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# DEPENDENCE OF HOUSING REAL ESTATE PRICES ON INFLATION AS ONE OF THE MOST IMPORTANT FACTORS: POLAND'S CASE

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### Abstract

The study aimed to examine the impact of inflation on the real estate market using Polish panel data for the last 13 years. It is based on a panel model, where price changes of one square meter of housing are determined as a function in changes of inflation, the central bank's base rate, dwellings built, as well as new mortgage loans. The quarterly dynamics of the average price of 1 square meter of housing in Poland's eight largest cities in the 2009-2021 period was studied. This price was modeled and predicted using one of the Box-Jenkins time series models: the Holt-Winter model of exponential smoothing with a damped trend. The forecasting results showed a small (up to 4%) relative error in comparison with the actual data. In addition, the moment (2017) of the price trend change was found. Therefore, piecewise linear regressions with high regression coefficients were used when modeling the impact of inflation changes on the real estate market indicators under consideration. The results obtained provide valuable insight into the relationship of real estate market indicators, allowing consumers to predict available options and make decisions in accordance with their preferences.

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**Keywords:** *real estate, housing, inflation, Poland.*

**JEL Classification:** *R15, R31, R42.*

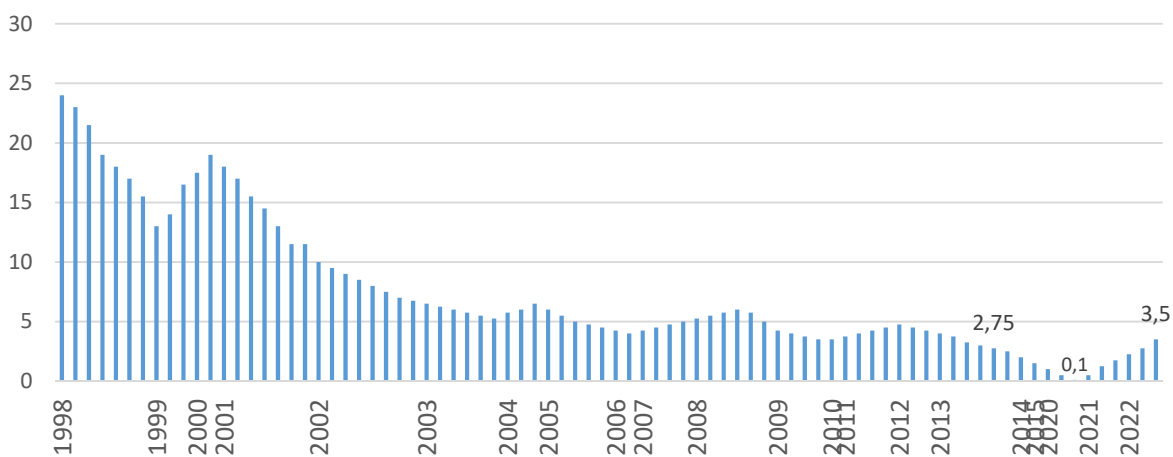
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### 1. Introduction

Because of the sharp decline in global production caused by restrictions due to the spread of the SARS-COV-2 coronavirus (Melnychenko, 2021a), as well as the global saving glut and migration processes (McGurk, 2020; Rosso, 2019), monetary authorities around the world have embarked on an unprecedented policy of increased short-term interest rates. Poland's central bank (National Bank of Poland, Narodowy Bank Polski, NBP) also changed the base interest rates, which in turn affected the cost of loans. In Poland, most household mortgages are issued based on a variable interest rate, which consists of a relatively stable bank margin and the interest rate on borrowings in the Polish interbank money market (WIBOR - Warsaw Interbank Offer Rate). As of early 2022, real estate market participants expect further uncertainty in the sentiment of investors and buyers based on the last five decisions of the Monetary Policy Council (the directing bodies of NBP), due to which October, November and December 2021 and January-March 2022 saw the base interest rates gradually rise from the historically lowest level of 0.1% to as much as 3.5%, the highest level in the last 7 years (Figure 1). Until October 2014, the reference rate was 2.5%, after which it decreased from 2% in 2014 to 0.1% in May 2020.

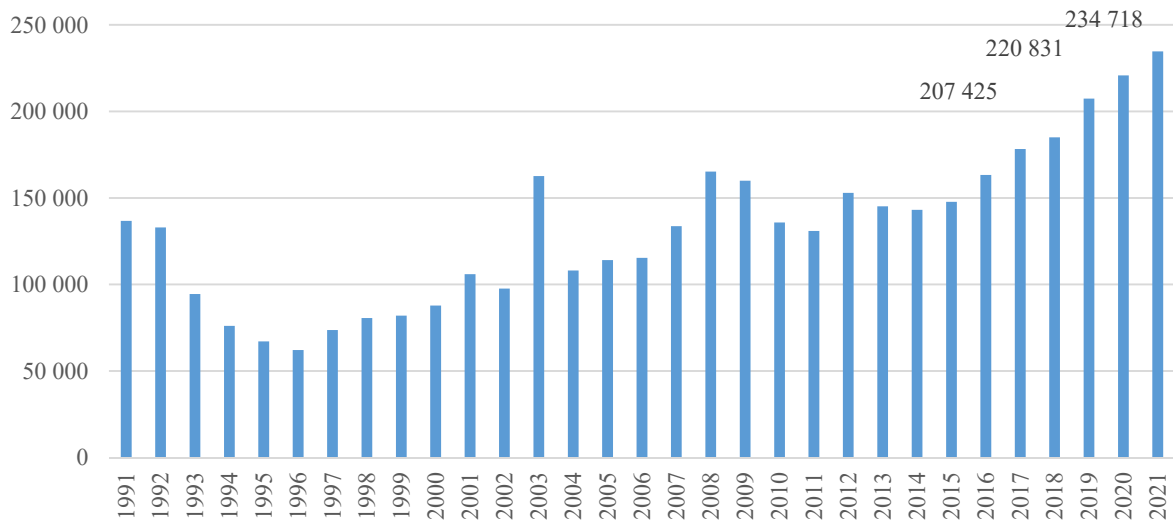


**Fig. 1.** Reference rate of the National Bank of Poland in the 1998–2022 period. *Source:* Developed by the authors based on (Narodowy Bank Polski, 2022b).

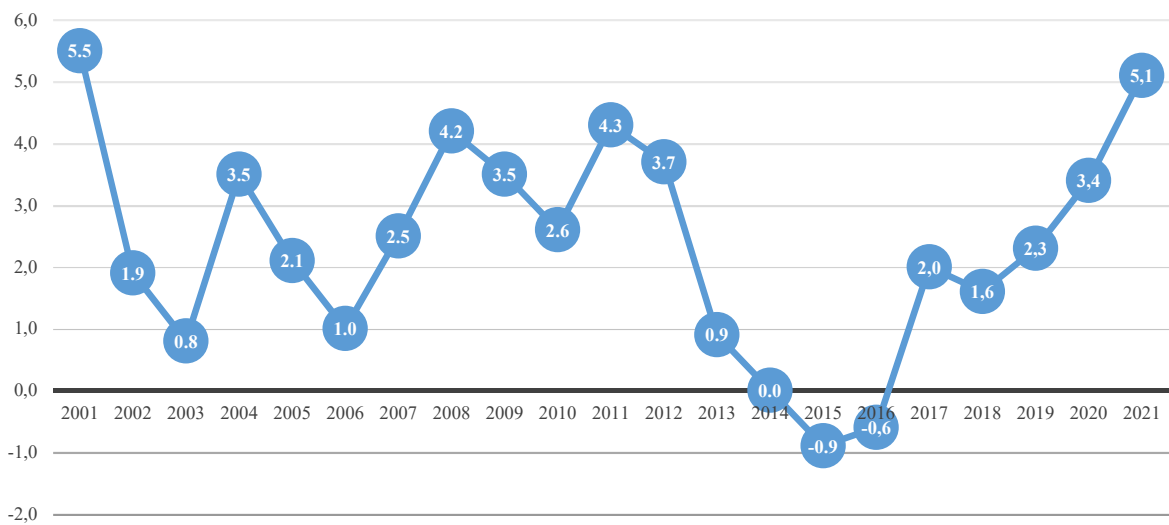
In the second half of 2021 and early 2022, the Polish real estate market underwent significant changes due to various circumstances, with the primary one being inflation and its consequences. Rising prices of construction materials and energy, as well as rising interest rates, have led to significant changes in the sentiment of both new and existing market participants (Osadcha et al., 2021). The real estate market in Poland is characterized by significant credit orientation, which has been facilitated by long-term stable or downward interest rates on mortgages and loans issued to businesses and secured by real estate. Since 2012, such foreign currency loans have been almost non-existent due to the stability of the Polish zloty and the rather attractive pricing policy of banks, as well as the low value of money in the financial market. Thus, PLN 526.7 billion, i.e. 71% of all loans issued to households, were mortgaged at the end of 2021 (Narodowy Bank Polski, 2022a). At the same time, 2021 saw the commissioning of 234 700 apartments in Poland, with 871 300 more under construction (Statistics Poland, 2021a). This was the third year in a row in which more than 200 000 apartments were commissioned (Figure 2). The last time such a volume was recorded was in the 1980s (Website Of The Republic Of Poland, 2022). At the same time, the number of permits for the construction of apartments is high and it is expected that the number of apartments commissioned in 2022 will be high as well. However, the most crucial question of a practical nature is whether they will be sold. In turn, the scientific problem raised in this study is to determine the impact of inflation on key indicators of the Polish real estate market such as the number of built, commissioned, and sold square meters and their prices.

This issue has become especially relevant for Poland now, as late 2021 and early 2022 have become a turning point for this industry. The relatively stable Polish currency began to significantly drop in price, inflation accelerated from its traditionally low value in recent years to over 5% year on year

(Figure 3), hitting a 10-year high of 9.2% in January 2022 compared to January 2021. This is mainly influenced by such factors as rising energy prices, expansion of the taxation of carbon emissions in the European Union and delays in supplies due to COVID-19 restrictions (Shkodina et al., 2020).



**Fig. 2.** Number of dwellings commissioned. *Source:* Developed by the authors based on (Statistics Poland, 2021a).



**Fig. 3.** Inflation rate in Poland in the 2001–2021 period. *Source:* Developed by the authors based on (Statistics Poland, 2021b).

High inflation, a significant increase in base rates of the National Bank of Poland and the WIBOR increase lead to increased monthly payments on existing loans and reduced household creditworthiness, causing uncertainty in the real estate market and fears of its participants about the instability of the purchasing power of buyers. Thus, today there is a need to analyze and scientifically substantiate trends in the Polish real estate market and develop appropriate recommendations for further development of the situation due to the variability of macroeconomic indicators, which have recently undergone significant changes and led to tensions among main real estate market participants.

This study focuses on the interdependence of changes in inflation and the real estate market and makes further contributions to the literature in this area. First, the Polish real estate market of recent years was studied, which revealed differences in the market structure in eight of Poland's largest cities. Second, due to the lack of evidence, this study seeks to expand knowledge about the impact of

changes in inflation on residential property prices in Poland. It is important to promote real estate market research to reduce the risk of financial difficulties among households buying real estate on credit, as well as increase financial security for developers by creating scientifically sound forecasts of market development under the influence of factors that have not been changing significantly in recent years. As far as the authors know, this article is one of the first to quantify the impact of inflation over the past 13 years, including the last periods of the second half of 2021 and early 2022, on the real estate market in Poland. As construction is one of the biggest debt burden spheres in the Polish economy right after the trade sector (KrajowyRejestrDługów,2021), empirical results can help developers take measures to avoid financial security problems, respond promptly to changes in macroeconomic indicators, including inflation, and forecast their activities based on the results of our research (Kharazishvili et al., 2020). Although this study combines a wealth of literature that seeks to explain the link between inflation and other economic indicators, we are filling a gap in the literature by focusing on inflation as a factor influencing the demand for residential real estate as a tool for investment and improved financial security and household welfare. After all, for most people who buy real estate to live in, owning a home is a guarantee of a stable existence, reliable investment and peace of mind for family life, recreation, as well as work, particularly recently due to the COVID-19 pandemic. That is, buying a home "is likely to be the single, most expensive purchase that they make during their lives" (EUROSTAT, 2021a). While it is fair to say that not all EU residents are property-oriented and some like to live in rented accommodation, Poland, which is the object of this study, is among those countries where the majority of the population lives and seeks to live in their own housing (85.6% live in their own dwelling and 14.4% in rented accommodation), in contrast to such countries as Switzerland, where the majority of the population rents housing, and Germany, where the distribution of owners and tenants is around 50/50 (EUROSTAT, 2021b). This study uses a significant sample (Poland's 8 largest cities) and period (2009-2021) compared to several previous studies that did not examine the issues raised in this paper, firstly due to the lack of such aggregation of factors that are of scientific and practical interest to real estate market participants at that time, and secondly, due to the relevance of current data.

Thus, the aim of this research is to study the impact of inflation on the real estate market in Poland in modern conditions on the basis of data for 2009-2021.

The article continues as follows. The following section provides an overview of the historical body of knowledge about real estate valuation, particularly in Poland, and evaluates supporting literature. Despite the decisive role of inflation and base rates in the formation of the real estate market and housing prices, previous studies have not conducted a thorough analysis of the relationship between the level of these factors with housing prices. Section 3 describes the data and hypotheses of the study. Section 4 focuses on our research strategy, its methodology, and the methods used in the analysis. Section 5 reflects the results of our research. In Section 6, we discuss the results of our study and how they can be interpreted in terms of previous research. The conclusions are presented in Section 7.

## 2. Literature review

Recent research emphasizes the importance of accurately predicting housing prices for both real estate market participants and the development of appropriate public policies (McGurk, 2020), as the level of information uncertainty plays an important role in consolidating the behaviors of participants in real estate transactions (Chang et al., 2016). At the same time, taking into account all possible factors influencing prices can increase the accuracy of such a forecast, so the scientific literature seeks to find them to identify relevant patterns. In particular, the possibilities of using computer mass systems, automated estimation models (Renigier-Biłozor et al., 2022) and artificial intelligence (Kuzior et al., 2019; Kwilinski & Kuzior, 2020; Melnychenko, 2020) are being studied. The relationship between property prices and construction costs is clear and logical (Brzezicka et al., 2018), and its most important components are labor, land, overheads and equipment and materials (Pulver, 1989; Assaf et al., 2001). The influence of macroeconomic factors is not so clear, although it has been studied in scientific publications. In particular, B. Grum and DK Govekar (Grum & DkGovekar, 2016) found that unemployment has the greatest impact on the price of residential real estate in Poland. Other studies found a positive relationship between price levels and current account deficits (Aizenman & Jinjara, 2009), as well as the importance of income level for home buying decisions made by young households in large metro areas (Kim et al., 2021). McQuinn, Monteiro and O'Toole (McQuinn et al.,2021) address the issues of the absence of information on consumer price expectations,

differences in quality between owner-occupied and rented dwellings and whether agents' expectations are rational in assessing the sustainability of house price changes. Agnello, Castro and Sousa (Agnello et al., 2020) "emphasize the role that monetary policy can play, namely, by affecting interest rates and avoiding (or reducing) the likelihood of housing booms". However, their analysis did not consider the impact of inflation, which is also one of the key indicators of a country's prosperity and development and reflects the financial condition of buyers, developers and sellers of real estate. In this case, Lian and others (Lian et al., 2019) find evidence that the risk of households' investment decisions increases along with declining interest rates, and monetary policy rates depend on inflation expectations (Kose et al., 2012). In turn, the interest rate is the most important monetary tool to control inflation (Ali & Anwar, 2013). The literature also proves that political (Czyżewski et al., 2017) and legislative decisions (Kowalczyk et al., 2019) determine the value of the real estate, at least indirectly through the value of land and building opportunities, as well as transaction costs (Manzhynski et al., 2018; Osadcha & Melnychenko, 2021b) related to taxes, housing valuation, etc. Although early research confirms the link between monetary policy and housing prices by calculating Taylor residues (Crowe et al. 2013), Li and others (Li et al. ,2022) found "controversy about whether monetary policy can effectively regulate the real estate market". Households need to perceive and expect inflation, which may underestimate or overestimate its level (Buono & Formai, 2018; Nautz et al., 2017), potentially leading to a decrease in confidence in the central bank and the effectiveness of its monetary policy. While such distortions in the perception of inflation and expectations of its level are very subjective and related to fundamental personality traits (Abildgren & Kuchler, 2021), they remain important for forecasting prices on the one hand, as these perceptions and expectations also affect the demand for the real estate market, and for the central bank on the other as it takes them into account when determining base rates, a factor that is important for our study. The idea that private residential real estate is a good hedge against both expected and unexpected inflation was confirmed in the earlier study (Fama & Schwert, 1977) and in some modern research (Lee, 2021).

The scientific literature also provides answers to the question of the dependence of real estate prices on the level of energy efficiency and thermal modernization (Pascuas et al., 2017), the factors of forced real estate sales (Renigier-Biłozor et al., 2018), and hedging inflation risks through investment in real estate (Salisu et al., 2020; Yeap & Lean 2017; Taderera & Akinsomi, 2020; Arnold & Auer, 2015), as well as the impact of improved road standards on housing prices (Theisen & Emblem, 2021). The dynamics of residential real estate prices for the Polish real estate market was investigated in Warsaw in different market segments (small, medium and large apartments in the primary and secondary market) and the dependence of prices between these segments (Brzezicka et al., 2019), real estate market analysis in Upper Silesia (Zuzańska-Żyśko, 2014) and analysis of foreign currency loans for housing (Buszko & Krupa, 2015).

The problem of identifying the relationship between inflation and the reaction of the real estate market in modern conditions remains unresolved though its solution would be useful for both developers and households, enabling them to forecast prices, supply and demand for residential real estate. Similar studies were conducted for the Czech Republic, examining the impact of changes in monetary policy rates on lending rates, including mortgages (Gregor & Melecký, 2018), as well as Turkey, in the context of the impact of the COVID-19 pandemic on the real estate sector there (Tanrivermiş, 2020), and China (Zhang, 2013) for the 1998-2010 period. Also, an early analysis of the impact of the macroeconomic policy shocks on real estate markets and real estate investment funds showed that the monetary policy shock corresponds to lower returns on real estate investments, and unpredictable changes in economic growth are associated with declining returns to these markets and funds (Ewing & Payne, 2005).

The relevance of our study lies in the fact that it is the first one to:

- analyze the most recent data;
- model and forecast the dynamics of the average price of 1 sq. m. of housing in Poland's eight largest cities;
- perform piecewise linear regression analysis between various indicators of the real estate market;
- build models of multiple linear regressions of price changes of 1 sq. m. of housing for each of Poland's eight largest cities based on changes in factors that characterize the real estate market.

### 3. Data

The analysis is based on an unbalanced set of data on inflation, the number of built and commissioned housing units, the number and cost of new mortgages, the level of the reference rate of the central bank and prices per 1 sq. m. of housing in Poland's largest cities (Warsaw, Katowice, Lodz, Wroclaw, Gdansk, Bialystok, Krakow and Poznan) for the 2009–2021 period. The period was chosen based on the availability of all data series. The dependent variable, i.e. the unit of statistical observation, is the change in the price per square meter of housing (SMP) in Poland's largest cities. Independent variables of interest for this study, which we used to analyze real estate price volatility, are indicators of inflation and the level of the central bank's reference rate. Such an analysis will predict real estate prices from the perspective of demand for it. In addition, the dependence of the number of constructed residential real estate on the same independent variables should be investigated to analyze the market situation from the perspective of its supply (Table 1).

**Table 1**

Variables used in the analysis of panel data

Name	Definition	Abbreviation	Source
Inflation	Harmonised Indices of Consumer Prices are designed for international comparisons of consumer price inflation.	HICP	Statistics Poland (STATISTICS POLAND 2021b)
Dwelling built	"A dwelling is a room or a suite of rooms in a permanent building designed for habitation by a private household. The most common forms of dwelling include detached houses, semi-detached or terraced houses, flats or bedsits. Dwellings should have separate access either to the road or to a communal space within a building (a staircase, corridor or passageway). Dwellings may be classified as occupied, secondary, seasonal or unoccupied. They are considered to be occupied if they provide the 'usual place of residence' to one or more persons"	DB	Eurostat (EUROSTAT 2021a)
New mortgage loans	New loan agreements signed for the purchase of dwellings (PLN)	ML	AMRON-SARFiN (AMRON 2022)
New mortgage loans, amount	New loan agreements signed by a borrower for the purchase of dwellings	MLA	AMRON-SARFiN (AMRON 2022)
Reference rate	A minimum money market intervention rate. One monetary policy instrument of the central bank of the Republic of Poland (Narodowy Bank Polski) is open market operations, i.e. transactions in which the central bank engages with commercial banks on its own initiative. Such transactions include the conditional and outright sale or purchase of securities or foreign currency, as well as the issue of own-debt securities by the central bank, whose minimum yield equals the reference rate	RR	Narodowy Bank Polski (NARODOWY BANK POLSKI 2022b)
Square meter price changes	Changes in average per square meter (sq. m.) prices in PLN	SMP	AMRON-SARFiN (AMRON 2022)
Square meter price	Average prices per square meter (sq. m.) in PLN	y	AMRON-SARFiN (AMRON 2022)

Source: own elaboration.

Table 2 presents descriptive statistics for the complete unbalanced data set of the panel with Poland's 8 largest cities for 13 years of observations (2009–2021). The units of measurement are the rates of change in percentages. The standard deviation of the HICP is 1.81 and RR is 1.26, which shows how diverse our sample is in terms of inflation and base rate, respectively. According to the panel, the lowest price of one square meter of housing in Poland was recorded in the Katowice metropolitan area in 2017 (PLN 2 767), and the highest was seen in Warsaw in the third quarter of 2021 (PLN 10 738), both in terms of the study period and historically.



Table 2

## Descriptive statistics

Variable	Mean	St. Dev.	Min	Max
HICP	2.15	1.81	-0.90	5.10
DB	3.08	8.24	-15.10	16.76
ML	2.05	15.31	-32.20	25.63
MLA	-2.05	13.18	-34.02	21.76
RR	2.39	1.26	0.78	4.50
SMPWarsaw	1.80	5.02	-5.88	10.73
SMP Katowice agglomeration	2.19	8.09	-7.99	21.63
SMPŁodz	2.99	7.69	-9.43	19.07
SMPWrocław	1.72	5.50	-8.11	9.52
SMPGdansk	3.31	6.19	-7.43	11.81
SMPBiałystok	2.34	5.45	-4.56	15.32
SMPKrakow	1.87	5.56	-7.04	10.44
SMPŁoznan	1.37	4.67	-5.85	8.94

Source: own calculations.

Table 3 presents the correlation matrix of dependent and independent variables. There is a significant level of negative correlation between the reference rate change and the change in the cost per square meter of housing. Also, simple relationships between model variables show that the change in the number of new mortgages is also negatively correlated with the reference rate change.

Table 3

## Correlation matrix

	HICP	RR	SMPWarsaw	SMP Katowice agglomeration	SMPŁodz	SMPWrocław	SMPGdansk	SMPBiałystok	SMPKrakow	SMPŁoznan	DB	ML	MLA
HICP	1.00												
RR	0.24	1.00											
SMPWarsaw	0.03	-0.88	1.00										
SMP Katowice agglomeration	0.14	-0.72	0.81	1.00									
SMPŁodz	0.05	-0.77	0.95	0.87	1.00								
SMPWrocław	-0.04	-0.80	0.95	0.78	0.95	1.00							
SMPGdansk	0.08	-0.83	0.89	0.77	0.86	0.90	1.00						
SMPBiałystok	0.11	-0.79	0.83	0.83	0.79	0.68	0.76	1.00					
SMPKrakow	0.03	-0.91	0.96	0.85	0.91	0.90	0.91	0.86	1.00				
SMPŁoznan	-0.17	-0.87	0.86	0.82	0.84	0.81	0.82	0.87	0.89	1.00			
DB	0.01	-0.38	0.20	0.13	0.07	0.03	0.23	0.48	0.26	0.34	1.00		
ML	-0.22	-0.50	0.58	0.34	0.59	0.78	0.68	0.16	0.53	0.42	-0.16	1.00	
MLA	-0.28	-0.34	0.42	0.19	0.44	0.63	0.52	-0.01	0.35	0.25	-0.18	0.97	1.00

Source: own calculations.

Note that the MLA and ML factors are multicollinear (there is an almost linear relationship between them). Therefore, further studies use one of these factors, i.e. ML.

Based on the latest literature, the following hypotheses were tested:

**H1:** There is a positive relationship between the growth of the central bank's base rate and real estate price increase in Poland.

**H2:** There is a negative relationship between the growth of the central bank's base rate and the level of household business activity increase in the Polish real estate market in the form of an increase in the number and amount of mortgages.

**H3:** There is a positive link between rising inflation and real estate price change in Poland.

**H4:** There is a negative relationship between rising inflation and the level of business activity increase of households in the Polish real estate market in the form of an increase in the number and amount of mortgages.

**H5:** There is a negative relationship between rising inflation and the level of business activity change of developers in the Polish real estate market in the form of an increase in the number of homes built.

#### 4. Methodology

The additive Holt-Winter model of exponential smoothing with a damped trend, a variant of the Box-Jenkins (Box & Jenkins, 1976) time series models, was used for modeling and forecasting the quarterly dynamics of the average price of 1 sq. m. of housing. That is, the dynamic series is represented as  $y_t = f(t) + S_t + E_t$ ,  $t = 1, 2, \dots$ ; where  $y_t$  - levels of the series,  $f(t)$  - piecewise linear trend (main trend),  $S_t$  - seasonal component,  $E_t$  - random deviations (so-called "white noise").

Piecewise linear regressions were used to test the hypotheses put forward, i.e.:  $Z = B_0 + B_1 * X$ , where  $X$  is a factor (independent variable) that affects the result of  $Z$ , and the coefficients  $B_0$  and  $B_1$  change depending on the considered intervals (2009–2016, 2017–2021).

The change in price per square meter (SMP) in this study is defined as a function of the level of regression factors (changes in inflation (HICP), the level of the reference rate of the central bank (RR), the number of built housing units (DB) and the number of new mortgages (ML)), as follows:

$$SMP_i = b_{0i} + b_{1i} * HICP + b_{2i} * RR + b_{3i} * DB + b_{4i} * ML + \varepsilon_i \quad (1)$$

where cities are denoted by the index  $i$  ( $i = 1, \dots, N=8$ );  $b_{ji}$  ( $j = 1, 2, 3, 4$ ) - regression coefficients estimated by regression analysis. This coefficient  $b$  shows that if other variables remain fixed, increasing the explanatory variable by one unit increases (or decreases) the change in the price of one square meter of residential real estate by  $b$  units.  $\varepsilon_i$  are random errors that cover all factors that affect the price per square meter but are not included in the model specification variables.

This method has demonstrated its effectiveness in various areas of estimation and forecasting (Melnychenko, 2021).

Model (1) presents a general specification aimed at studying the impact of numerous factors on the Polish real estate market, where changes in the price per square meter of housing are considered as an exogenous (dependent) variable while levels of other factors are considered as endogenous (explanatory, independent) variables.

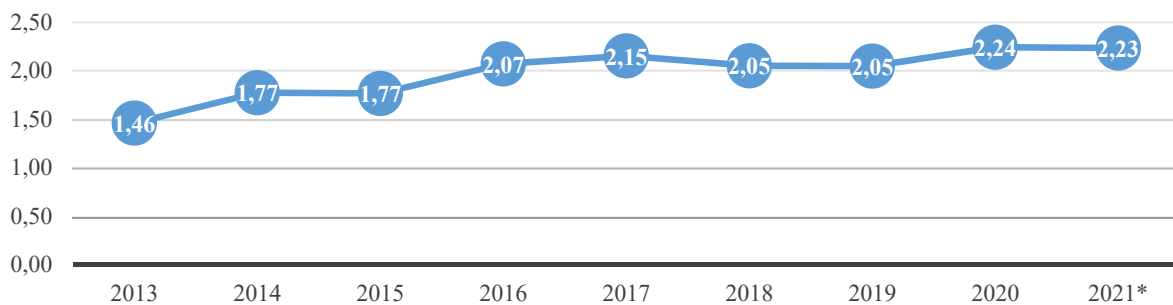
We conducted tests at the level of Poland's eight largest cities using panel data.

The economic theory underlying Equation (1) is as follows:

- the price per square meter indicator shows a more accurate price of the property and allows the buyer to evaluate the object and compare it with others without considering additional factors. Thus, comparing the price per square meter of two apartments sold for the same price in different locations will help understand the value of each of them. For example, a 26 sq. m. apartment in the city center can cost the same as a 100 sq. m. apartment on the city outskirts;
- the price per square meter measure should be used when analyzing the dynamics, comparing the value of the real estate, as the price of a particular property today is difficult to compare with its past value or its predicted future value due to the lack of identical real estate on the one hand and variability of impact factors on the other. For example, a certain piece of real estate may cost 100 000 zlotys today, but it is impossible to find its genuine past value as it had not been sold at a given time; however, similar real estate may have been sold, subject to factors affecting its price (e.g. housing conditions, time since the last renovation, existing infrastructure nearby, etc.). This will also apply in the future. The average price per square meter in the region reflects the state of real estate prices, including all factors influencing it;
- the inflation rate measure reflects the state of the country's economy and shapes the expectations and business activity of both businesses and households, which account for the largest share of home buyers. Demand for housing is determined by the real income of the population and depends on the level of prices, their dynamics in the country as a whole and their impact on the components of real estate values;



- the reference rate of the National Bank of Poland determines the level of profitability of bank bonds issued by the central bank. Short-term transactions of purchase and sale of such bonds are used to regulate liquidity in the interbank market;
- the central bank's base interest rate (reference rate) affects the level of interest rates on loans and the creditworthiness of property buyers through WIBOR, the average interest rate on the Polish interbank money market, as the WIBOR rate is directly dependent on the central bank's reference rate. It is calculated as the arithmetic mean of the rates given by the participants after the deviation of the two ejections (highest and lowest quotations). In 30-40% of cases, real estate in Poland is bought on credit (Narodowy Bank Polski, 2022a). Most of the concluded loan agreements are based on a variable interest rate, which is defined as the sum of the bank's margin rate (Figure 4) and WIBOR rate (Figure 1), which has a direct impact on real estate supply and demand, as well as the number and amount of mortgages and loans.



\* 2021 – data for 3 quarters

**Fig. 4.** Average margin of the mortgage loan offer (of 300 000 zlotys, at an LtV level of 75% for a period of 25 years) for the 2013–2021 period, in per cent. *Source:* Developed by the authors based on (AMRON 2022).

The model in equation (1) is a general specification, where the potentially omitted variables were the unemployment rate, the current account of the country's stock index, gross domestic product and industrial production, and it was expected that these indicators would correlate with real estate prices.

## 5. Results

We analyzed the quarterly dynamics of prices for 1 sq. m. in the Polish real estate market in the largest cities between 2009 and 2021 (data for three quarters of 2021) (variable  $y(t)$ ,  $t=1(Q1\ 2009)$ ,  $2, \dots, 51(Q3\ 2021)$ ). The result was that during the whole 2009-2021 period, the dynamics (trend) was changing starting from 2017. This is shown in Figure 5.

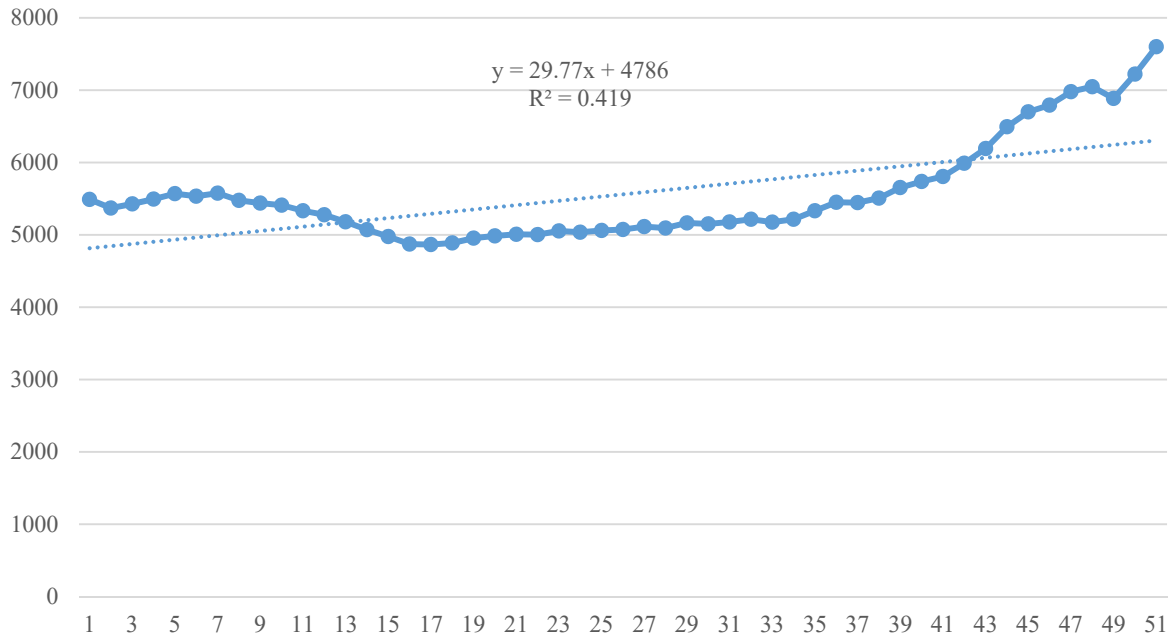
The analysis of the quarterly dynamics of the average price of 1 sq. m. of residential real estate showed that the linear trend had a rather low coefficient of determination  $R=0.4198$ . Therefore, using the STATISTICS program's "Piecewise linear regression" module, we built a piecewise linear trend (for the 2009–2016 period:  $y=5283.44-3.91*t$ ,  $t=1, 2, \dots, 32$ ; and the 2017–2021 period:  $y=5\ 087.76+33.41*t$ ,  $t=33, 34, \dots, 51$ ). The regression coefficient was  $R=0.898$ . To verify that this approach is correct, we modelled (using the 2009–2020 period) and forecast (for three quarters of 2021 and subsequent periods) the dynamics of the average price of 1 sq. m of living space, using the Holt-Winter exponential smoothing model with a damped trend, a known Box-Jenkins model (BOX, JENKINS 1976). Figure 6 shows the results of this modeling and forecasting.

Note that the relative forecasting errors for the first quarter of 2021 do not exceed 3.4%, for the second quarter – 0.4%, and for the third quarter – 4%.

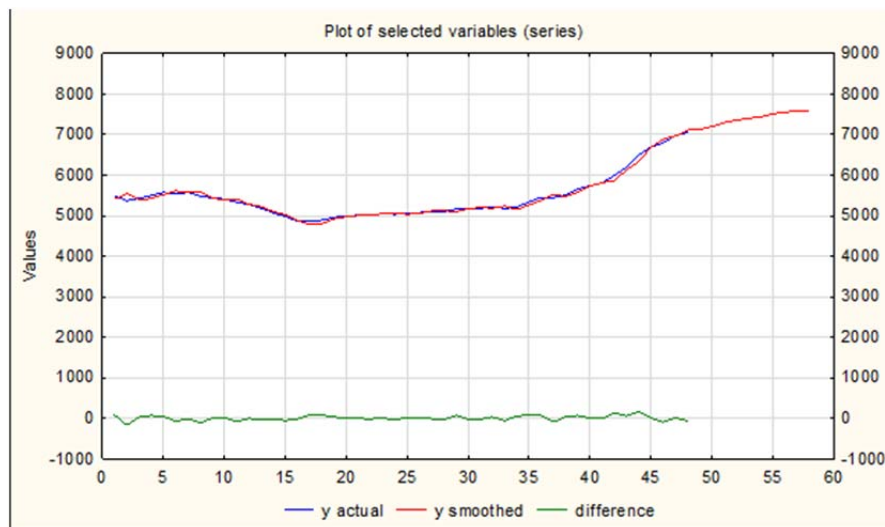
Let us find out how these factors affect the various indicators of the Polish real estate market. It turned out that if we consider the entire period from 2009 to 2021, the usual linear regression has fairly low regression coefficients  $R$ . Therefore, in the future, we will build piecewise linear models at these intervals.

To test hypothesis H1, the following piecewise linear models were constructed: for the 2009–2016 period:  $SMP=5.5-2.03*RR$ , and for the 2017–2021 period:  $SMP=10.97-2.24*RR$ ; when this regression coefficient takes the value of  $R=0.93$ , there may exist a close relationship between the factors. While

hypothesis H1 generally remains unconfirmed, it is worth paying attention to a nearly two-fold increase in the free member of the model.



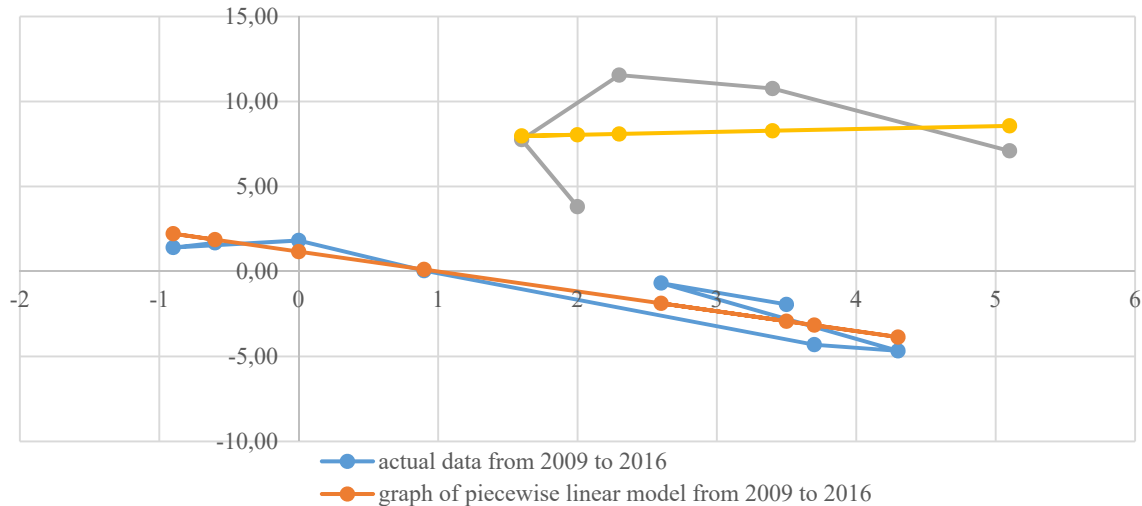
**Fig. 5.** Quarterly dynamics of the average price of 1 sq. m. of residential real estate in the 2009–2021 period (with a trend). *Source:* Developed by the authors.



**Fig. 6.** Graphs of the original (*y* actual), smoothed (modeled) and difference (between original and modeled) with forecast time series, as well as modeling errors. *Source:* Developed by the authors.

To test hypothesis H2, the following piecewise linear models were built: for the 2009–2016 period:  $ML=7.19-5.39*RR$ , and for the 2017–2021 period:  $ML=2.61+6.67*RR$ ; at this time, the regression coefficient was  $R=0.86$ , indicating a significant relationship between the factors. We believe that free terms and not coefficients at the RR factor, which is measured in per cent, should be given a bigger role in these equations. Still, hypothesis H2 was not confirmed.

Let us test hypothesis H3. For this purpose, the following piecewise linear models were built: for the 2009–2016 period:  $SMP=1.15-1.17*HICP$ , and for the 2017–2021 period:  $SMP=7.7+0.17*HICP$ ; the regression coefficient was  $R=0.93$ , indicating a close relationship between the factors. Hypothesis H3 was confirmed, as shown in Figure 7.



**Fig. 7.** Graphs of the actual relationship between the change in the inflation factor (x-axis) in percent and the change in the price of 1 sq. m. of housing together with the constructed piecewise linear regression (x-axis) in percent. *Source:* Developed by the authors.

Therefore, when forecasting, it is necessary to use a model that has been operating since 2017 (after the beginning of inflation).

Hypothesis H4 was similarly tested. The following piecewise linear models were constructed: for the 2009–2016 period:  $ML = -2.25 - 2.91 \cdot HICP$  and for the 2017–2021 period:  $ML = 14.95 - 0.26 \cdot HICP$ , with a regression coefficient of  $R = 0.79$ , which indicates a significant relationship between the factors. Thus, hypothesis H4 was confirmed for the entire 2009–2021 period.

Hypothesis H5 was tested similarly. The models constructed were as follows:  $DB = -4.53 - 0.5 \cdot HICP$  for the 2009–2016 period and  $DB = 7.33 + 0.58 \cdot HICP$  for the 2017–2021 period with a regression coefficient of  $R = 0.85$ , which suggests that hypothesis H5 holds only in the case of the 2009–2016 period and not in the case of the 2017–2021 period. The increase in the number of apartments built can be explained by the inflation expectations of developers, as real estate prices in Poland have a steady upward trend.

Next, a regression analysis was carried out for each of Poland's eight largest cities according to formula (1). The analysis uses the STATISTICS program's "Ridge multiple regression" module with the rejection of insignificant factors. Table 4 shows the results of regression analysis (left regression models with the most significant factors and a high coefficient of determination  $R^2$ ).

**Table 4**

Estimates of parameters  $b_{0i}$ , ( $i = 1, \dots, N=8$ );  $b_{ji}$  ( $j = 1, 2, 3, 4$ ) linear multiple regressions of price change of 1 sq. m. of living space (SMP) on various factors

	SMP Warsaw	SMP Katowice agglomeration	SMP Lodz	SMP Wroclaw	SMP Gdansk	SMP Bialystok	SMP Krakow	SMP Poznan
$b_0$	7.436 (3.865)**	14.247 (5.330)**	12.576 (4.321)**	7.436 (2.133)**	6.767 (3.110)**	10.149 (2.077)**	9.532 (1.565)**	5.450 (4.089)*
HICP	0.674 (0.458)*	1.576 (0.946)*	1.249 (0.767)*	0.674 (0.375)**	0.956 (0.462)**	0.795 (0.507)*	0.852 (0.338)**	-
RR	-2.990 (1.191)**	-6.089 (1.820)**	-4.969 (1.475)**	-2.990 (0.728)**	-2.883 (0.967)**	-4.064 (0.747)**	-4.002 (0.549)**	-2.360 (1.148)**
DB	-0.110 (0.108)*	-0.244 (0.240)*	-0.192 (0.195)*	-0.110 (0.096)*	-	-	-	0.045 (0.116)*
ML	0.164 (0.325)*	-0.050 (0.138)*	0.110 (0.112)*	0.164 (0.055)*	0.410 (0.299)*	-0.106 (0.072)*	0.048 (0.045)*	0.337 (0.311)*

R-squared	0.89	0.77	0.76	0.89	0.9	0.77	0.9	0.79
R	0.97	0.92	0.87	0.94	0.95	0.89	0.95	0.89
Total panel (unbalanced) observations	13	13	13	13	13	13	13	13

Source: Research results. Notes: Standard error in parentheses; \*  $p > 0.05$ ; \*\*  $p < 0.05$ .

Let us comment on the results obtained by the example of the change in the price of 1 sq. m. of real estate in Warsaw and Wrocław. For these cities, the same models of multiple linear regression (1) were created:

$$SMP = 7.436 + 0.674 * HICP - 2.990 * RR - 0.110 * DB + 0.164 * ML + \varepsilon \quad (2)$$

With all factors of the model held constant, the SMP will increase by approximately 7.4%. If inflation (HICP) increases by 1% (with other factors held constant), then SMP will increase by approximately 8.1%. The influence of other factors is estimated similarly, taking into account the estimates of the coefficients for these factors.

## 6. Discussion

This study is consistent with Fisher's theory of interest rates (Fisher, 1930), which states that there is a positive relationship between nominal interest rates and expected inflation rates and that causal relationships range from inflation to interest rates. In this case, the causal links range from inflation to interest rates. Thus, it is natural that a negative correlation was found between the level of the central bank reference rate and the dynamics of prices per 1 sq. m. of housing in Polish cities. Our research is also consistent with the work of Rahman and Shahzad, Hussein (Rahman et al., 2020), who studied the impact of oil prices and inflation on residential property prices in the United States, Britain, and Canada using models of the cointegration time series. In their paper, long-run coefficients of inflation rate highlight the significance for residential prices in the US, UK and Canada, which is confirmed in our research results concerning Poland, using models of multiple linear regressions.

Decisions about buying real estate depend on several factors, including real estate prices, household income and inflation expectations. This is consistent with a study (Dräger & Nghiem, 2021), which found that German "consumers are more likely to increase current spending if they plan to increase spending in the future and if they expect higher inflation". A study carried out in the Netherlands indicates that high inflation expectations negatively affect the decision to purchase durable goods (Coibion et al., 2019). However, a study based on microdata from the Michigan Consumer Survey (Bachmann et al., 2015) shows a small impact of higher inflation expectations on willingness to spend money on durable goods. Such differences can be explained by the different cultural backgrounds in which the research was conducted. Although there is no direct evidence, we believe that Polish households tend to reduce savings and increase current expenditures as inflation (also expected) and base rates rise, given the experience of Polish households since the 1990s, which corresponds both to the latest (Coibion et al., 2020) and early (Łyziak, 2003) research.

Inflation and base interest rates are important factors and indicators of the functioning of the economy, which together with many other variables shape the real estate market. This is consistent with a study by Belej, according to which "the real estate market can not only receive signals from the environment, but under specific circumstances, such signals can also be transmitted by the market. The above implies that significant changes in the legal, social, economic and political environment are drivers of change in sets of market elements and their attributes and that they contribute to the development of the real estate market" (Belej, 2013), as well as one by Bouchouicha and Ftiti, stating that "real estate prices are considered as one of the channels of asset prices through which monetary policy affects the economy. This is achieved through their effects on the aggregate demand using household wealth effect and direct effect on housing expenditure," (Bouchouicha & Ftiti, 2012). In addition, monetary policy decisions are key drivers of changing housing prices in China (Xu & Chen, 2012). At the same time, the assessment of the relationship between property prices on the one hand, and inflation and base rates on the other, will increase the transparency of the housing market by providing additional, objective information about the structure and dependence of the market on these factors to the buyers, developers and sellers of real estate to predict the likelihood of financial

difficulties. This is consistent with a study of the relationship between real estate transparency and default based on data from 46 countries (Gholipour et al., 2020).

The choice of Polish cities for this study is in line with previously conducted research on the assessment of the residential real estate market in the form of a rating, which is an element of market analysis and is a decision-making system support for market participants (Renigier-Biłozor et al., 2017).

## 7. Conclusions

The purpose of this article was to study the impact of inflation on the real estate market in Poland. Our results show that the level of residential real estate prices is related to the inflation rate. We used a model based on the method of regression analysis to demonstrate the dependence of changes in the cost of one square meter of housing on changes in inflation. Scenarios of the relationship between the rise in the central bank's base rate and the level of household business activity in the Polish real estate market, in the form of an increase in the number and amount of mortgage loans, were also considered, as was the relationship between rising inflation and real estate prices in Poland and that between rising inflation and the level of household business activity in the Polish real estate market in terms of the number of homes built.

The results of panel models (1) show that a 1% increase (with other factors unchanged) in the inflation rate (HICP) leads to a per square meter price increase of 8.1, 15.8, 13.8, 8.1, 7.7, 10.9 and 10.4% in the major cities of Warsaw, Katowice, Lodz, Wroclaw, Gdansk, Bialystok and Krakow, respectively. Further, a 1% increase in the reference rate (RR), with other factors unchanged, leads to a decrease in the change in the price of 1 sq. m. of housing amounting to 2.99, 6.09, 4.97, 2.99, 2.88, 4.06, 4.00 and 2.36% respectively.

However, to correctly build the regression and improve the model's adequacy, we used a piecewise linear model, because the usual linear regression had a fairly low regression coefficient R. In this sense, 2017 was a turning point, and as such, we launched the model between 2009-2016 and 2017-2021. Thus, the increase in the inflation rate leads to higher real estate prices in all Polish cities studied except Poznan, where inflation change does not significantly impact the price increase.

Our study also shows an interesting impact of the central bank reference rate on housing prices. Reference rate changes lead to a decline in housing price growth. This is also related to an increase in the WIBOR, a component of the value of mortgage loans, which in turn determine the final cost for buyers, 30-40% of whom buy a home on credit. Thus, an increase in the base rate leads to a decrease in demand due to the inability of buyers to pay monthly payments on mortgages, which in turn leads to lower real estate prices.

The results complement the literature on the relationship between macroeconomic indicators and the real estate market in terms of the dependence of housing prices on inflation.

## 8. Limitations

This study has some limitations. First, the findings of the study are limited by the data on which the results are based. In particular, the results do not distinguish between city sizes and types, nor do they account for their being located in the western, eastern, northern or southern part of Poland even though these regions sometimes differ significantly in terms of income levels, which affects the perception of inflation and its impact on real incomes, creditworthiness and more. Moreover, the study used primary market data, i.e. about housing sold by developers. While prices on the secondary market do not differ significantly, it is advisable to study this market in detail. Although the empirical link between inflation and business activity in individual regions was not found, the presented sample of Poland's eight largest cities reflects the overall picture of the country.

## 9. Future research directions

Given the above limitations, further research should focus on the analysis of samples not only from large cities but also from medium, small and other localities, where the relationship between real estate price dynamics and inflation may differ. In future studies, it is also advisable to analyse this dependence in other countries to objectively assess the impact of inflation on the real estate market.

Future areas of research should also include exploring the use of artificial intelligence, in-depth analysis, and machine learning to take into account all possible factors influencing the real estate market, or at least most of such factors, to predict trends and allow buyers, sellers and developers to

make timely and appropriate decisions. Furthermore, in next research the issue of housing real estate prices should be considered in context of arbitrage pricing theory.

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