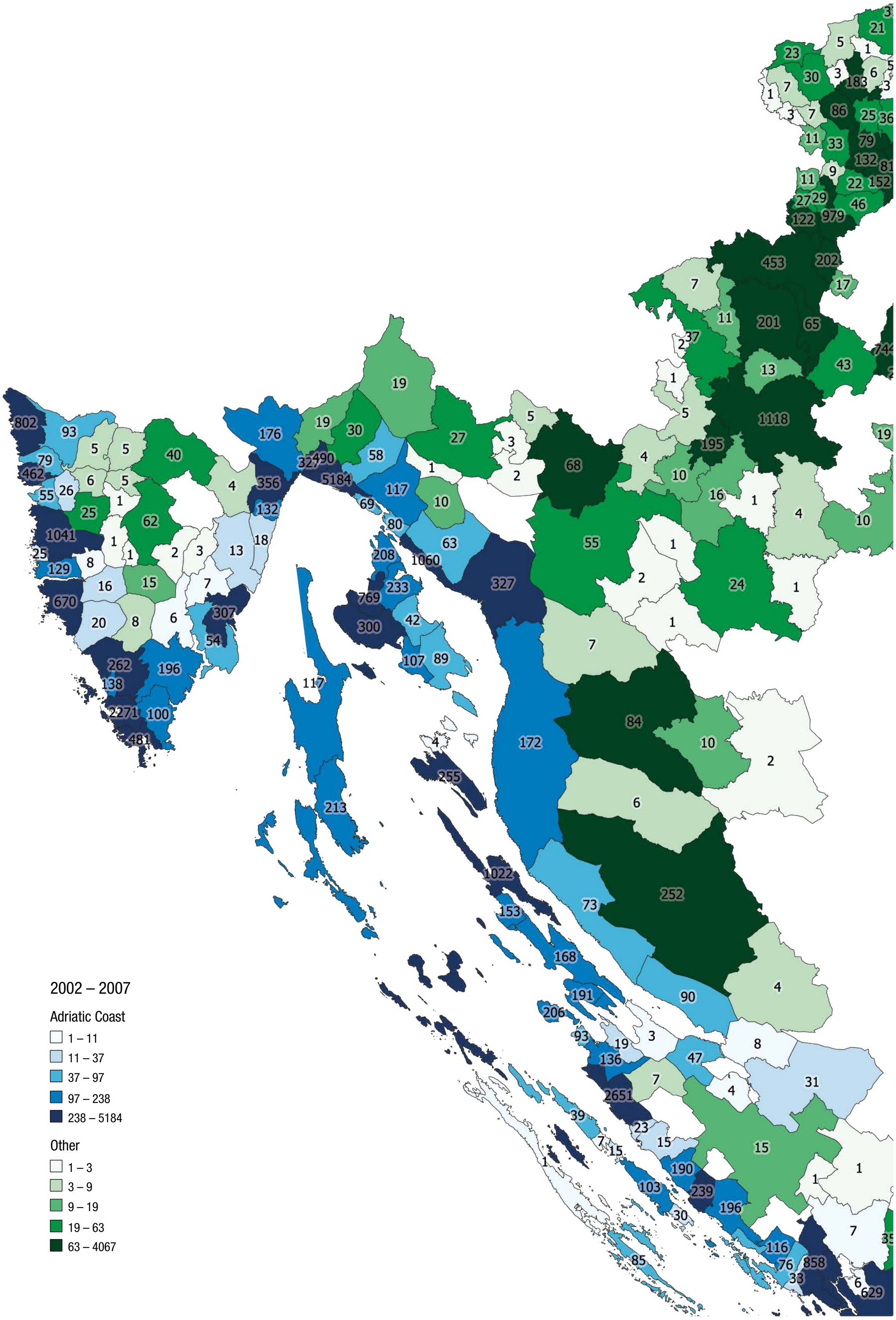
Note: These values are interpreted as deviations from the prices for the Trnje neighbourhood.
Source: CNB.

Figure 20 Distribution of residential property sold in the period from 2002 to 2007 for the regions Adriatic Coast and Other – 1st part



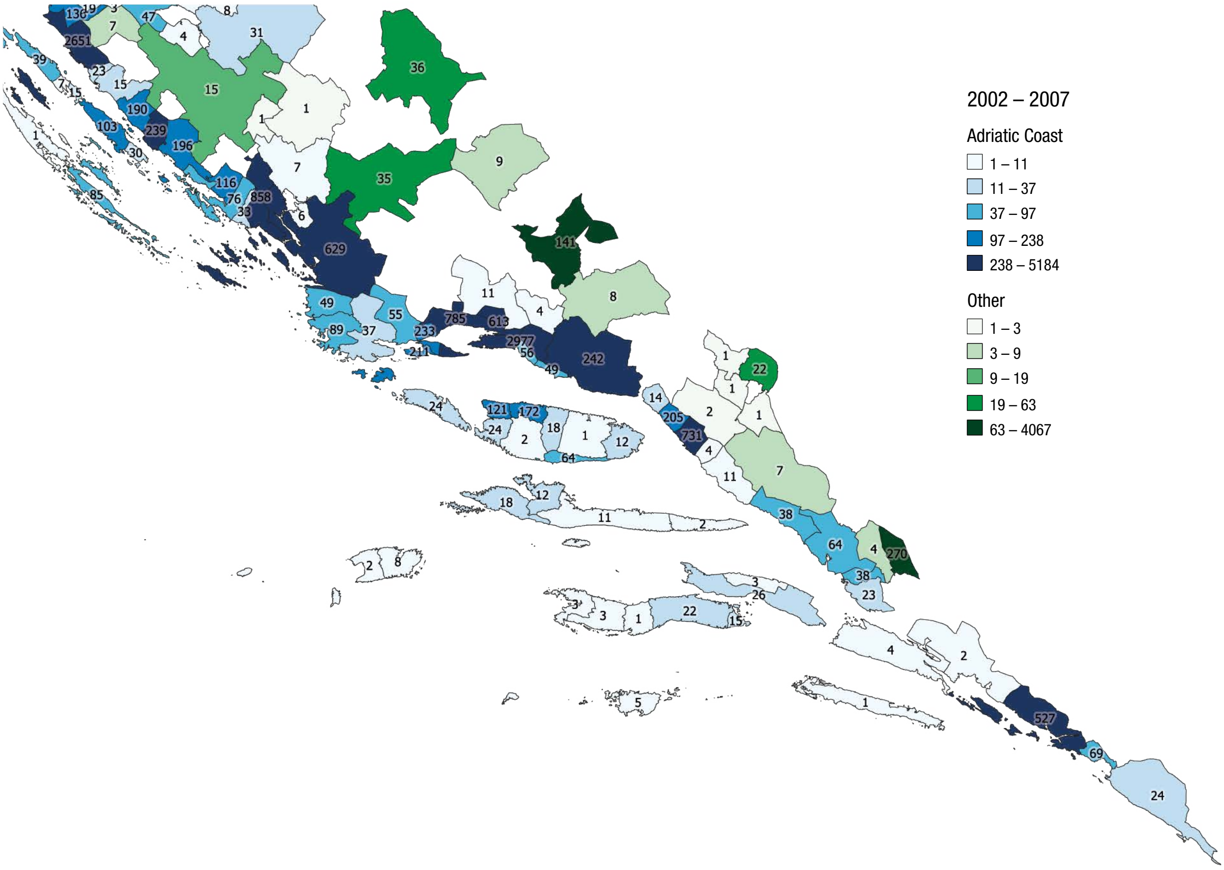
Source: CNB.

Figure 21 Distribution of residential property sold in the period from 2002 to 2007 for the regions Adriatic Coast and Other – 2nd part



Source: CNB.

Figure 22 Distribution of residential property sold in the period from 2002 to 2007 for the regions Adriatic and Other – 3rd part



Source: CNB.

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