Price indices for residential premises in small areas on the example of a selected market in Poland

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Abstract The discussion about the real estate price indices in Poland dates back to the beginning of the transformation period. Despite the statutory regulations, the creation of these indices continues to face formal, organizational as well as methodological obstacles. The methodology for building these indices, despite the rich foreign experience in this area, is also not established. The proposed article refers to the Nobel Prize winner from 2013 prof. Robert Shiller, who pointed to the need to build house price indices in homogeneous areas, for example, due to the level of urbanization, population size and based on them, the construction of aggregated price indices for larger areas. The foundation of the construction of property price indices in this concept is the definition of a typical home, which is a permanent reference point in subsequent periods of the study. In the proposed article discusses the problem of constructing price indices of housing in small areas, indicating a typical dwelling in trading on the secondary market. On this basis, an attempt was made to determine the price index for a small area, i.e. a homogeneous area due to the price-setting factors important for the residential real estate market. Each transaction is described by a set of several quantitative and qualitative features. Price indices will be determined to take into account the methodology used to determine them in the literature. The research hypothesis concerning the discrepancy of the indices values will be verified using various criteria for selecting the spatial extent of the studied area. The obtained results are a contribution to further research on other local markets and for other types of real estate.

1. Introduction
The measurement of the house price level and dynamics is complex due to the character of the market, heterogeneity of housing stock as well as difficult access to relevant data. These issues are solved in various ways depending on the country, however, in the last few years, hedonic methods prevail.

Apartments are highly inhomogeneous goods [1]. Even two identical apartments differ in their location on a different floor or in another district of the city. Other costs may also be caused by their maintenance, which determines the attitude of buyers and the transaction price. The price is also influenced by other measurable features such as space, number of rooms, age of the building, or technology. However, also personal traits significantly affect prices; it is individually assessed the distance from shops, schools, cultural centres, or communication. It is also a fashion for the location in a specific district, which is influenced by the proximity of other types of real estate, including beneficial effects such as green or recreational areas and unfavourable locations such as industrial areas or exposing neighbouring properties to excessive noise or air pollution. Besides, the assessment of all these parameters may change over time as a result of changes in buyers' preferences and as a result of the natural depreciation of the housing stock and its modernization. Also, macroeconomic factors, apart from cyclical economic fluctuations caused by social and economic changes, significantly affect price fluctuations, and as a result, determine the dynamics and amplitude of fluctuations in housing price indices. The study of the dynamics of house prices is associated with the
identification of market mechanisms of price changes, growth parameters, local market potential and directions of spatial impact [2] external effects on the housing market [3].

The assumptions made are of particular importance in advanced methods of measuring housing price indices. They affect the accuracy of the measurement, which is the subject of theoretical studies and empirical research. Researchers indicate that (among others [4], [5], [6]) for the two biggest problems related to the measurement of price trends in residential real estate markets and the construction of price indices. The first of these is the heterogeneity of flats, which creates difficulties in comparing the prices of different flats, as these flats almost always differ in qualitative features. Besides, their impact on the price changes over time according to the fashion and changes in the preferences of buyers. Buyers change their preferences and their hierarchy. These features reflect the changing preferences of buyers who value the purchased flat through their own and variable during the waiting period [7]. Price-building features of the flat and their change cause a change in the price, which, however, should not affect the measurement of the pure price dynamics.

Another barrier that makes it challenging to build a sample of representative data in each of the periods for which price indices are determined is a relatively small number of housing transactions creating homogeneous real estate samples that are the most similar to each other. Dwellings similar in type, location, and other features, and even the same apartments are usually sold at long intervals. Both price-building characteristics and their market evaluation change over time. This causes that between the periods studied it is challenging to obtain a representative sample of housing transactions, such as in the base period. Also, the set of prices that can be observed in a given period is determined by the type of flats that were traded at that time. Hence, there is no final and stable set of apartment features that can be used to construct timeless price indices.

The solution to the above problems is a priority in the process of building high-quality housing price indices [8]. For this reason, numerous researchers modify traditional methods of determining price indices, using more and more advanced statistical and econometric methods. As a result of this research, in addition to the simplest method of measuring price trends on the housing market, i.e. using the average or median, a group of methods for creating price indices based on classical and non-classical models was created. Among them, there are proposals for numerous modifications of hedonic regression, which, to some extent, take into account the problem of data heterogeneity.

The inaccuracy of measurements becomes particularly important when large, often heterogeneous markets are analysed, which are strongly influenced by macroeconomic factors. Robert Shiller [9] assumed that the home price indices must be set for small and homogeneous areas and then be aggregated for larger areas. To choose the research area you can use traits of the property (most often qualitative) or environmental features of the property. These assumptions allow to differentiate relatively homogenous groups of apartments due to their quantitative or qualitative traits and to construct the apartment price indices for small areas.

In practice, many methods and different indicators of property prices coexist, often determined based on own and limited sets of data held by the institution constructing a given indicator. First of all, they differ in the approach to reduce the features of the examined objects to comparability, in order to overcome the limitations that their change brings along with the passage of time and changes in the preferences of buyers. In addition to simple indexes (Laspeyre, Paasche or Fisher indexes), three primary groups of methods are used: mix-adjustment, hedonic regression, models based on resale of apartments [10] and their compilations, e.g. hybrid method [9], [11], [12].
The simplest methods for determining housing price indices are methods based on averages: the arithmetic mean, the weighted arithmetic mean and the geometric mean. In each case, for a given period, the average transaction price of apartments is determined, which is the basis for determining single-base or chain indexes. The method works well for similar observations and balanced samples, i.e., homogeneous, also due to the number of samples and distributions of particular types of dwellings in groups. The advantage of these methods is the simplicity of calculations.

The second group of methods is a method based on hedonic regression. At the same time, they differ in the reference point or values adopted for estimation in single years. An advantage of hedonic regression is the inclusion of price-building features in models, the disadvantage being the instability of these features over time. Hence, the numerous modifications of hedonic methods. In selected methods, the equation estimated for the first period can be used as the basis point, and in the next ones, the data for typical transactions (reassessing method) should be taken into account or the average values of features for the set of transactions included in subsequent periods should be determined (reassessment method).

Indices of housing prices and real estate, in general, have more and more practical applications, hence the increasing interest of researchers in improving the way they are designated. There is a number of areas where residential property price indices play a role. The following applications are considered:

- as a macro-economic indicator of economic activity;
- for use in monetary policy and inflation targeting;
- as a tool for estimating the value of a component of real wealth;
- as a financial stability or soundness indicator to measure risk exposure;
- as a deflator in the National Accounts;
- as an input into citizens’ decision making on whether to buy or sell residential property;
- as an input into the Consumer Price Index;
- for use in making inter-area and international comparisons.

In Poland, the only institution determining quarterly and annual house price indices for the primary and secondary market since 2006 for the most important cities is the National Bank of Poland. (NBP)

The study aims to determine the index of house prices in multi-family buildings on the local market with concentrated and similar buildings, due to the industrial technology of erection. Hedonic indexes and their modification were used to implement the set goal. The obtained results were compared with indexes based on averages and hedonic indices determined for the whole city by the NBP. The obtained results will be a methodological guide for the examination of other cities areas, with a particular focus the division into small areas. The study used tools of descriptive statistics and multidimensional analysis. The calculations were made in the Statistica 13.0 package.

2. Research methods

Two groups of the methods are used in the calculation of house price indices: simple methods and complex methods. The simplest methods are based on some measure of central tendency of the distribution of transaction prices in a period, in particular, the mean or the median. The complex methods to a varying extent take into account the importance of the quality indices elements: mix-adjustment, hedonic regression methods, repeat sales methods or hybrid methods. Using simple methods it's important to remember that since house price distributions are generally positively skewed (predominantly reflecting the heterogeneous nature of housing, the positive skew in income distributions, and the zero lower bound on transaction prices). It means that the median or geometric mean rather than the arithmetic mean is often used. As no data on housing characteristics are required
to calculate the median, price indices that track changes in the price of the median house sold from one period to the next can be easily constructed. Another attraction of median indices is that they are easy to understand. One major drawback of simple median based indices is that they provide very noisy estimates of price change. The set of houses actually traded in a period, or a sample there of, is typically small and not necessarily representative of the total stock of houses. Also, changes in the mix of properties sold will therefore affect the sample median price more than the median price of the housing stock. Additionally, a bigger problem than short-term noise is systematic error or bias. A median index will be subject to bias when the quality of the housing stock changes over time. Bias can also arise if certain types of houses are sold more frequently than other types of houses and at the same time exhibit different price changes.

The mix-adjustment method (the method of adjusted weighted prices) consists in the division of the studied population into homogeneous groups due to selected criteria - the characteristics of apartments, most often measured on weak scales. For each group, the average price is determined, which is weighted by the share (number) of a given group in the surveyed population. The reference period for index dynamics is the base period. The value of the index is determined as the weighted average price of a flat in a given period. The quality of the obtained indicator is determined by the selection of objects for each group, that is, the correct definition of a set of features that distinguishes the group. The acquired value of the index is also affected by the change in the preferences of buyers over time, especially when the index for long time series is constructed.

It should be noted that in this method, the change in the size of the surveyed population results in a change in the number of observations in each group, however, if the groups are defined accurately enough so that all its elements have similar price distributions and their trend, the change in sample size will not ultimately affect the adjusted price. When the same characteristics of flats are adopted in the tested samples, then the adjusted price method and the hedonistic regression method give very similar results. The advantage of the method is its simple construction, which, with a stable set of features and the structure of observations, allows the determination of useful housing price indices [13], [14].

However, both the hedonic method and the mix-adjustment method require a large number of observations, gathering information on all required features and high data reliability [15]. In some cases, such extensive information is not available. Then, you can limit the study to the set of sales price observations of a given flat at two time points (re-sale) and on this basis estimate the rate of change in prices. As in the previous methods, the effectiveness of the re-sale method is based on several assumptions. The most important of these is the acceptance that there were no changes in the characteristics of a given flat between the two investigated transactions affecting its price. Fulfilling the above assumption is the more difficult the longer the time between transactions in the same apartment. The advantage of the method is the observation of a limited set of objects, as well as the lack of the need to describe objects with an excessive number of features. The disadvantage is the load on the result with the selection of the sample because only those apartments that have been sold have been taken into account (the reasons for such decisions are also unknown). This sample may not be representative of the entire population. Also, the assumption about constancy in time of housing characteristics influences the load on the value of the determined index. The classic method of re-sale has undergone numerous modifications, eliminating the imperfections of the classical approach.

The most of popular complex methods based on hedonic indices method – the regression model where the property price is a function of its characteristics (both quantitative and qualitative). Regression models estimated separately for each study period are used to determine the apartment price indices. Usually, regression models are estimated separately for each study period are used to determine the apartment price indices. In this method, we assume the impact of the apartment characteristics on its price, to appraise which the following models are most frequently used.
Qualitative characteristics in the model adopt zero-one values. Estimating the model by means of the MNK method facilitates indicating the impact of variables on an apartment price in a given period. As the next step, standardization should be performed by applying the system of weights to the characteristics in a chosen period.

Another popular complex method is the repeat sales method, which utilizes information on the same properties which have been sold more than once. Because only “matched models” are used, there is no change in the quality mix to control for. In its basic form, the only information required is price, sales date, and address of the property. So the repeat sales method is much less data-intensive than hedonic methods. Also, the repeat sales method will automatically control for micro location (address), something which hedonic methods are unable to do. The long-term disadvantage of applying these indices is the fact that the structural changes in housing resources on the market are not taken into account.

All three methods have disadvantages. Both the hedonic method and the mix-adjustment method of determining the indexes are burdened with the same problems if there is no control all the significant features of the apartments accepted into the models. If certain features have been omitted in the hedonic regression or the structure of observations in groups has changed due to the mention of features characterizing the dwellings in a given sample, then there are inaccuracies in the estimated price indices. Besides, if the characteristics of apartments not included in the model were more significant in some phases of the business cycle, then the amplitude of fluctuations in the index in this period may be unjustifiably underestimated or inflated.

In the article, the arithmetic mean (due to homogeneous development of the housing estate) and the geometric price of housing (due to the lower sensitivity to outliers) were calculated in each analyzed period and on their basis the chain indexes. In the next step, the hedonic regression model was chosen, which in the general form can be written as:

\[
Y = \alpha_0 + \sum_{i=1}^{n} \alpha_i \cdot X_i + U
\]

where

- \(Y\) – dependent variable, usually unit price logarithm.
- \(X\) – independent variable,
- \(U\) – random error component.

However, modified [16] in which the regression coefficients for the base period are estimated. In the next step, a repricing index is calculated as the quotient of two components:

\[
I_n = \frac{p_n}{p_{n-1}} = \frac{QUPI_n}{QAF_n}
\]

where the numerator means the quotient of the geometric mean house prices on the secondary market in subsequent periods (quality unadjusted price index GUPI), while the denominator (quality adjustment price index QAF) means the changing index of unit price, using hedonic regression. The estimated parameters of the equation from the base period are used for subsequent periods. In subsequent periods, the average states of quantitative traits and the frequency of occurrence in the case of qualitative features are used.

The proposed method is the starting point for further in-depth analysis and modifications of the proposed indicators.

3. Date and research results

To choose the research area it could be used traits of the property (most often qualitative) or environmental features of the property. These assumptions allow to differentiate relatively homogeneous groups of apartments due to their quantitative or qualitative traits and to construct the
apartment price indices for small areas. The analysis covered one of the cities area in Szczecin – Słoneczne district over the years of 2004-2017. The choice of this research is determined by two reasons: objects are supported by their history and homogeneous building and years are supported by a phase of the business cycle on the real estate market.

Research hypothesis: the indices of housing prices assigned to a small area differ from the housing price indices for the whole city. To achieve this objective the information contained in the notarial deeds were used, in which each transaction described is a set of quantitative and qualitative variables. Each transaction, on the second housing market, was described with the following variables:

- \( P \) unit price (PLN/m²),
- \( AR \) area of sold apartments (m²),
- \( LE \) level (available, unavailable),
- \( NO \) number of rooms (1, 2, 3, 4),
- \( BR \) building renovation (yes, no),
- \( LO \) location in the building (available, unavailable),
- \( TE \) thermomodernization (yes, no),
- \( TK \) technical condition (good, bed),
- \( NE \) neighbourhood (advantage, disadvantageous),
- \( TR \) transport accessibility (advantage, disadvantageous).

For the city of Szczecin, NBP determines the average unit prices of apartments sold on the secondary market and the primary market for other largest cities in Poland. On the basis of the values published by the National Bank of Poland (website), quarterly price dynamics for the entire city of Szczecin in 2006-2018 were determined (Figure 1).

![Figure 1. Average transaction apartments price for Szczecin (2006-2018)](image_url)

Three trends can be observed in the considered period. Average unit prices of flats on the secondary market in Szczecin increased until the end of the third quarter of 2008 (from 2888 PLN/m² at the end of the third quarter of 2006 to 4,794 PLN/m² at the end of the third quarter of 2008), before falling until the end of 2015 up to the level of 3,753 PLN/m². It is only from the beginning of 2016 that the trend of rising prices can be seen again, even to the level of PLN 5,016 PLN/m² at the end of 2018. In the analysed period, average unit prices of flats in Szczecin fluctuated in the range of 3-5 thousand. PLN/m².
In the first step, the study focused on determining average prices and average value of another variable for each examined year. For each year, the following reference values (price apartment) were calculated from the obtained basics value.

For the surveyed local housing market in Szczecin, the average unit prices of apartments increased from 2004 to the end of 2010, longer than in the whole city, and the end of 2010 reached the level of 4,090 PLN/m². The drop-in prices in the following years lasted until the end of 2015, similarly as in the whole city of Szczecin, whereas at the end of 2015, the average prices reached 3,683 PLN/m².

At the end of the audited period, prices on the Słoneczne housing estate reached the average level of 3,859 PLN/m² and were lower than in the whole city by 12% (4,319 PLN/m²). In addition, the parameters of the trend power function were estimated, which was best suited to the empirical data ($R^2=74.27\%$). Evidence of the estimation has been adjusted in the graph below (Figure 2).

![Figure 2](image)

**Figure 2. Average transaction apartments price for Słoneczne district in Szczecin (2004-2017)**

Because the arithmetic mean is sensitive to outliers, the geometric mean of the unit prices of flats sold on the secondary market in the Słoneczne district was also determined for the surveyed area. In addition, the parameters of the trend power function were estimated, which was best suited to the empirical data ($R^2=65.12\%$). Evidence of the estimation has been adjusted in the diagram below (Figure 3).

![Figure 3](image)

**Figure 3. Geometric mean transaction apartments price for Słoneczne district in Szczecin (2004-2017)**
For the city of Szczecin, the NBP also sets a quarterly and annual hedonic index of housing prices sold on the secondary market, similarly to other major cities in Poland. The index has been created since 2006. On the basis of the values calculated by the National Bank of Poland [17] an annual chart of the changes of this index was determined, which will be useful to compare the tendencies in the studied market location with respect to the whole city (Figure 4).

![Figure 4. Three NBP prices apartments index for Szczecin (2006-2018)](image)

For the basic year (2004), the equation of multiple regression was determined, in which the dependent variable is the natural logarithm of the unit price of flats sold on the examined secondary market. The results of the estimation of this model are presented in the table (Table 1).

| Variable | Value of Coefficient | Standard error | t Stat | p-Value |
|----------|----------------------|----------------|--------|---------|
| free term | 7.860 | 0.126 | 62.617 | 0.000 |
| TE | 0.075 | 0.034 | 2.220 | 0.030 |
| LE | -0.009 | 0.003 | -2.723 | 0.009 |
| NO | -0.036 | 0.054 | -0.665 | 0.509 |
| AR | -0.004 | 0.004 | -1.002 | 0.321 |
| LO | 0.015 | 0.041 | 0.368 | 0.714 |
| TK | -0.089 | 0.053 | -1.691 | 0.096 |
| NE | 0.007 | 0.043 | 0.164 | 0.870 |
| TR | -0.028 | 0.041 | -0.677 | 0.501 |

$R^2=51.33\%$, $S(x)=0.10$

The regression equation from the basic year shows the mean values of variables from the multiple years of the analysis, defining the QUPI and QAF values used for calculating the price index (Table 2).

| Variable | Value of Coefficient | Standard error | t Stat | p-Value |
|----------|----------------------|----------------|--------|---------|
| free term | 7.860 | 0.126 | 62.617 | 0.000 |
| TE | 0.075 | 0.034 | 2.220 | 0.030 |
| LE | -0.009 | 0.003 | -2.723 | 0.009 |
| NO | -0.036 | 0.054 | -0.665 | 0.509 |
| AR | -0.004 | 0.004 | -1.002 | 0.321 |
| LO | 0.015 | 0.041 | 0.368 | 0.714 |
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| NE | 0.007 | 0.043 | 0.164 | 0.870 |
| TR | -0.028 | 0.041 | -0.677 | 0.501 |

$R^2=51.33\%$, $S(x)=0.10$
The determined values of the hedonic index, the author used values which are based on the index calculated on the basis of medium arithmetic and geometric values on a single graph (Figure 5). G-arithmetic arithmetic indexes show a high similarity, with arithmetic having a lower fluctuation amplitude. The hedonic index indicates similar trends, especially in 2009-2017, after a boom in the real estate market. In the years 2005-2008, its major fluctuations and annual shift in time are visible.

Comparing the indexes designated for the whole city by the NBP and for the small city area (Słoneczne district), there is a large similarity in the general tendency, however, in the period of the economic situation, there are variations and time cuts. This can be explained by the greater fashion for certain districts of the city, which results in higher prices, price imbalances in the longer term. Thus, it significantly influences the calculated index. The obtained results confirm, therefore, Shiler's concept of counting local indexes and aggregating them for larger areas, even within cities.

4. Conclusions
Monitoring the development of house prices (RPPIs) is considered important, especially in times of economic turbulence. Yet the way house price development is measured varies per country and even within a country, there are sometimes two or more competing methods in use. This situation is of course not favourable for the design of consistent policy measures based on solid international comparisons. The housing market is heterogeneous and the buyers’ preferences are not fixed in time. Also, the housing markets are local and properties are not identical. A characteristic feature of the real estate, including residential properties, is the small similarity and variability in time of characteristics significantly affecting their market price, which complicates the use of simple methods of determining price indices.
Broadly speaking, two separate types of RPPI can be distinguished: a constant quality price indices for the stock of residential housing at a particular moment in time: a constant quality price indices for residential property sales that took place during a particular period of time or the construction of these two types of indices will be different. The study focused on the first type of indicators. The article discusses the methods for determining housing price indices, focusing on hedonic models and indexes. Having a full set of transaction prices from notarial deeds regarding the sale of flats in the Słoneczne housing estate, a hedonic model was constructed for the unit price of a flat, taking into account the characteristics of flats and their changes over time, and compared with simple indexes based on arithmetic and geometric mean.

The obtained hedonic housing price index is in line with the tendencies on the housing market in Szczecin and indexes designated for the whole city by the NBP. Therefore, it can be considered that it describes the tendency well. Of course, changing the scope of the analysed transactions and expanding the study to the single-family housing as well would change the structure of variables so much that in the model, it would probably have to remain other explanatory variables than just the floor area. The result obtained confirms that neither in time nor in space are the features significantly affecting the price of flats permanent.

Acknowledgements
The project is financed within the framework of the program of the Minister of Science and Higher Education under the name "Regional Excellence Initiative" in the years 2019-2022, project number 001/RID/2018/19, the amount of financing PLN 10,684,000.00.

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