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PREDICTIVE AUTOREGRESSION MODELING OF RESIDENTIAL PROPERTY MARKET TRENDS In Ukraine (2019-2023)

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INTRODUCTION

At the current stage, when Ukraine is in a crisis situation due to a combination of extremely negative factors (full-scale Russian aggression, dependence on energy resources imports, the consequences of the coronavirus), the problem of forecasting the main parameters of the market evolution is gaining particular importance and relevance. The correctness and effectiveness of the decisions taken for efficient restoration of national economy depends on the consideration of the mentioned problem during the period of systemic crisis, the consequences of which cannot be assessed without analyzing their possible impact on the future. Of course, any future situation is highly uncertain. Therefore, there are no ways to accurately "guess" its development. At the same time, there are many techniques, methods and appropriate tools that allow to identify trends, the logic of the development of certain processes and, based on comparison with past experience, to predict the characteristics of the most likely development of events.

The complexity of the problem of forecasting market parameters at the moment is due to the fact that developing crisis phenomena, provoked by an imbalance of supply and demand in one or more product markets, spread to the markets of other products due to the interconnectedness of the economic system. From the point of view of the possibility of forecasting, this period is characterized by increased uncertainty, when the subsequent behavior of certain market indicators is difficult to predict, and a conclusion can be drawn only from a joint analysis of the behavior of various factors that affect the value of the forecasted indicator.

The basis of the forecast is usually the analysis of the evolution of market processes in past years, the identification and detailed study of relationships between phenomena and fundamental indicators accompanying these processes, the description of their quantitative and qualitative characteristics, and the identification of stable patterns. To the greatest extent, the state of the market and its dynamics in the relevant segment are reflected in the market prices. The fact is that prices are formed under the influence of all factors, including solvent demand, the availability of real estate on the market and, accordingly, the level of offers, accompanying conditions for acquisition - the development of the credit system, interest rates and down payment requirements. After all, prices are influenced by market expectations. Thus, the market price absorbs all relevant information about the object known to market participants.

The effectiveness of forecasting can be increased by analyzing processes over the market in three main directions simultaneously.

The first direction is related to the study of the processes of price changes in the market, the identification of stable trends that appeared in the

past, and regarding which there are reasons to assume that they will remain in the future. Models and statistical methods of time series analysis, developed within the traditional methodology of random processes, are usually used as the main tools for this. This analysis and forecasting methods based on it are usually used in a situation of calm market development, far from crisis phenomena and unexpected price jumps.

In crisis conditions, it may be more useful to analyze the development of similar phenomena in the past. For this, it is necessary to identify general invariants characteristic of similar crises, to build adequate models of price dynamics during the rise and fall of crisis processes. At the same time, the methodology of statistical similarity should be used as a tool for analyzing such processes. In this case, the use of fractals, which have been developed in recent years in various fields and, in particular, during the analysis of economic processes, can be effective. And this is the second direction of the market analysis.

As a third additional direction the identification of complex regularities characterizing the mechanisms of development of the market processes, including in periods of crisis development, is the analysis of connections between various processes affecting each other. Such an analysis allows you to identify patterns of phenomena, hidden springs, pushing prices and other parameters of the market in one direction or another. In this case, the methodology of studying multidimensional time series and, above all, its most important branch - correlation and regression analysis - act as the main tools of the research in this case. Note that despite its simplicity, such an analysis has a number of nuances, ignoring which often leads to serious errors in the interpretation of its results.

In the course of the research, an attempt was made to analyze the evolution of residential property market prices, to one degree or another, touching on all the mentioned areas. The results of such an analysis can be used as the basis for forecasting the future development of the real estate market.

1. PRICE FORECASTING METHODOLOGY. STATISTICAL METHODS BASED ON TREND ANALYSIS

The use of statistical models and methods for forecasting purposes is the most common way of analyzing the accumulated arrays of quantitative information about the dynamics of certain indicators in order to model the process of their further change and development. Today, the statistical processing of market data increasingly involves the compilation of regression equations and the estimation of parameters, going beyond the bounds of paired linear analysis and the basic concepts of statistical tools.

Before starting the analysis of real processes characterizing the dynamics of the real estate market, a brief overview of the methods that will be used in the work should be given.

A time series is a sequence of values of a random variable, for example, real estate prices in a given market segment, generated sequentially over time. If time is continuous, the time series is also called continuous. If time changes discretely, we get a discrete time series. This article deals exclusively with discrete time series, in which observations are made at fixed time intervals, such as a month, quarter, or year.

It should be noted that the idea of using mathematical models to describe the behavior of economic systems is generally accepted. If the economic laws governing market processes could be accurately described by systems of differential equations, the calculation of market indicators at any moment in time would not be a significant problem. In this case, it would be possible to predict exactly how, for example, prices will change in the future. However, economic processes are largely influenced by uncontrollable factors. Causal relationships do not lend themselves to rigorous analysis, and many phenomena are revealed only when they have already manifested. In addition, there are many parameters expressed indirectly, which also need to be taken into account. For such systems, it is not possible to propose a deterministic model that allows accurate calculation of the future behavior of the system. Nevertheless, its analogue can be considered, which allows to determine the probability that some future value will lie in a specific interval. Such a model is called probabilistic or stochastic. Accordingly, time series models that allow describing the dynamics of processes on the real market are stochastic.

According to these terms, if the future values of a time series are precisely determined by some mathematical function, the time series is deterministic. Otherwise, if it is possible to describe the future values only with the help of random values, we get a random time series. Time series characterizing the behavior of market parameters are random.

Most often, time series describing market processes (for example, real estate prices or stock quotes) show a non-stationary character. This, first of all, manifests itself in the fact that the values of the time series do not fluctuate around a fixed average, but reveal a clearly expressed tendency to rise or fall. Also, in many cases, the values of the time series are characterized by the presence of a periodic component, a consequence of the seasonality of certain processes. Among the models describing non-stationary processes, the most common are regression models. They are characterized by the fact that, although the level in relation to which fluctuations occur can take on different values at different moments of time, the behavior of the series (after excluding the variable level) turns out to be similar in many respects. It should be noted that regression analysis methods are the most popular among the entire set of statistical methods for forecasting time series. They are based on the detection of general trends that are associated with the emerging trends and the construction of a mathematical model of the trend, expressed by an equation, which is used to calculate the predictive values of the studied phenomenon. At the same time, the simplest type of regression model is one in which the time factor acts as an independent variable.

Along with trend models, autoregression models are used to forecast time series, based on the detection of relationships between the value of the analyzed time series yt at the current moment in time and a series of values corresponding to previous moments in time: y_{t-1},y_{t-2},... We note that the construction of autoregressive models directly with the transformation of the original non-stationary series, if it exists, to a stationary form is sensible using a set of some simple operations before calculating the coefficients of the model.

At the same time, the order of the autoregression model (the number of factors included in it as factor indicators of the previous levels of the series) directly depends on the type of the series, and more precisely, on the degree of correlation between the sequences of its levels. In this regard, the inclusion of actual variables in the autoregression model is limited for each specific case to a certain number of parameters, exceeding which is impractical from the point of view of the adequacy of the obtained results (the inclusion of insignificant variables in the model, as a rule, reduces the accuracy of the forecast obtained by such a model). In turn, several parameters make it possible to focus only on a limited number of series values when making a further forecast.

2. THE DEPENDENCE MODEL OF APARTMENT PRICING

2.1. Analysis of the trajectory of changes in apartment prices in Ukraine (June 2019 - March 2023)

As a starting point for the process of forecasting prices in the real estate market, it is necessary to analyze the available data and trace evolution of apartment prices in recent years.

First, it should be noted that, as is known, prices in real estate markets in each region are formed under the influence of general trends throughout the country. Another feature of the real estate market is that price increases/decreases in one of the market segments inevitably cause corresponding price changes in others. It should also be mentioned that initially the increase in purchasing power responds to the demand for residential properties. At the same time, the processes on the real estate market in different cities and in different market segments are developing in a similar way. That is why, in order to see the general picture of the development of the country's real estate market, it is necessary to consider the prices evolution both in terms of specific cities and the whole of Ukraine. Below is an analysis of price evolution on the secondary market of apartments in Ukraine over the past 45 months.

The "VERITEX®" group forms the information and analytical base of the real estate market of Ukraine, using the appropriate automated and calculation products and packages of application programs. It was from it that the initial data for the price analysis were taken. They really reflect the state of the market at any point in time from the period under consideration.

The creation of the primary electronic database is carried out by monitoring and accumulating information flows from the existing real estate market and their subsequent in-depth processing. All this becomes possible through the use of methods of mathematical and statistical analysis, geospatial and cluster analysis, machine learning and modeling, in particular neural networks and combinations of these methods.

The use of modern database management methods (PostgreSQL), geographic information systems (QGIS), a script library (Python) and a package of applied programs for numerical analysis (MathLab) allows you to systematically obtain generalized results, formulate the patterns of the modern real estate market, as well as predict its priority directions for the future development

The results of data processing are presented here in the form of time series displayed on the corresponding graphs with a given frequency. The dynamics of changes in the values of the time series of average prices for

apartments in the secondary market of Ukraine in the dollar equivalent, for the considered period (June 2019 - March 2023), is shown in Figure 2.1.1.

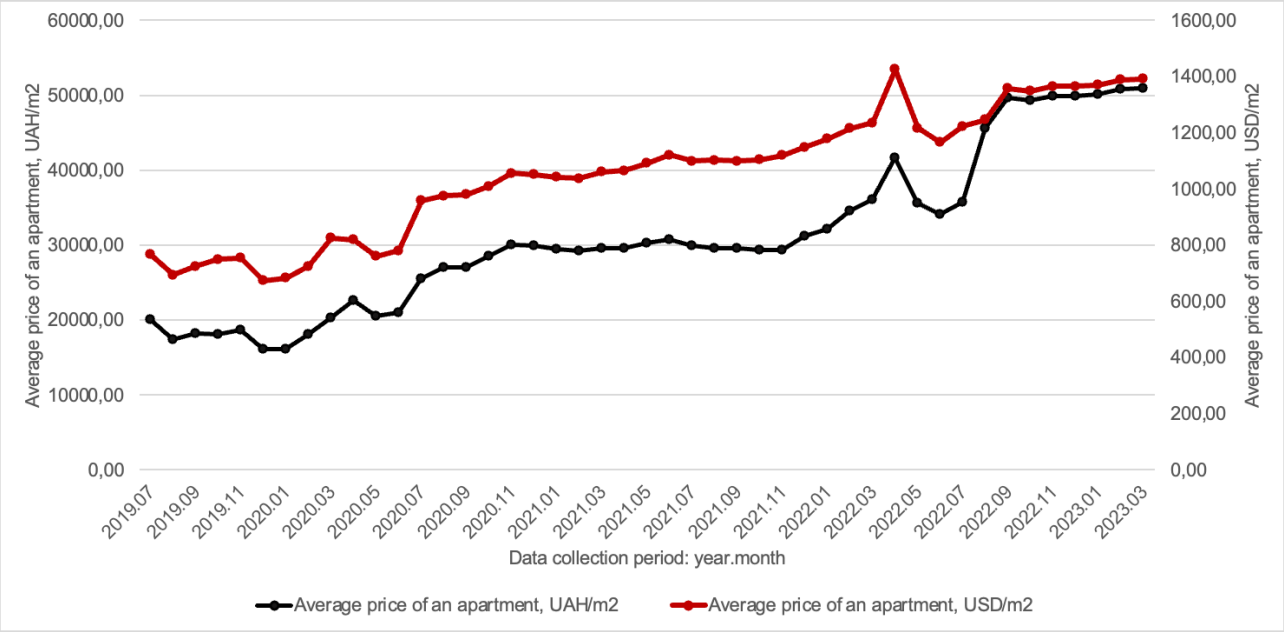
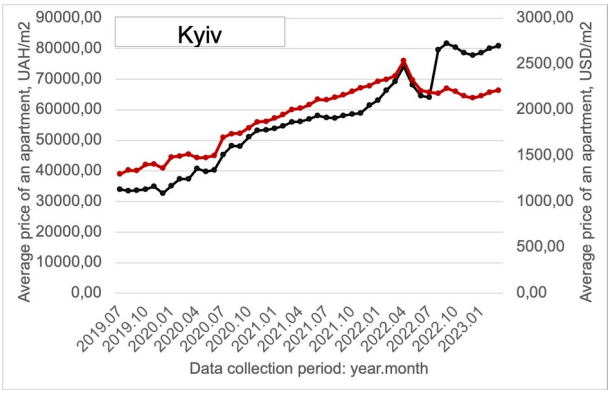
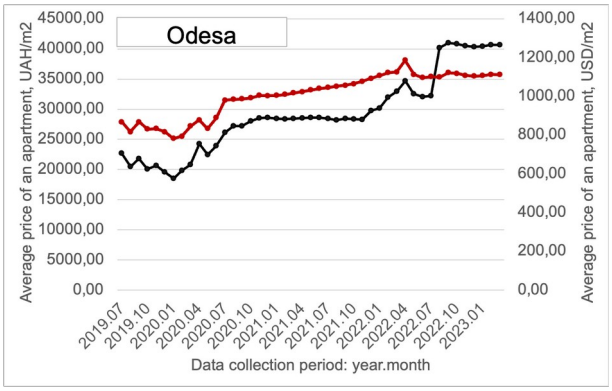


Fig. 2.1.1. Dynamics of the average price of an apartment ($/m^2) on the secondary real estate market of Ukraine for June 2019 - March 2023

We emphasize once again that the prices in dollar terms were used in the calculations. Similar dynamics, but already in hryvnia prices (the official rate of the National Bank of Ukraine on the date of calculations - 36.5686 UAH/USD), across the entire country and the largest cities, is shown in Figure 2.1.2.





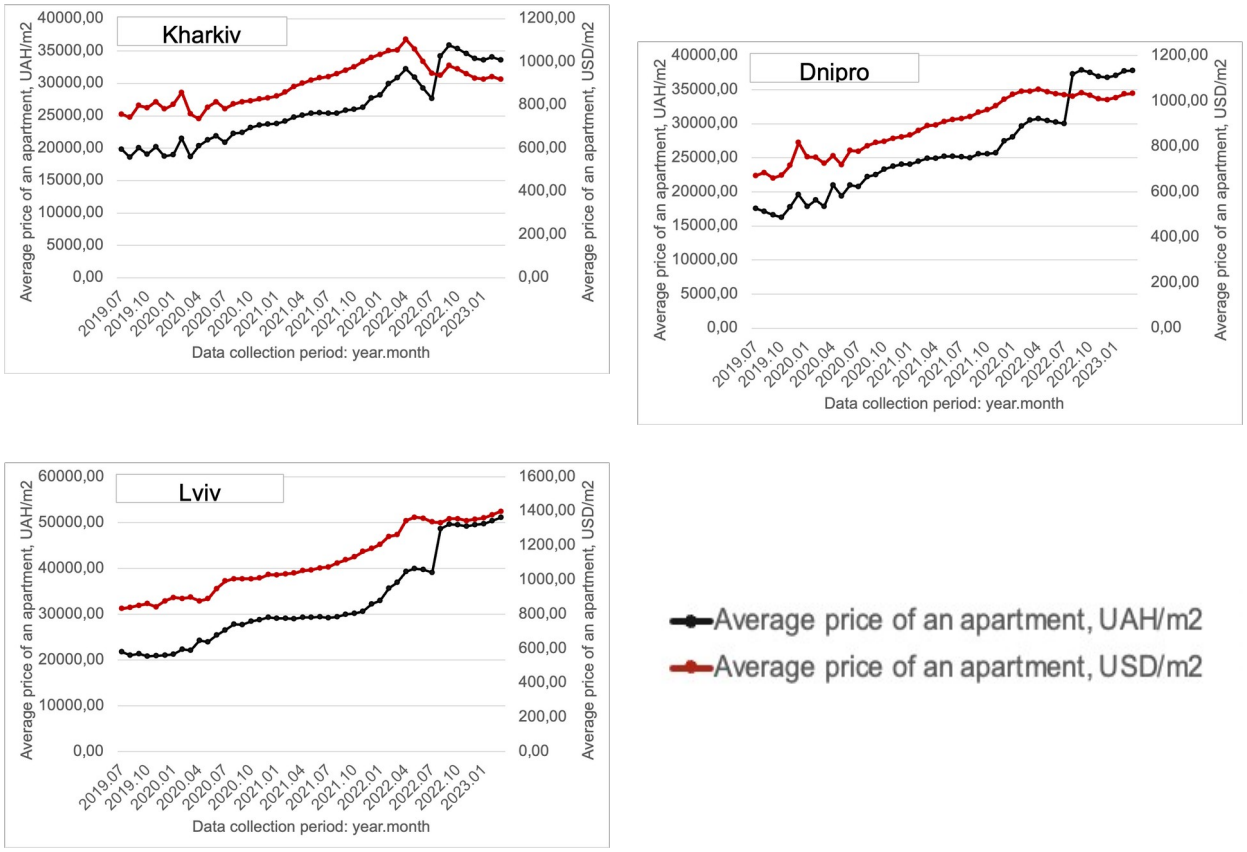


Fig. 2.1.1. Evolution of the average price of an apartment ($/m^2) on the secondary real estate market of the biggest cities in Ukraine for June 2019 - March 2023

The first obvious conclusion from the above graphs is the fact that in the periods between crises, prices on the real estate market of Ukraine grow practically monotonously. There are short-term intervals when the trajectory of the price movement changed direction. In general, analyzing the schedule and events characteristic of the corresponding time period, several stages can be distinguished:

- Until the end of 2019, we observe the continuation of the trends of earlier periods, which were characterized by relative stability.
- The impact of the coronavirus was most noticeable in the first months (from January 2020 to May), it is obvious that the market suffered from shocks caused by the energy crisis, the reduction of purchasing power, the growth of inflationary expectations, and so on.
- However, already in the summer (from June 2020), the market adapted, and buyers began to realize the delayed demand. Until then, the indicators returned to the pre-quarantine level and returned to stable growth.
- 2022 was very unpredictable for objective reasons, one way or another connected with the start of a full-scale war, so the market reaction was also difficult to predict. There is a rather sharp increase in April, which can be attributed to increased demand due to the influx of

refugees, which provoked an increase in prices. However, in the following period, this abnormal growth leveled off, the market returned to relatively stable growth.

- Although it is also worth noting that this trend in 2022 is not characteristic of all cities. Yes, Kharkiv is a front-line city that suffers quite a lot from shelling, so the market reacted accordingly by lowering prices and demand. It is obvious that the cost of square meters has increased significantly in the western regions (this can be clearly seen on the graph that describes the dynamics of prices in Lviv, but similar trends apply to Ivano-Frankivsk and Volyn). Such a situation is quite predictable, because this is where most of the temporarily displaced and evacuated persons were directed.
- A similar picture was observed in Kyiv after the liberation of the region and the cessation of the offensive on the capital. The main relocation of businesses and the relocation of their families from the front-line areas to the capital took place in August - early October. However, as of the end of 2022, we note a drop in prices on the market, which may be provoked by an increase in missile strikes, which causes negative dynamics.
- Some regions are not very far from the zones of active hostilities, but in summer 2022 the prices have increased in the Dnipropetrovsk region. Again, this is connected with immigrants. People chose relatively safe regions, but which are closer to their native homes. The number of offers decreased, which provoked an increase in prices.
- Now there is a certain stagnation of traditionally active business cities, in particular Dnipro, Kharkiv, Odesa.
- Such cities as Odesa have not undergone significant changes, because this direction was popular even before the war. The smallest price increase affected the frontline regions. Yes, in Kharkiv the prices have fallen noticeably.
- It was mentioned above about the effect of missile strikes on prices on the secondary market of Kyiv, so it was possible to assume that they will be the cause of revival of demand and price increases in other regions. But they do slow down the decision to enter into purchase agreements, but they do not create a new wave of migration. The strikes took place throughout Ukraine, which is why no significant changes took place.
- The beginning of 2023 was not marked by significant changes in the market, which is starting to gradually recover both in Ukraine as a whole and in various regions. The only exceptions are Kharkiv and other cities that remain close to the front.

Thus, the study of the general evolution of real estate prices for June 2019 - March 2023 shows, on average, a growing trend, which is stimulated

by an increasing demand for residential square meters. As an anomalous phenomenon from the point of view of the general dynamics that have developed in the real estate market over the past 12 years, the behavior of prices during periods of crises caused by extraordinary events and conditions (pandemic and war) observed in 2020 – 2023 is of particular interest.

2.2. Analysis of apartment prices evolution using high-order polynomials

The initial step in regression analysis of data is to check their homogeneity. Thus, referring to fig. 2.1.2, which illustrates the general trajectory of prices throughout the analyzed period, one cannot fail to note the structural changes present in it. In different periods, there are sharp jumps and falls in prices, which were accompanied by certain exogenous factors and processes. The graph illustrates the conclusion about the presence of significantly different processes that occur sequentially in different periods of time, which significantly complicates the approximation using high-order polynomials and reduces the accuracy of the obtained results.

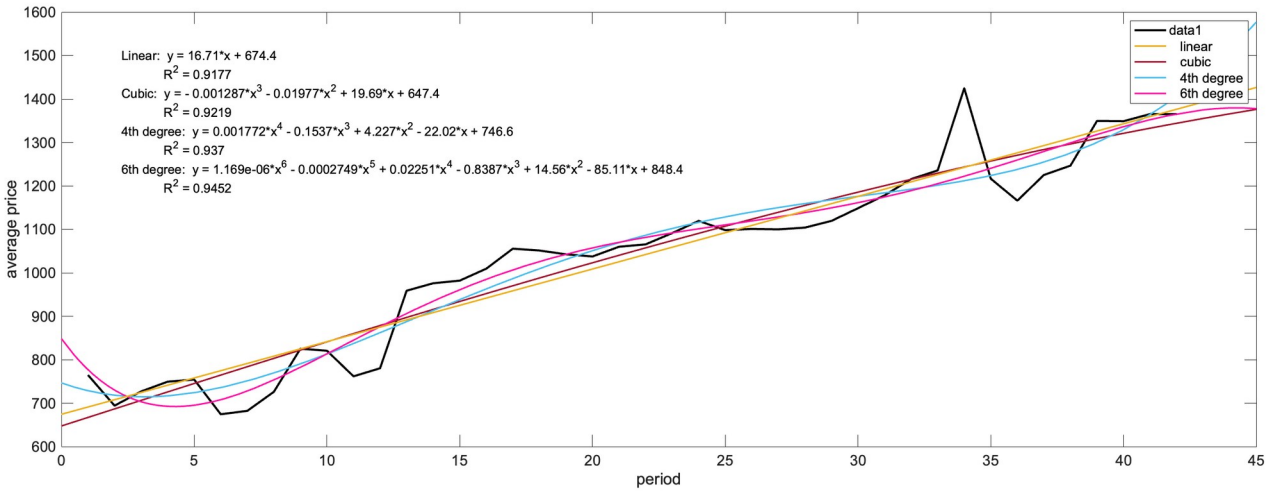


Fig. 2.2.1. Interpolation of the apartment price trajectory using high-order polynomials

Thus, the investigated time series contains various trends. In fig. 2.2.1, it can be noted that the trend line, represented by a polynomial of a rather high degree, still cannot fully approximate changes in the indicator.

A good interpolation of the time series using a high-order polynomial, which does not reflect the internal mechanisms of price movement, does not guarantee a high accuracy of the forecast of further price behavior. Here we should pay attention to a very common misconception that the use of an interpolation function with a high coefficient of determination allows us to qualitatively predict the further dynamics of the series. Even if there is a fairly accurate interpolation of the time series, which gives values of the coefficient of determination close to unity, it is not always possible to obtain a good result in the extension of the interpolating function for the forecast period. Moreover, at high degrees of the polynomial, such a forecast becomes unstable and, on the contrary, leads to larger errors than models with a simpler structure (low dimensionality).

The division of the series into parts leads to a decrease in the volume of the studied sample (within each segment), which affects the decrease in the accuracy of the approximation and subsequent forecast. Such a division is justified only if it is possible to distinguish time intervals within which a single price change mechanism is preserved. At the same time, there are reasons to claim that this mechanism will be preserved in the near future (during the forecast period).

From the point of view of making investment decisions, the most important task is to identify predictors that indicate that a change in trends should occur in the near future. Usually, such predictors are considered to be factors that to one degree or another influence the processes of pricing in the real estate market.

In order to describe the cause-and-effect relationships and the dynamics of the development of processes over time, generated by these relationships, we will use the methods of correlation and regression analysis, which allow us to establish statistical dependencies between different time series.

2.3. Dependence of the value of the apartment price on macroeconomic factors

Identification and detailed analysis of relationships between phenomena and indicators of various nature, description of their quantitative and qualitative characteristics, is certainly one of the most important component of any research, including economic. In this context, we have to use the theoretical foundations of correlation and regression analysis. From the point of view of the data processing procedure, two types of tasks should be distinguished: the study of interdependence between several random series, or the study of the dependence of one time series (values of market prices) on the basic values that form the time series of data, for example, the values of average incomes of the population that change in time, the amount of the gross product or the terms of mortgage lending. The first type of tasks is to establish the relationship between time series based on correlation analysis. In the second case, the apparatus of multiple regression is used. From a mathematical point of view, these approaches have a lot in common. However, replacing one method with another can lead to errors in the interpretation of results.

Interdependence between two stationary processes is usually characterized by a correlation coefficient, which is determined in the same way as for two random variables. If there is reason to expect a delay in one of the processes, correlations are calculated on random variables shifted by a fixed time interval or “lag”. In this case, the correlation value can vary depending on the lag, reflecting the real processes of delay in the dynamic system, which in this case is understood as the market.

Thus, correlation analysis is a useful tool that to some extent and under certain conditions characterizes the interdependence of random variables. However, it should also be taken into account that, in general, the analysis of relationships between two time series is a complex task that cannot be exhausted by the calculation of only the correlation coefficient and does not allow making sufficiently reliable judgments about the relationship between two or more series. In this regard, the correlation coefficient of the series, in the absence of confidence that the random variables are described by the normal distribution law, can be considered rather as an indicator of the presence of any relationship than as an accurate measure of its expression. Before proceeding to the discussion of the methods and directly to the data analysis, one important remark should be made: statistical dependence, no matter how strong it may be, cannot be a basis for asserting the presence of a cause-and-effect relationship. This statement lies beyond statistics. It can be done only on the basis of a meaningful analysis of the processes that give rise to this connection. Therefore, it should be noted that the use of correlation-regression analysis methods in the practice of market research is

not always flawless, and its incorrect application or incorrect interpretation of the results can lead to serious errors.
It is known that the real estate price includes several components that have fundamental and accidental value (Fig. 2.3.1). The fundamental (regular) component of the time series contains trend, cyclical and seasonal trends. The random component is noise, which slightly deviates the value of the time series from the trend. Experts note that there are certain fundamental price-forming factors in the real estate market, which have the greatest influence on determining the price of real estate and forming its trend. There are several classifications of such factors. One of the most common classifications is shown in Figure 2.3.2.

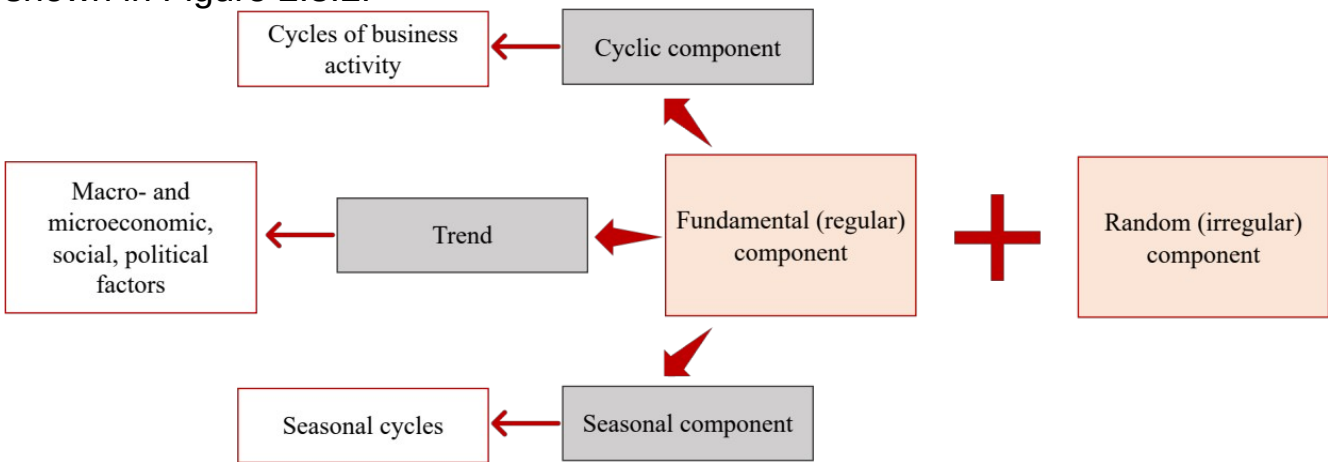


Fig. 2.3.1. Components of the time series of real estate prices

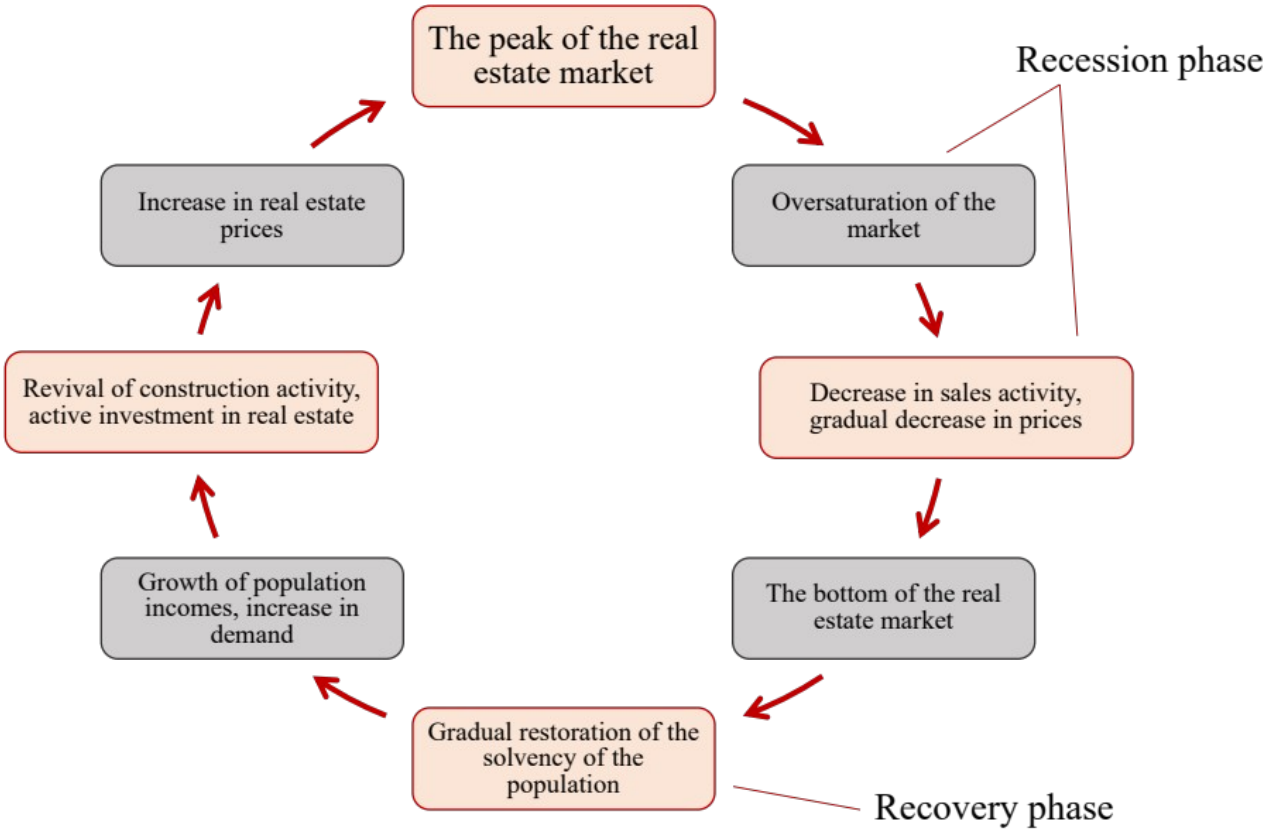


Fig. 2.3.2. Cyclical processes of the real estate market

In addition, the level of influence of external and internal factors on the real estate market differs in different layers of this market. For example, legislative and macroeconomic factors are important at the national level (macroeconomic indicators of development, economic and political risk of the country, legislative activity of the state, etc.), at the regional level the price of real estate is determined by both macro and micro factors (movement of investment funds, demographic processes, climatic conditions); prices at the local level mainly depend on the territorial and administrative status, the level and nature of the development of economic sectors, infrastructure, and the political orientation of local authorities (Fig. 2.3.3).

Among the price-forming factors in the residential real estate market, macroeconomic factors play an important role. Using connection graphs and systems of structural regression equations, two groups of macroeconomic factors that simultaneously affect real estate market processes are distinguished. The first group of factors can be identified as the level of business activity. The active development of the economy, on the one hand, helps to increase the level of employment and incomes of the population, and thus expands the solvent demand for housing, on the other hand, by increasing the volume of housing construction, it expands the supply of housing. The second group of factors is related to credit and cash flows and the inflationary process. The increase in production and consumer prices causes an increase in the cost of new housing construction, inflationary expectations force the population to look for alternative means of preserving their own savings and income, and in the conditions of an underdeveloped securities market and distrust of financial and banking institutions, it stimulates them to invest in real estate on a less risky secondary market housing

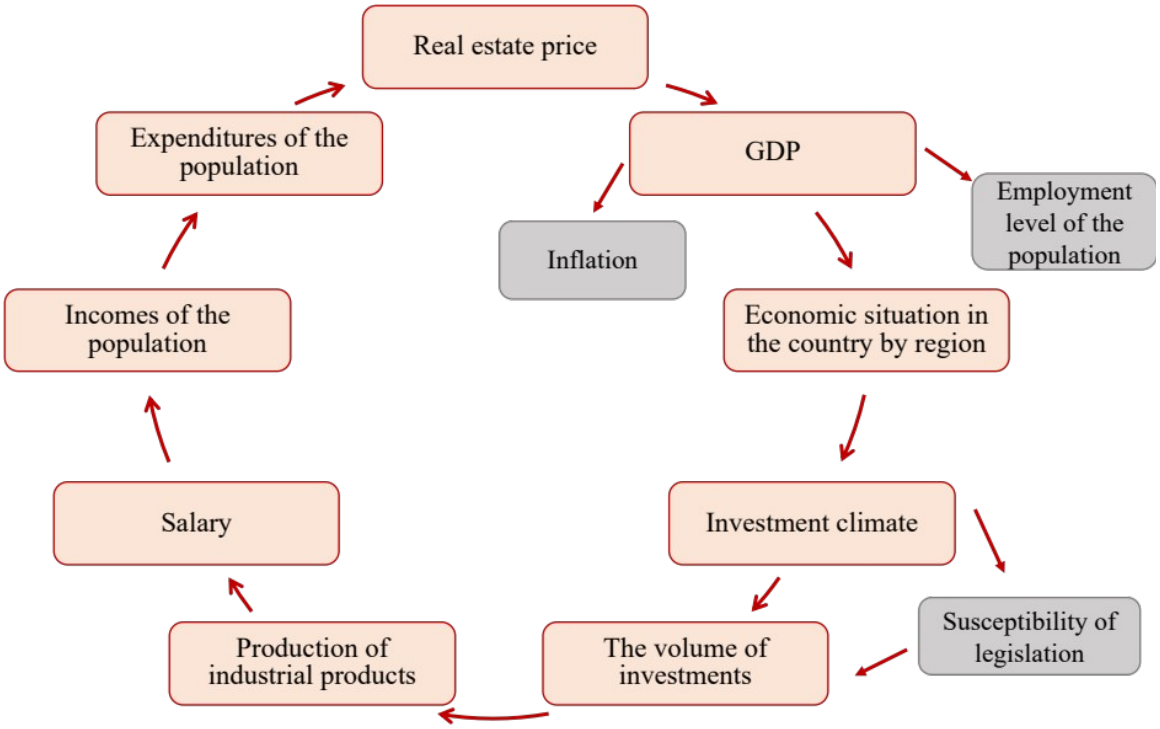


Fig. 2.3.3. Scheme of cyclical formation of real estate prices

In order to investigate the behavior of the real estate market in more detail, it is advisable to use the relationship between macroeconomic indicators and real estate prices. For further research, 6 factors were chosen: GDP, inflation, exchange rate, oil price, average salary, economic sentiment indicator. Data for 40 periods are taken into account - monthly indicators (July 2019 - October 2022). As a result, we received Table 2.1 of the initial data:

Table 2.1

Source data on the average price of apartments and the main macroeconomic indicators in Ukraine for the period June 2019 - December 2022

Year-month	№ period	Average price, $/m2	GDP, mln. UAH	NBU exchange rate USD/ UAH	Inflation, %	The price of oil, $/bbl	Average salary, UAH	Economic sentiment indicator
2019-07	1	764,75	36908,67	26,18	9,1	66,58	10970,82	103,31
2019-08	2	694,19	39208,05	25,02	8,8	61,02	10537,01	102,64
2019-09	3	726,93	39637,41	25,14	7,5	58,61	10687,06	102,01
2019-10	4	749,39	41861,58	24,20	6,5	60,78	10727,34	101,42
2019-11	5	754,25	41490,73	24,82	5,1	60,2	10679,14	100,89
2019-12	6	674,42	43672,84	23,97	4,1	62,47	12263,61	100,42
2020-01	7	682,23	44933,59	23,69	3,2	66,15	10726,94	100,01
2020-02	8	726,05	43216,83	25,03	2,4	54,31	10847,15	99,66
2020-03	9	825,23	44689,62	24,59	2,3	50,5	11445,82	99,38
2020-04	10	820,61	40385,47	27,63	2,1	22,72	10429,8	99,17

2020-05	11	761,71	41995,95	26,96	1,7	26,56	10541,52	99,01
2020-06	12	780,29	42721,19	26,87	2,4	38,61	11578,5	98,90
2020-07	13	958,78	43598,40	26,67	2,4	42,09	11804,41	98,84
2020-08	14	975,87	42501,80	27,68	2,5	43,4	11446,12	98,82
2020-09	15	981,95	43140,35	27,56	2,3	45,75	11998,49	98,82
2020-10	16	1009,46	42396,60	28,31	2,6	40,87	12173,89	98,84
2020-11	17	1055,49	42530,91	28,45	3,8	39,24	11986,69	98,86
2020-12	18	1051,27	42749,52	28,50	5	47,25	14178,85	98,87
2021-01	19	1042,54	43312,93	28,27	6,1	51,73	12336,78	98,85
2021-02	20	1037,55	43697,52	28,13	7,5	56,21	12548,85	98,79
2021-03	21	1059,92	44089,61	27,95	8,5	63,31	13612,21	98,68
2021-04	22	1065,41	44316,21	27,82	8,4	64,65	13543,08	98,50
2021-05	23	1091,31	44421,37	27,73	9,5	66,82	13499	98,24
2021-06	24	1119,46	44742,11	27,47	9,5	70,63	14312,85	97,90
2021-07	25	1098,09	44956,67	27,23	10,2	75,61	14345,13	97,45
2021-08	26	1100,94	45394,04	26,82	10,2	75,31	13997	96,90
2021-09	27	1099,94	44950,19	26,89	11	71,31	14239,3	96,24
2021-10	28	1103,96	45035,19	26,62	10,9	79,24	14044,81	95,47
2021-11	29	1119,45	45178,72	26,28	10,3	84,55	14282,18	94,60
2021-12	30	1148,63	43150,49	27,21	10	68,94	17453,23	93,63
2022-01	31	1178,18	42540,85	27,28	10	78,41	14577	92,57
2022-02	32	1215,65	40267,21	28,46	10,7	89,29	14133,18	91,45
2022-03	33	1235,63	38652,93	29,25	13,7	107,65	13016,16	90,30
2022-04	34	1424,79	38137,19	29,25	16,4	104,45	12081,96	89,14
2022-05	35	1216,53	37633,93	29,25	18	106,97	12582,42	88,02
2022-06	36	1166,01	37159,13	29,25	21,5	115,9	13957,63	86,98
2022-07	37	1225,12	36730,51	29,25	22,2	111,44	13499,87	86,10
2022-08	38	1246,59	29094,11	36,57	23,8	99,93	12745,82	85,44
2022-09	39	1349,54	28873,56	36,57	24,6	92,17	13387,48	85,08
2022-10	40	1348,88	28741,49	36,57	26,6	88,86	13663,20	85,12
2022-11	41	1365,32	28718,27	36,57	26,5	94,50	13675,69	85,67
2022-12	42	1365,10	28825,96	36,57	26,6	87,05	13722,31	86,84

As a next step, a general statistical analysis of the available data have been conducted with results grouped in Table 2.2. According to the calculated indicators, we can see that the estimate of the standard deviation of the price of a square meter of an apartment is $214.05, which is 20.71% of its average value. The estimate of the standard deviation of the GDP is equal to 12.34% of the average value, the exchange rate is 12.24%, the average salary is 12.03%, the economic sentiment indicator is 5.8%.

Table 2.2

General statistical analysis of the initial data for apartments secondary market in Ukraine for the period June 2019 - December 2022

	Average price, $/m^2	GDP, mln. UAH	NBU exchange rate USD/ UAH	Inflation, %	The price of oil, $/bbl	Average salary, UAH	Economic sentiment indicator
Average value	1033,75	40625,23	28,20	10,15	68,86	12720,96	95,66
Standard error	33,03	773,46	0,53	1,18	3,61	236,08	0,86
Median	1062,67	42535,88	27,60	8,95	66,37	12664,12	98,59
Standard deviation	214,05	5012,60	3,45	7,62	23,36	1529,95	5,55
Sampling variance	45816,45	25126144,85	11,91	58,01	545,86	2340749,37	30,78
Excess	-0,94	1,28	1,97	-0,04	-0,58	0,52	-0,72
Asymmetry	-0,17	-1,50	1,55	1,00	0,20	0,43	-0,82
Interval	750,37	16675,76	12,88	24,90	93,18	7023,43	18,23
Minimum	674,42	28718,27	23,69	1,70	22,72	10429,80	85,08
Maximum	1424,79	45394,04	36,57	26,60	115,90	17453,23	103,31
Sum	43417,39	1706259,68	1184,53	426,50	2892,04	534280,29	4017,83
Number	42,00	42,00	42,00	42,00	42,00	42,00	42,00
Highest value	1424,79	45394,04	36,57	26,60	115,90	17453,23	103,31
Lowest value	674,42	28718,27	23,69	1,70	22,72	10429,80	85,08
Confidence level (95%)	66,70	1562,04	1,08	2,37	7,28	476,77	1,73

Thus, the performed selective assessment of deviations at the level of 7-22% of the average values of the indicators indicates, on the one hand, the presence of a significant variation of the indicators and the feasibility of its research and analysis, and on the other hand, it allows us to assume the homogeneity of the sample indicators.

The next stage of the analysis is the verification of the assumption about the existence of a relationship (dependence or interdependence between indicators). According to the average monthly data for the period from July 2019 to March 2023, a correlation-regression analysis was performed and paired correlation coefficients were obtained, which determine the closeness of the relationship between the variables. As a result, a matrix of paired correlation coefficients was obtained (table 2.3).

Table 2.3

Correlation matrix of the connection between the price of apartments and macroeconomic indicators

	avg	*gdp*	*course*	*inf*	*nafta*	*wages*	*iemm*
avg	1,0000						
gdp	0,8539	1,0000					
course	0,7526	-0,8601	1,0000				
inf	0,7763	-0,8261	0,8242	1,0000			
nafta	0,6910	-0,5202	0,4782	0,8419	1,0000		
wages	0,6946	-0,0330	0,3438	0,4509	0,4836	1,0000	
iemm	-0,5076	0,7410	-0,8188	-0,9006	-0,8027	-0,4987	1,0000

The following designations were used: period – serial number of the period, avg – average price per square meter. m apartment, gdp – GDP, course – dollar exchange rate, inf – inflation rate, nafta – world oil price, wages – average monthly wage in Ukraine, iemm – economic sentiment indicator.

Based on the correlation matrix, we can see that GDP (r=0.85), inflation (r=0.78) and dollar exchange rate (r=0.75), to a lesser extent world oil prices (r=0.69) and average salary (r=0,69). At the same time, the indicator of economic sentiment has almost no effect. Thus, 5 factors were determined for the construction of single- and multi-factor models.

However, a characteristic feature of the mechanism of formation of variation and dynamics of socio-economic indicators is the lateness of the influence of factors, when the cause and effect are disconnected in time. Often, the influence of one factor on others does not occur immediately, but with a certain delay. That is why there is a need to study the presence of delayed influence of factors on the formation of real estate prices, that is, time lags. For this purpose, correlation matrices were constructed, which take into account the delay in the influence of the relevant factors for 1, 2, 3, 4, 5, 6 months (see Table 2.4).

Table 2.4

Correlation matrix of the relationship between the price of apartments and macroeconomic indicators (taking into account the time lag)

Time lag = 1 month							
	avg	*gdp*	*course*	*inf*	*nafta*	*wages*	*iemm*
avg	1,000						
gdp	0,851	1,000					
course	0,764	-0,837	1,000				
inf	0,740	-0,801	0,799	1,000			
nafta	0,677	-0,515	0,470	0,858	1,000		

wages	0,713	0,006	0,331	0,444	0,477	1,000	
iemm	-0,453	0,721	-0,808	-0,896	-0,803	-0,491	1,000

Time lag = 2 months

	avg	*gdp*	*course*	*inf*	*nafta*	*wages*	*iemm*
avg	1,000						
gdp	0,846	1,000					
course	0,739	-0,802	1,000				
inf	0,707	-0,766	0,763	1,000			
nafta	0,633	-0,493	0,443	0,866	1,000		
wages	0,724	0,053	0,320	0,440	0,469	1,000	
iemm	-0,389	0,687	-0,788	-0,885	-0,799	-0,485	1,000

Time lag = 3 months

	avg	*gdp*	*course*	*inf*	*nafta*	*wages*	*iemm*
avg	1,000						
gdp	0,843	1,000					
course	0,773	-0,745	1,000				
inf	0,683	-0,713	0,707	1,000			
nafta	0,594	-0,485	0,430	0,893	1,000		
wages	0,726	0,115	0,309	0,438	0,461	1,000	
iemm	-0,309	0,635	-0,757	-0,870	-0,806	-0,481	1,000

Time lag = 4 months

	avg	*gdp*	*course*	*inf*	*nafta*	*wages*	*iemm*
avg	1,000						
gdp	0,843	1,000					
course	0,709	-0,636	1,000				
inf	0,652	-0,641	0,632	1,000			
nafta	0,571	-0,471	0,407	0,915	1,000		
wages	0,754	0,186	0,322	0,447	0,456	1,000	
iemm	-0,198	0,556	-0,714	-0,847	-0,810	-0,489	1,000

Having analyzed the results of the calculations, we see that there is a time lag when we consider the influence of wages and exchange rates on the price of an apartment. Thus, the correlation coefficient between the price and wages is the highest with a delay of 4 months (r=0.75), and between the price and the exchange rate - 3 months (r=0.77). We must take these conclusions into account in further calculations so that modeling and forecasting correspond to the real picture.

Let's start with regression analysis in the context of pairwise regression. In the general sense, regression is the dependence of the average values of any random variable on some other or several variables. The equation that connects these quantities is called the regression equation, and the corresponding graph is the regression line of the quantity Y on X. So, the regression equation in linear form for one factor:

$$Y=bx+c,$$

where a and b are regression coefficients – parameters estimated from statistical data.

Thus, the method of regression analysis consists in deriving the regression equation, which is used to find the average value of a random variable, if the value of the other is known. In our case, it is necessary to derive such an equation, with the help of which we will find the average price of a square meter of an apartment, if the values of the above macroeconomic factors are known.

Let's start with the pairwise regression dependence of the apartment price and GDP. For this, it is necessary, first of all, to analyze the dynamics of Ukraine's GDP (Fig. 2.3.4) to determine the main tendencies and trends. For visual convenience, the periods were numbered according to the scheme given in table 2.5. However, in order to objectively assess the picture, it is necessary to use the indicator in the dollar equivalent. The values are calculated using the official exchange rate of the NBU.

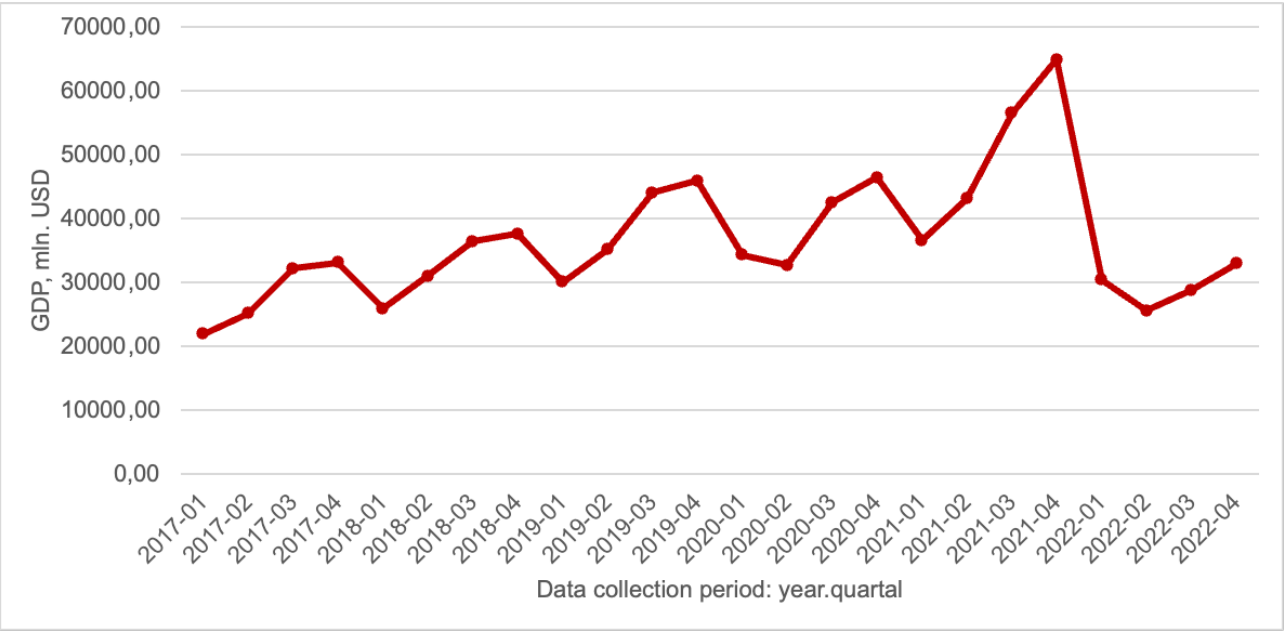


Fig. 2.3.4. Evolution of the nominal GDP of Ukraine for 2017-2022, million USD

So, from the graph, we can see that in 2016-2017, thanks to the considered steps of the Government, it was possible to stabilize the

economy, therefore, positive trends were observed in 2017. The real gross domestic product in 2017 compared to 2016 (in constant 2010 prices) increased by 2.5% - up to UAH 2,982.92 billion (in actual prices). According to the updated data of the State Statistics Service, the GDP for the first quarter of 2017 compared to the corresponding quarter of the previous year increased by 2.8% - to 591.008 billion UAH, for the second quarter it increased by 2.6% - to 664.760 billion UAH, for the third quarter it increased by 2 .4% - to 833.130 billion UAH, for the fourth quarter it increased by 2.2% - to 894.022 billion UAH. According to the results of 2018, the indicator continued to grow and increased by 3.2%. It is believed that the main driving force of economic growth will remain private consumption, which will increase this year due to the preservation of high growth rates of real wages against the background of active migration processes.

According to the results of 2019, the gross domestic product of Ukraine increased by 3.2% and amounted to 3.974 trillion hryvnias. Thus, the economic growth of Ukraine slowed down by 0.2 percentage points compared to 2018, when the GDP grew by 3.4%. For 2020, the country's nominal GDP was 4,194.1 billion UAH. Compared to 2019, it decreased (at constant 2016 prices) by 4.0%, which is obviously due to the destructive impact of the coronavirus pandemic.

GDP in 2021 grew by only 3%. Among the reasons are the rapid increase in the price of energy carriers and their shortage, the impact of low harvests in 2020, slower recovery of the service sector, limited capacities of certain production sectors, more significant losses from the pandemic, as well as rapid fiscal consolidation.

During 2022, the economy of Ukraine suffered the largest losses, damages and damages in the entire history of independence, however, thanks to the Armed Forces, the coordinated work of the Government and business, the rapid restoration of destroyed/damaged critical infrastructure facilities, as well as financial support from international partners, the economy was able to be sustained.

In the 1st quarter of 2022, the decrease in real GDP compared to the 1st quarter of 2021 is 15.1%, in the 2nd quarter of 2022 - 37.2%, in the 3rd quarter of 2022 - 30.8%, the fall in the end of 2022 is estimated at 30.4% (in 2021, GDP grew by 3.4%). This is objectively the worst result since independence, but better than most experts expected at the start of the full-scale invasion, when estimates ranged from a 40-50% drop in GDP or more.

At the same time, in December, the fall in GDP was estimated at the level of -34, which is somewhat better than the estimates for November (fall in GDP at the level of 37) (respectively, the IV quarter - a fall at the level of 35.5), taking into account a certain stabilization of the energy supply situation after the shelling in in November

Subsequent terrorist missile attacks by the Russian Federation caused, although not critical, damage (in particular, to energy infrastructure), which continued to put pressure on business sentiment and activity.

Thus, we observe that a significant restraining factor is the tense geopolitical situation, which will have a negative impact on investment decisions. In addition, despite the gradual fading of the pandemic, the consequences of the corona crisis remain quite tangible. Relatively high energy prices and the shortage of certain types of raw materials, especially in the first half of the year, also limit the potential for growth.

Taking into account the indicated trends, we will try to interpolate the GDP trajectory (Fig. 2.3.5).

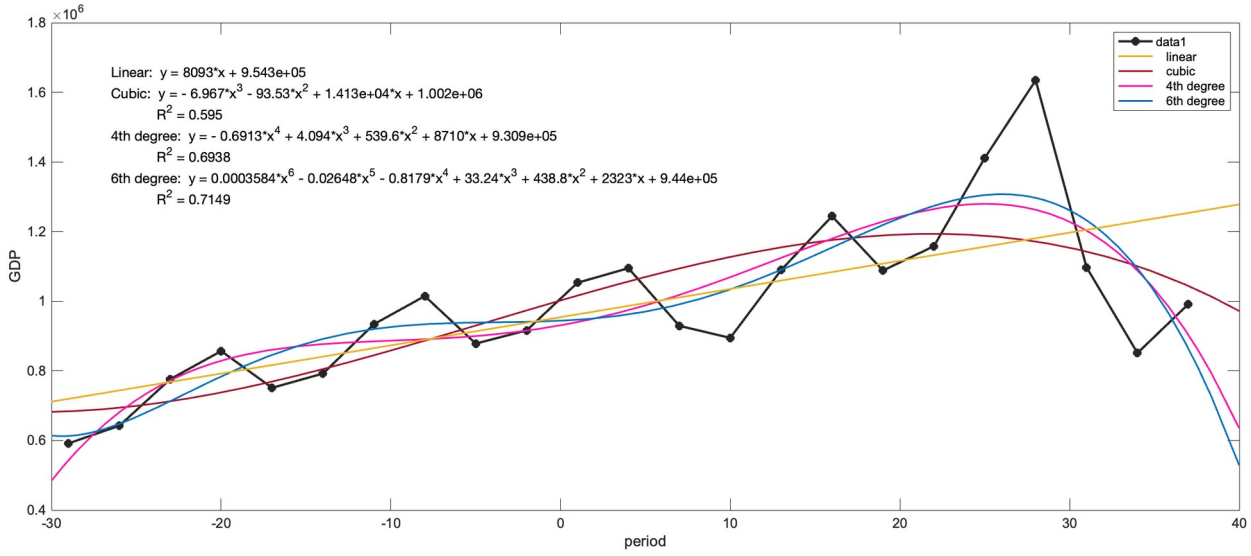


Fig. 2.3.5. Trend models for describing the dynamics of Ukraine's GDP

4 trend models were selected that roughly describe the dynamics of this indicator. Interpolation was carried out using a linear model and polynomials of degrees 3, 4 and 6, the coefficients of each of the equations and the results of their statistical significance are grouped in table 2.5.

Table 2.5

GDP interpolation results

Period	GDP, mln USD (Y)	Linear model		Polynomial model (3rd degree)		Polynomial model (4th degree)	
		Predicted value (Y1)	Y-Y1	Predicted value (Y2)	Y-Y2	Пронозоване значення (Y3)	Predicted value (Y1)
-29	591765,00	683489,43	-91724,43	543321,68	48443,32	612808,21	-21043,21
-26	642544,40	693845,71	-51301,31	681345,95	-38801,55	647578,14	-5033,74
-23	776311,32	712300,12	64011,20	772752,62	3558,70	712873,59	63437,73
-20	856953,90	737724,00	119229,90	829180,00	27773,90	783949,60	73004,30
-17	751384,87	768988,70	-17603,83	860922,51	-109537,64	845950,97	-94566,10
-14	792372,06	804965,57	-12593,51	876930,68	-84558,62	891791,96	-99419,90
-11	934021,22	844525,95	89495,27	884811,16	49210,06	920224,04	13797,17
-8	1014852,87	886541,18	128311,68	890826,71	124026,16	934091,85	80761,01
-5	878460,06	929882,63	-51422,57	899896,19	-21436,13	938777,16	-60317,10
-2	916259,32	973421,62	-57162,30	915594,59	664,73	940831,06	-24571,75
1	1053251,20	1016029,50	37221,69	940153,00	113098,19	946794,20	106457,00
4	1094915,06	1056577,63	38337,43	974458,64	120456,42	962205,13	132709,93
7	929365,02	1093937,35	-164572,33	1018054,83	-88689,81	990796,86	-61431,84
10	894754,21	1126980,00	-232225,79	1069141,00	-174386,79	1033881,40	-139127,19
13	1089605,36	1154576,93	-64971,57	1124572,70	-34967,34	1089922,53	-317,17
16	1244285,51	1175599,49	68686,02	1179861,59	64423,92	1154296,61	89988,90
19	1088338,45	1188919,02	-100580,56	1229175,44	-140836,99	1219241,56	-130903,10
22	1157904,14	1193406,86	-35502,73	1265338,14	-107434,00	1273993,92	-116089,78
25	1411544,84	1187934,38	223610,47	1279829,69	131715,15	1305114,06	106430,78
28	1634536,25	1171372,90	463163,36	1262786,20	371750,06	1296999,48	337536,77
31	1097440,70	1142593,77	-45153,07	1202999,89	-105559,18	1232586,21	-135145,51

34	851353,04	1100468,35	-249115,31	1087919,10	-236566,06	1094238,42	-242885,38
37	991814,04	1043867,98	-52053,93	903648,28	88165,76	864826,00	126988,04
Coefficients		p1=	-6,967	p1=	-0,6913	p1=	0,0003584
		p2=	-93,53	p2=	4,094	p2=	-0,02648
		p3=	1,41E+04	p3=	539,6	p3=	-0,8179
		p4=	1,00E+06	p4=	8710	p4=	33,24
		R^2=	0,595	p5=	9,31E+05	p5=	438,8
				R^2=	0,6938	p6=	2323
						p7=	9,44E+05
						R^2=	0,7722

Based on the correlation coefficient calculated above between the average price per square meter of an apartment and GDP, which is 0.85, we assume a high degree of dependence of these indicators, therefore, to identify the stochastic relationship between apartment prices and GDP, we will construct a correlation field of indicators and a regression function.

The results of checking the statistical significance of the built power regression equation of the 1st and 2nd degree in graphic format are shown in Figures 2.3.6 and 2.3.7. The results of the relevant calculations are shown in Table 2.6.

Table 2.6

Checking the statistical significance of apartment price trend models depending on GDP

Period	x	y	X = ln x	Y = ln y	X^2	Y^2	XY	Power-law regression (1st degree)			Power-law regression (2nd degree)		
								Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals
1	35472,82	764,78	10,48	6,64	109,76	44,08	69,56	692,23	-72,55	-0,09	668,13	-96,66	-0,13
2	35761,94	695,34	10,48	6,54	109,93	42,83	68,62	704,72	9,38	0,01	683,47	-11,86	-0,02
3	36067,32	726,23	10,49	6,59	110,11	43,40	69,13	718,04	-8,19	-0,01	699,66	-26,57	-0,04
4	36388,79	748,64	10,50	6,62	110,29	43,80	69,51	732,21	-16,43	-0,02	716,67	-31,97	-0,04
5	36725,99	753,60	10,51	6,62	110,49	43,89	69,64	747,23	-6,37	-0,01	734,48	-19,11	-0,03
6	37078,43	676,77	10,52	6,52	110,69	42,48	68,57	763,11	86,34	0,13	753,07	76,30	0,11
7	37445,47	684,71	10,53	6,53	110,89	42,63	68,75	779,84	95,13	0,14	772,40	87,68	0,13
8	37826,28	726,43	10,54	6,59	111,11	43,40	69,44	797,41	70,98	0,10	792,41	65,98	0,09
9	38219,92	823,52	10,55	6,71	111,33	45,07	70,84	815,80	-7,72	-0,01	813,06	-10,46	-0,01
10	38625,27	820,39	10,56	6,71	111,55	45,02	70,87	834,98	14,59	0,02	834,28	13,89	0,02
11	39041,05	762,27	10,57	6,64	111,77	44,04	70,16	854,90	92,63	0,12	856,01	93,74	0,12
12	39465,85	780,43	10,58	6,66	112,00	44,35	70,48	875,51	95,09	0,12	878,16	97,74	0,13
13	39898,07	959,21	10,59	6,87	112,23	47,14	72,74	896,76	-62,45	-0,07	900,66	-58,55	-0,06
14	40336,00	975,81	10,60	6,88	112,47	47,38	73,00	918,58	-57,23	-0,06	923,41	-52,40	-0,05
15	40777,73	980,40	10,62	6,89	112,70	47,44	73,12	940,88	-39,52	-0,04	946,31	-34,09	-0,03
16	41221,22	1010,47	10,63	6,92	112,93	47,86	73,52	963,56	-46,91	-0,05	969,26	-41,21	-0,04
17	41664,27	1055,40	10,64	6,96	113,15	48,46	74,05	986,51	-68,89	-0,07	992,14	-63,26	-0,06
18	42104,53	1050,46	10,65	6,96	113,38	48,40	74,08	1009,61	-40,85	-0,04	1014,84	-35,62	-0,03
19	42539,49	1042,52	10,66	6,95	113,60	48,29	74,07	1032,72	-9,80	-0,01	1037,22	-5,30	-0,01
20	42966,48	1037,94	10,67	6,94	113,81	48,23	74,09	1055,68	17,75	0,02	1059,15	21,21	0,02
21	43382,69	1059,52	10,68	6,97	114,02	48,52	74,38	1078,33	18,81	0,02	1080,48	20,96	0,02
22	43785,14	1066,63	10,69	6,97	114,21	48,61	74,51	1100,48	33,86	0,03	1101,08	34,45	0,03

23	44170,71	1091,20	10,70	7,00	114,40	48,93	74,82	1121,94	30,74	0,03	1120,78	29,58	0,03
24	44536,10	1118,67	10,70	7,02	114,58	49,28	75,14	1142,48	23,80	0,02	1139,42	20,75	0,02
25	44877,89	1098,74	10,71	7,00	114,74	49,03	75,00	1161,87	63,13	0,06	1156,83	58,09	0,05
26	45192,48	1100,98	10,72	7,00	114,89	49,06	75,07	1179,88	78,90	0,07	1172,84	71,85	0,07
27	45476,12	1100,01	10,72	7,00	115,02	49,04	75,11	1196,25	96,24	0,09	1187,25	87,24	0,08
28	45724,91	1103,71	10,73	7,01	115,14	49,09	75,18	1210,71	107,00	0,10	1199,88	96,17	0,09
29	45934,79	1119,62	10,73	7,02	115,24	49,29	75,37	1222,98	103,36	0,09	1210,52	90,90	0,08
30	46101,55	1147,99	10,74	7,05	115,32	49,64	75,66	1232,78	84,79	0,07	1218,97	70,98	0,06
31	46220,82	1179,37	10,74	7,07	115,37	50,02	75,97	1239,81	60,44	0,05	1225,01	45,64	0,04
32	46288,09	1215,55	10,74	7,10	115,40	50,45	76,30	1243,79	28,24	0,02	1228,42	12,87	0,01
33	46298,67	1234,50	10,74	7,12	115,41	50,67	76,47	1244,41	9,92	0,01	1228,95	-5,54	0,00
34	46247,73	1418,74	10,74	7,26	115,39	52,67	77,96	1241,40	-177,34	-0,13	1226,38	-192,37	-0,14
35	46130,29	1217,37	10,74	7,10	115,33	50,47	76,30	1234,47	17,10	0,01	1220,43	3,06	0,00
36	45941,20	1167,92	10,74	7,06	115,24	49,89	75,82	1223,35	55,43	0,05	1210,85	42,93	0,04
37	45675,17	1225,83	10,73	7,11	115,12	50,57	76,30	1207,81	-18,02	-0,01	1197,35	-28,48	-0,02
38	45326,75	1247,26	10,72	7,13	114,95	50,82	76,43	1187,61	-59,64	-0,05	1179,66	-67,60	-0,05
39	44890,33	1351,85	10,71	7,21	114,75	51,97	77,23	1162,58	-189,27	-0,14	1157,46	-194,39	-0,14
40	44360,16	1348,99	10,70	7,21	114,49	51,94	77,12	1132,56	-216,43	-0,16	1130,45	-218,55	-0,16

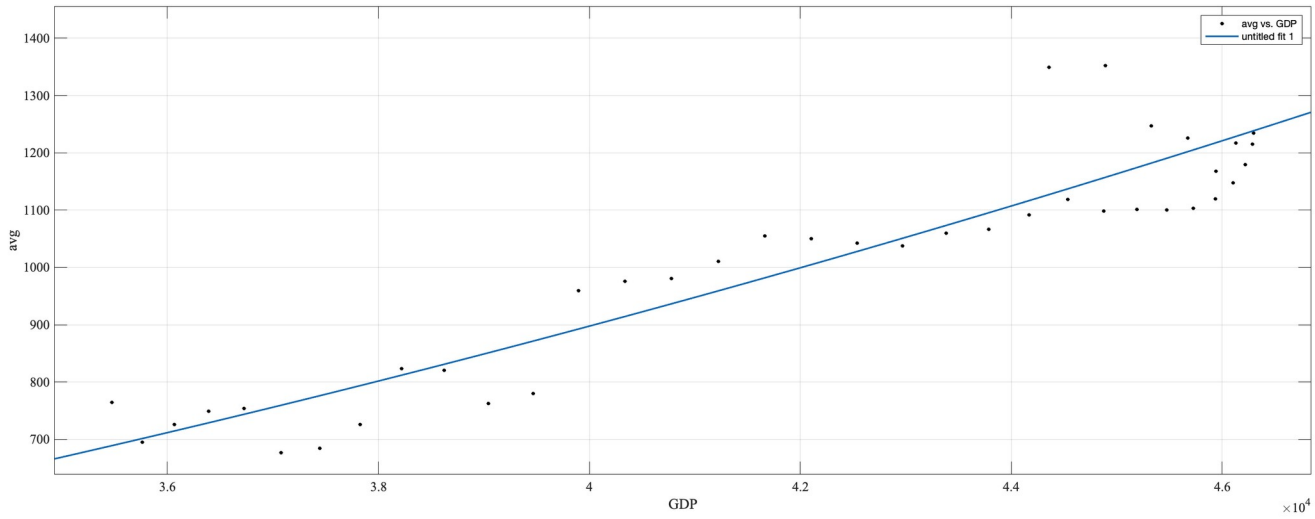


Fig. 2.3.6. Power-law regression (1st degree) of the apartment price depending on the GDP

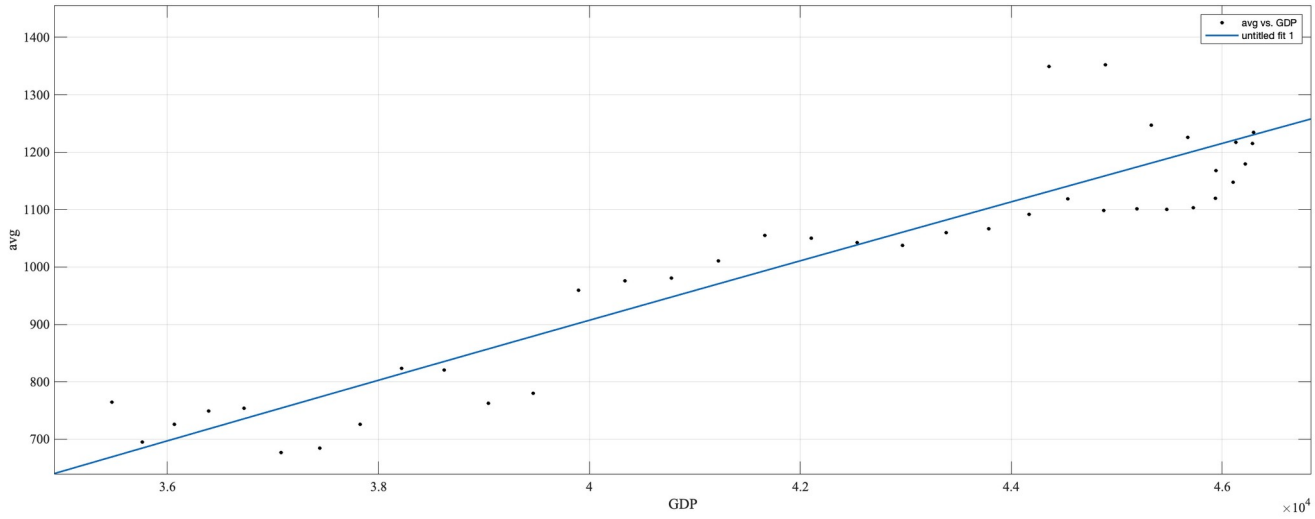


Fig. 2.3.7. Power-law regression (2nd degree) of the apartment price depending on the GDP

The built-in regression function makes it possible to calculate forecast values of the average cost of living space for a given value of GDP. After the calculations, we can say that the relationship between the indicators is direct and with an increase in GDP, housing prices increase. This chart graphically reflects the concentration of sample values of real estate prices around our estimated regression equation. Their deviation from the regression line is the result of the action of the random component (the action of all other factors not included in the model).

Using a similar methodology, we will consider the next factor - the level of consumer inflation.

From Figure 2.3.8, we can see that until April 2020, inflation had a downward trend, then until October, the indicator was more or less stable with

minor fluctuations. The main conditions for the formation of domestic prices during 2020 were: relatively limited demand due to forced measures to prevent the active spread of the COVID-19 pandemic; state support of the economy in the existing conditions; gradual devaluation of the hryvnia; the dynamics of world prices, which was formed as a result of destructive processes in the world economy, also associated with measures to contain the spread of the disease. Under difficult conditions against the background of quarantine measures, the formation of consumer prices depended on changes in priorities in consumption and, accordingly, on the adaptation of trade agents to these changes. Thus, both the volumes of retail trade and consumer prices, primarily for essential goods, grew at a faster rate

In subsequent periods, inflation began to rapidly accelerate. In December 2021, the consumer price index (CPI) increased by 0.9% for the month. Such dynamics continued until October 2021. The biggest pro-inflationary risk was the sharp rise in energy prices on world markets. In the future, we can see the impact of the inflation targeting regime and the increase of the NBU discount rate in the following periods, which led to a temporary decline and stabilization. With the beginning of a full-scale war, inflation began to rise rapidly.

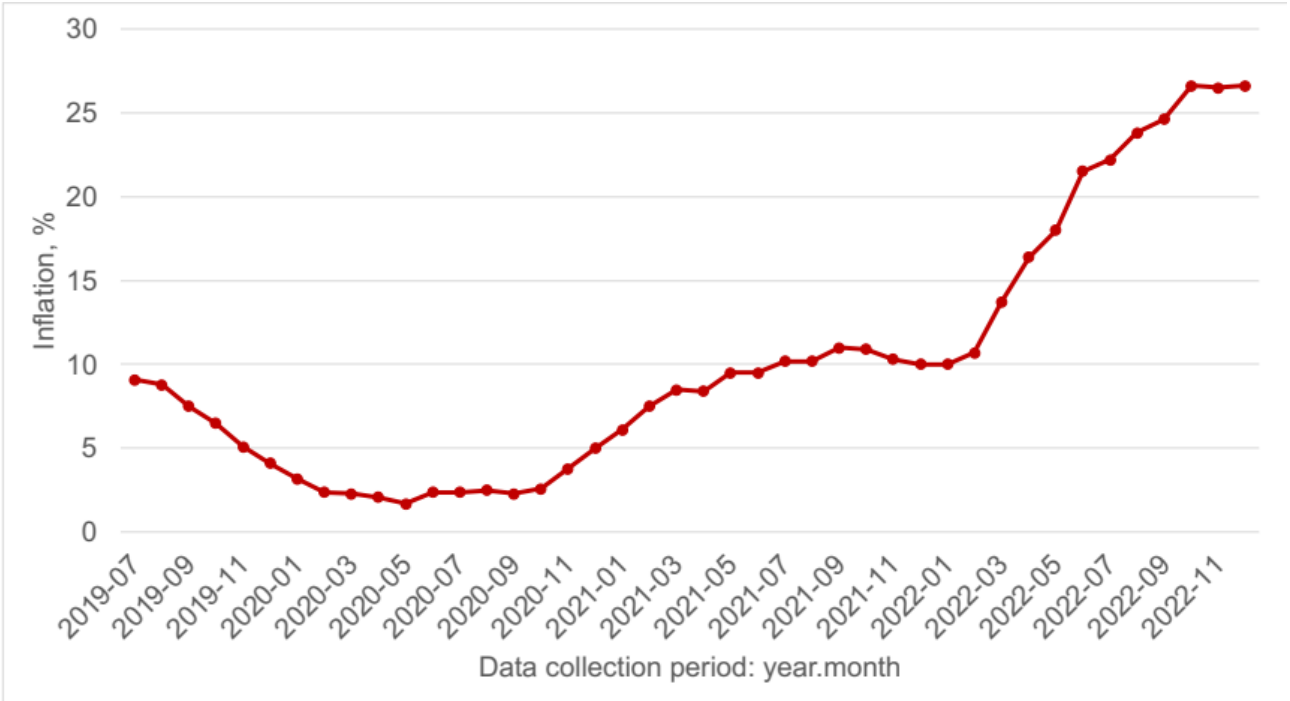


Fig. 2.3.8. Evolution of inflation in Ukraine for July 2019 - December 2022, %

The acceleration of inflation in 2022 is primarily related to the consequences of Russia's full-scale military aggression. Among them: destruction of enterprises and infrastructure, disruption of production and supply chains, growth of business production costs, situational hype demand for certain goods and services. Indirect consequences of the war also had an impact, in particular exchange rate effects and deterioration of population and

business expectations over the course of the year. In addition, prices in Ukraine were pressured by the global acceleration of inflation - it was last year that most countries updated their multi-year inflation highs.

Despite the war and high global inflation, the actual rates of price growth in Ukraine remained under control, and inflationary pressure stabilized in recent months.

Figure 2.3.9 shows inflation interpolation models. 4 trend models were selected that roughly describe the dynamics of the indicator. Interpolation was carried out using a linear model and polynomials of degrees 3, 4 and 6, the coefficients of each of the equations and the results of their statistical significance are grouped in table 2.7.

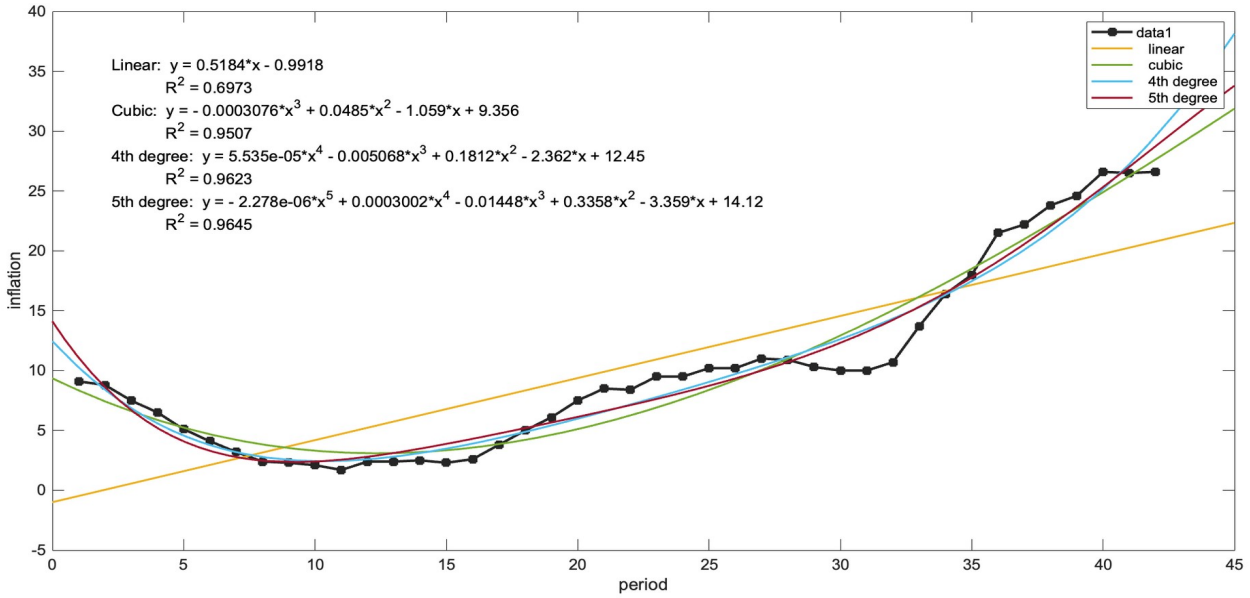


Fig. 2.3.9. Trend models for describing the dynamics of the inflation rate

Table 2.7

Results of inflation rate interpolation

Period	Inflation, % (Y)	Linear model		Polynomial model (3rd degree)		Polynomial model (4th degree)		Polynomial model (6th degree)	
		Predicted value (Y1)	Y-Y1	Predicted value (Y2)	Y-Y2	Пронозоване значення (Y3)	Y-Y3	Predicted value (Y1)	Y-Y1
1	9,1	-0,47	9,57	8,35	0,75	10,26	-1,16	11,08	-1,98
2	8,8	0,04	8,76	7,43	1,37	8,41	0,39	8,63	0,17
3	7,5	0,56	6,94	6,61	0,89	6,86	0,64	6,70	0,80
4	6,5	1,08	5,42	5,88	0,62	5,59	0,91	5,20	1,30
5	5,1	1,60	3,50	5,24	-0,14	4,57	0,53	4,09	1,01
6	4,1	2,12	1,98	4,68	-0,58	3,78	0,32	3,30	0,80
7	3,2	2,64	0,56	4,21	-1,01	3,19	0,01	2,78	0,42
8	2,4	3,16	-0,76	3,83	-1,43	2,78	-0,38	2,48	-0,08
9	2,3	3,67	-1,37	3,53	-1,23	2,54	-0,24	2,37	-0,07
10	2,1	4,19	-2,09	3,31	-1,21	2,44	-0,34	2,40	-0,30
11	1,7	4,71	-3,01	3,17	-1,47	2,46	-0,76	2,56	-0,86
12	2,4	5,23	-2,83	3,10	-0,70	2,59	-0,19	2,80	-0,40
13	2,4	5,75	-3,35	3,11	-0,71	2,81	-0,41	3,12	-0,72
14	2,5	6,27	-3,77	3,19	-0,69	3,12	-0,62	3,49	-0,99
15	2,3	6,78	-4,48	3,35	-1,05	3,49	-1,19	3,89	-1,59
16	2,6	7,30	-4,70	3,57	-0,97	3,91	-1,31	4,32	-1,72
17	3,8	7,82	-4,02	3,86	-0,06	4,39	-0,59	4,76	-0,96
18	5	8,34	-3,34	4,21	0,79	4,90	0,10	5,22	-0,22
19	6,1	8,86	-2,76	4,63	1,47	5,44	0,66	5,69	0,41

20	7,5	9,38	-1,88	5,12	2,38	6,00	1,50	6,16	1,34
21	8,5	9,89	-1,39	5,66	2,84	6,59	1,91	6,65	1,85
22	8,4	10,41	-2,01	6,26	2,14	7,19	1,21	7,15	1,25
23	9,5	10,93	-1,43	6,91	2,59	7,81	1,69	7,67	1,83
24	9,5	11,45	-1,95	7,62	1,88	8,44	1,06	8,21	1,29
25	10,2	11,97	-1,77	8,39	1,81	9,08	1,12	8,79	1,41
26	10,2	12,49	-2,29	9,20	1,00	9,75	0,45	9,40	0,80
27	11	13,01	-2,01	10,07	0,93	10,43	0,57	10,07	0,93
28	10,9	13,52	-2,62	10,98	-0,08	11,14	-0,24	10,78	0,12
29	10,3	14,04	-3,74	11,93	-1,63	11,89	-1,59	11,57	-1,27
30	10	14,56	-4,56	12,93	-2,93	12,67	-2,67	12,42	-2,42
31	10	15,08	-5,08	13,97	-3,97	13,50	-3,50	13,34	-3,34
32	10,7	15,60	-4,90	15,05	-4,35	14,39	-3,69	14,36	-3,66
33	13,7	16,12	-2,42	16,17	-2,47	15,34	-1,64	15,45	-1,75
34	16,4	16,63	-0,23	17,33	-0,93	16,38	0,02	16,64	-0,24
35	18	17,15	0,85	18,52	-0,52	17,52	0,48	17,92	0,08
36	21,5	17,67	3,83	19,74	1,76	18,77	2,73	19,29	2,21
37	22,2	18,19	4,01	20,99	1,21	20,14	2,06	20,75	1,45
38	23,8	18,71	5,09	22,27	1,53	21,67	2,13	22,29	1,51
39	24,6	19,23	5,37	23,58	1,02	23,36	1,24	23,90	0,70
40	26,6	19,74	6,86	24,91	1,69	25,23	1,37	25,56	1,04
41	26,5	20,26	6,24	26,27	0,23	27,32	-0,82	27,28	-0,78
42	26,6	20,78	5,82	27,64	-1,04	29,64	-3,04	29,02	-2,42
Coefficients		*p1=*	*0,5184*	*p1=*	*-0,0003076*	*p1=*	*5,54E-05*	*p1=*	*-2,28E-06*
		p2=	*-0,9918*	*p2=*	*0,0485*	*p2=*	*-5,07E-03*	*92=*	*3,00E-04*
		R2=	*0,6973*	*p3=*	*-1,059*	*p3=*	*1,81E-01*	*p3=*	*-1,45E-02*
				p4=	*9,356*	*p4=*	*-2,36E+00*	*p4=*	*3,36E-01*
				R2=	*0,9507*	*p5=*	*1,25E+01*	*p5=*	*-3,36E+00*

						R2=	*9,62E-01*	*p6=*	*1,41E+01*
								R2=	*9,65E-01*

Based on the correlation coefficient calculated above between the average price per square meter of an apartment and the level of inflation, which is 0.78, we assume a high degree of dependence of these indicators, therefore, to identify the stochastic relationship between apartment prices and inflation, we will construct a correlation field of indicators and a regression function.

The results of checking the statistical significance of the constructed exponential and power regression equation of the 1st and 2nd degree in graphic format are shown in figures 2.3.10, 2.3.11, 2.3.12. The results of the relevant calculations are shown in Table 2.8.

Table 2.8

Checking the statistical significance of apartment price trend models depending on the level of inflation

№	x	y	X = ln x	Y = ln y	X^2	Y^2	XY	Power-law regression (1st degree)			Power-law regression (2 degree)			Exponential regression		
								Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals
1	9,1	765	2,2	6,6	4,9	44,1	14,7	1059,1	294,4	0,4	1031,7	266,9	0,3	999,9	235,1	0,3
2	8,8	694	2,2	6,5	4,7	42,8	14,2	1052,0	357,8	0,5	1024,5	330,3	0,5	994,3	300,1	0,4
3	7,5	727	2,0	6,6	4,1	43,4	13,3	1018,7	291,7	0,4	992,5	265,6	0,4	970,2	243,3	0,3
4	6,5	749	1,9	6,6	3,5	43,8	12,4	989,7	240,3	0,3	966,5	217,1	0,3	952,1	202,8	0,3
5	5,1	754	1,6	6,6	2,7	43,9	10,8	942,5	188,2	0,2	927,4	173,2	0,2	927,4	173,1	0,2
6	4,1	674	1,4	6,5	2,0	42,4	9,2	901,9	227,5	0,3	897,0	222,6	0,3	910,1	235,7	0,3

7	3,2	682	1,2	6,5	1,4	42,6	7,6	857,9	175,7	0,3	867,3	185,1	0,3	894,8	212,6	0,3
8	2,4	726	0,9	6,6	0,8	43,4	5,8	809,6	83,5	0,1	838,2	112,1	0,2	881,4	155,4	0,2
9	2,3	825	0,8	6,7	0,7	45,1	5,6	802,7	-22,6	0,0	834,3	9,1	0,0	879,8	54,5	0,1
10	2,1	821	0,7	6,7	0,6	45,0	5,0	788,1	-32,5	0,0	826,3	5,7	0,0	876,5	55,9	0,1
11	1,7	762	0,5	6,6	0,3	44,0	3,5	755,2	-6,5	0,0	809,6	47,8	0,1	869,9	108,2	0,1
12	2,4	780	0,9	6,7	0,8	44,4	5,8	809,6	29,3	0,0	838,2	57,9	0,1	881,4	101,1	0,1
13	2,4	959	0,9	6,9	0,8	47,1	6,0	809,6	-149,2	-0,2	838,2	-120,6	-0,1	881,4	-77,4	-0,1
14	2,5	976	0,9	6,9	0,8	47,4	6,3	816,3	-159,6	-0,2	842,0	-133,9	-0,1	883,1	-92,8	-0,1
15	2,3	982	0,8	6,9	0,7	47,5	5,7	802,7	-179,3	-0,2	834,3	-147,7	-0,2	879,8	-102,2	-0,1
16	2,6	1009	1,0	6,9	0,9	47,8	6,6	822,8	-186,7	-0,2	845,7	-163,7	-0,2	884,8	-124,7	-0,1
17	3,8	1055	1,3	7,0	1,8	48,5	9,3	888,2	-167,3	-0,2	887,4	-168,1	-0,2	905,0	-150,5	-0,1
18	5,0	1051	1,6	7,0	2,6	48,4	11,2	938,7	-112,6	-0,1	924,5	-126,8	-0,1	925,6	-125,6	-0,1
19	6,1	1043	1,8	6,9	3,3	48,3	12,6	977,1	-65,4	-0,1	955,7	-86,9	-0,1	945,0	-97,5	-0,1
20	7,5	1038	2,0	6,9	4,1	48,2	14,0	1018,7	-18,9	0,0	992,5	-45,0	0,0	970,2	-67,3	-0,1
21	8,5	1060	2,1	7,0	4,6	48,5	14,9	1044,7	-15,2	0,0	1017,3	-42,6	0,0	988,7	-71,3	-0,1
22	8,4	1065	2,1	7,0	4,5	48,6	14,8	1042,2	-23,2	0,0	1014,9	-50,5	0,0	986,8	-78,6	-0,1
23	9,5	1091	2,3	7,0	5,1	48,9	15,7	1068,4	-22,9	0,0	1041,1	-50,2	0,0	1007,5	-83,9	-0,1
24	9,5	1119	2,3	7,0	5,1	49,3	15,8	1068,4	-51,1	0,0	1041,1	-78,4	-0,1	1007,5	-112,0	-0,1
25	10,2	1098	2,3	7,0	5,4	49,0	16,3	1083,8	-14,3	0,0	1057,1	-40,9	0,0	1020,8	-77,3	-0,1
26	10,2	1101	2,3	7,0	5,4	49,1	16,3	1083,8	-17,1	0,0	1057,1	-43,8	0,0	1020,8	-80,1	-0,1
27	11,0	1100	2,4	7,0	5,7	49,0	16,8	1100,4	0,5	0,0	1075,0	-24,9	0,0	1036,3	-63,6	-0,1
28	10,9	1104	2,4	7,0	5,7	49,1	16,7	1098,4	-5,6	0,0	1072,8	-31,1	0,0	1034,4	-69,6	-0,1
29	10,3	1119	2,3	7,0	5,4	49,3	16,4	1085,9	-33,5	0,0	1059,4	-60,0	-0,1	1022,7	-96,7	-0,1
30	10,0	1149	2,3	7,0	5,3	49,7	16,2	1079,5	-69,2	-0,1	1052,6	-96,0	-0,1	1017,0	-131,7	-0,1
31	10,0	1178	2,3	7,1	5,3	50,0	16,3	1079,5	-98,7	-0,1	1052,6	-125,6	-0,1	1017,0	-161,2	-0,1
32	10,7	1216	2,4	7,1	5,6	50,5	16,8	1094,3	-121,3	-0,1	1068,4	-147,3	-0,1	1030,5	-185,2	-0,2
33	13,7	1236	2,6	7,1	6,9	50,7	18,6	1150,2	-85,4	-0,1	1132,2	-103,4	-0,1	1090,3	-145,3	-0,1

34	16,4	1425	2,8	7,3	7,8	52,7	20,3	1192,7	-232,1	-0,2	1185,4	-239,4	-0,2	1147,2	-277,6	-0,2
35	18,0	1217	2,9	7,1	8,4	50,5	20,5	1215,3	-1,2	0,0	1215,4	-1,2	0,0	1182,2	-34,3	0,0
36	21,5	1166	3,1	7,1	9,4	49,9	21,7	1259,6	93,6	0,1	1277,8	111,8	0,1	1262,7	96,7	0,1
37	22,2	1225	3,1	7,1	9,6	50,6	22,0	1267,8	42,6	0,0	1289,8	64,7	0,1	1279,5	54,4	0,0
38	23,8	1247	3,2	7,1	10,0	50,8	22,6	1285,7	39,1	0,0	1316,8	70,2	0,1	1318,6	72,0	0,1
39	24,6	1350	3,2	7,2	10,3	51,9	23,1	1294,3	-55,3	0,0	1330,0	-19,5	0,0	1338,6	-10,9	0,0
40	26,6	1349	3,3	7,2	10,8	51,9	23,6	1314,8	-34,1	0,0	1362,4	13,5	0,0	1390,0	41,1	0,0
41	26,5	1365	3,3	7,2	10,7	52,1	23,7	1313,8	-51,5	0,0	1360,8	-4,5	0,0	1387,3	22,0	0,0
42	26,6	1365	3,3	7,2	10,8	52,1	23,7	1314,8	-50,3	0,0	1362,4	-2,7	0,0	1390,0	24,9	0,0

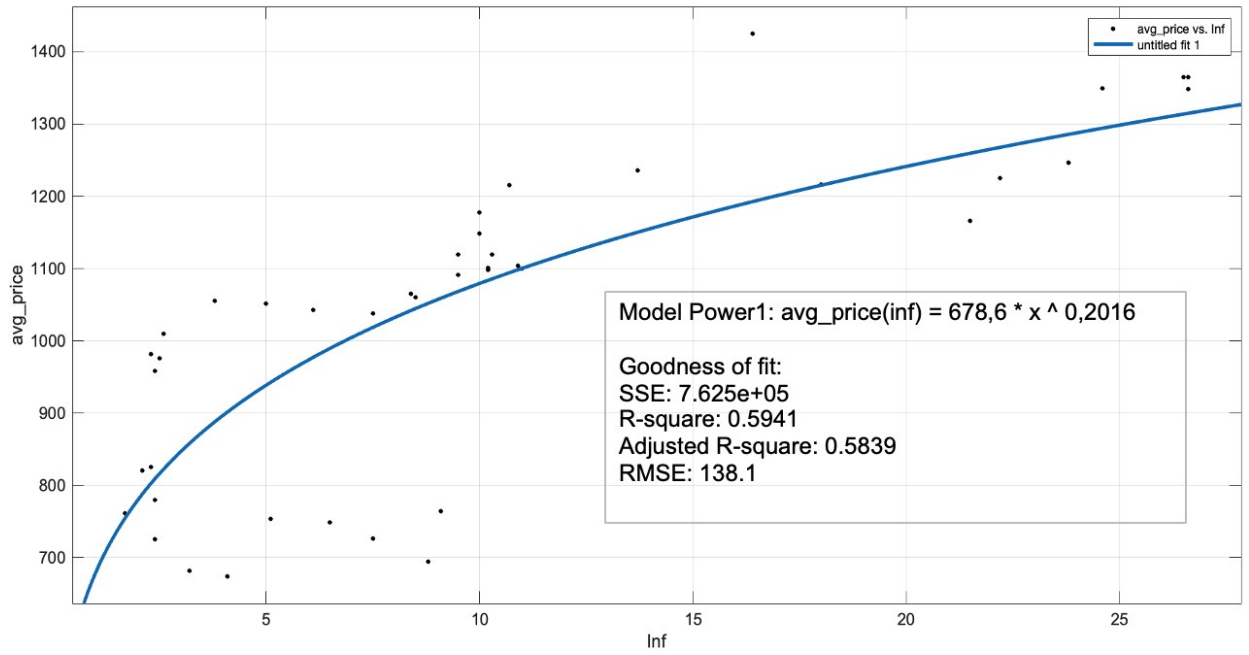


Fig. 2.3.10. Power-law regression (1st degree) of the price of an apartment depending on the level of inflation

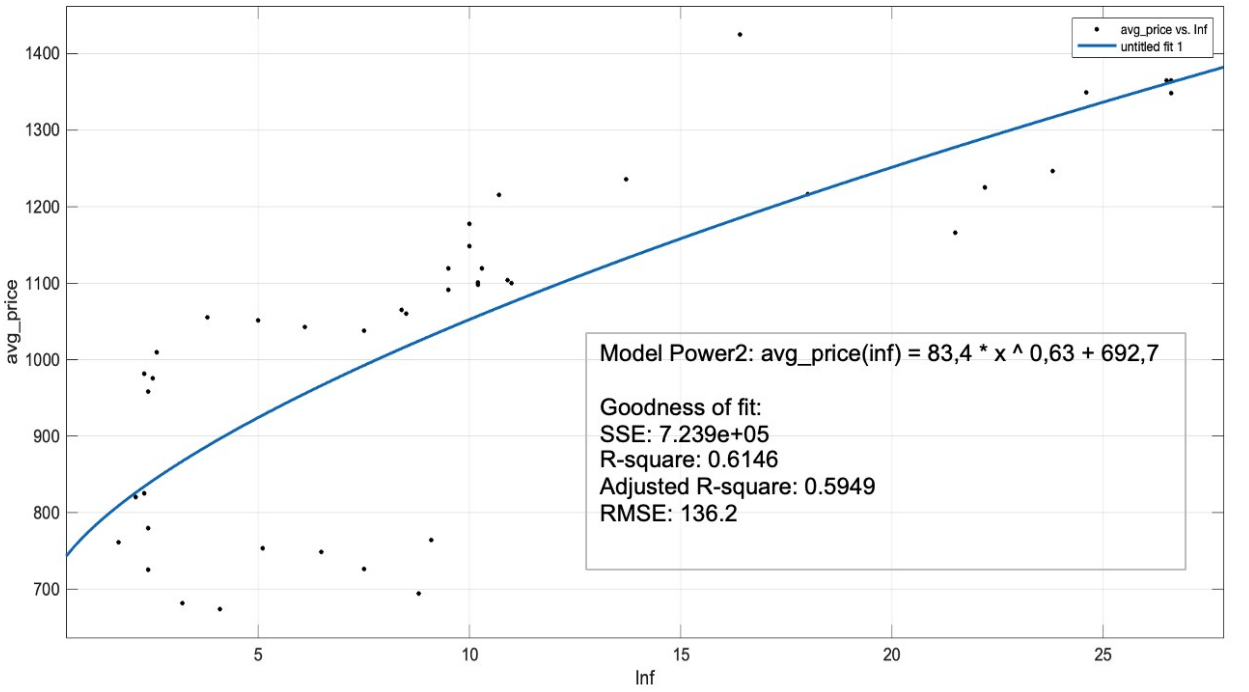


Fig. 2.3.11. Power-law regression (2nd degree) of the price of an apartment depending on the level of inflation

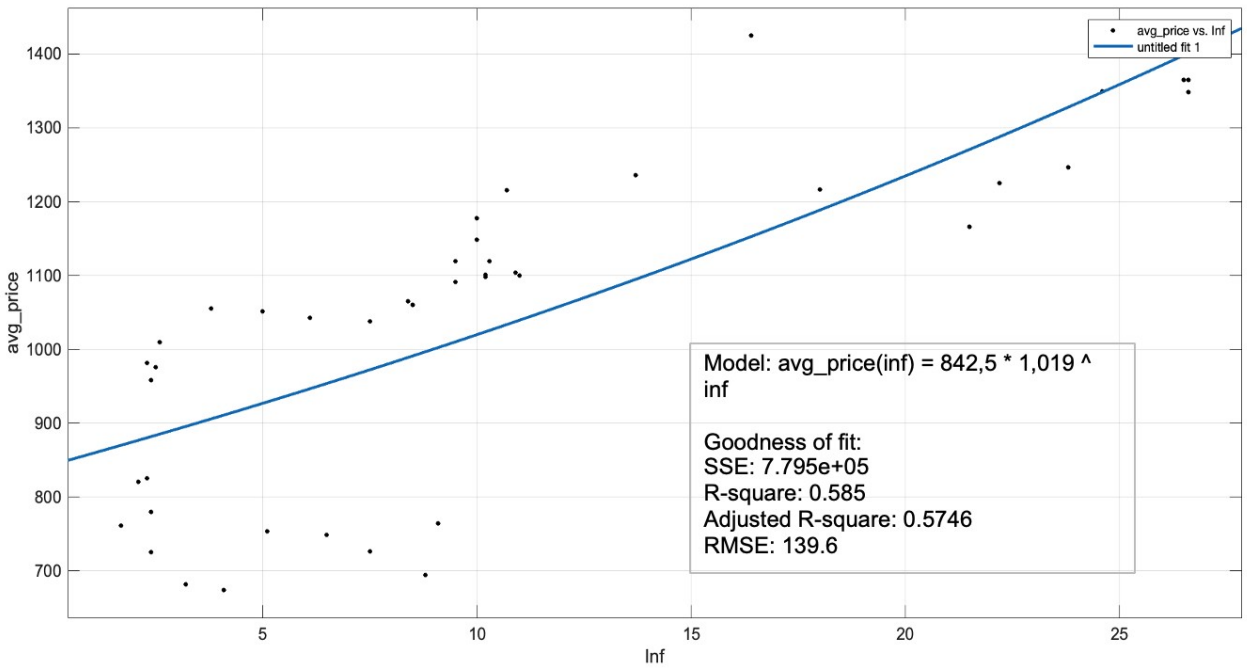


Fig. 2.3.12. Exponential regression of the price of an apartment depending on the level of inflation

Similarly, the regression function that was built makes it possible to calculate the forecast values of the average cost of living space for a given value of inflation. After the calculations, we can say that the relationship between the indicators is direct and with an increase in inflation, housing prices rise. This chart graphically reflects the concentration of sample values of real estate prices around our estimated regression equation. Their deviation from the regression line is the result of the action of the random component (the action of all other factors not included in the model).

Continuing the research, we move on to the next indicator - the exchange rate (Fig. 2.3.13). The course of work is similar, so we will present the results, commenting only on the most important points.

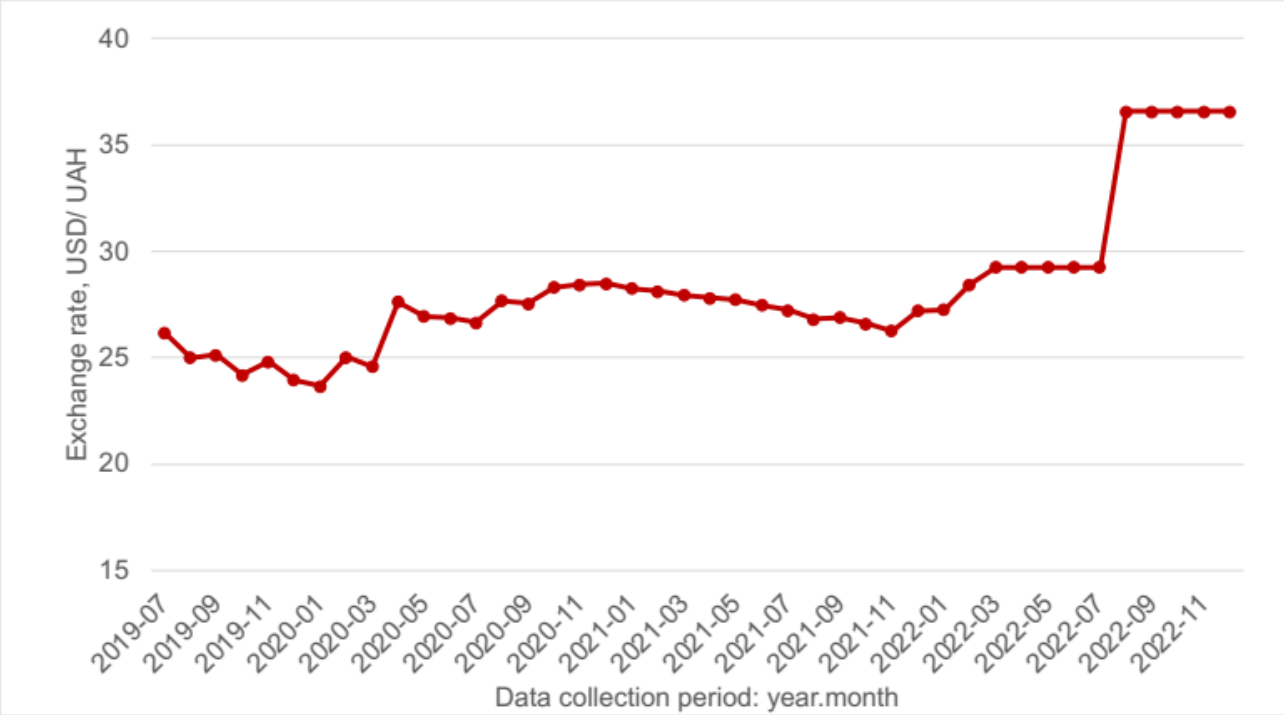


Fig. 2.3.13. Exchange rate evolution for the period July 2019 - December 2022

The exchange rate of the hryvnia to the dollar in Ukraine always attracts the attention of citizens, affects business expectations, is reflected in the price and tariff policy, and acts as a kind of trigger for investors. In turn, for quite a long period, the exchange rate of the hryvnia against the dollar was not relatively stable, with minor fluctuations related to various factors, for example, the decisions of the National Bank of Ukraine regarding the discount rate, the sale of foreign currency by exporters of agricultural products, who, due to high grain prices, sell their harvest immediately from the fields stability of Ukraine's credit ratings according to various agencies and so on. After the start of a full-scale war, the NBU abandoned the floating exchange rate regime and determines fixed values, which is why the exchange rate trends in recent periods are connected.

Similarly, trend models were built (Fig. 2.3.14), according to which the predicted values of the indicator were calculated (Table 2.9).

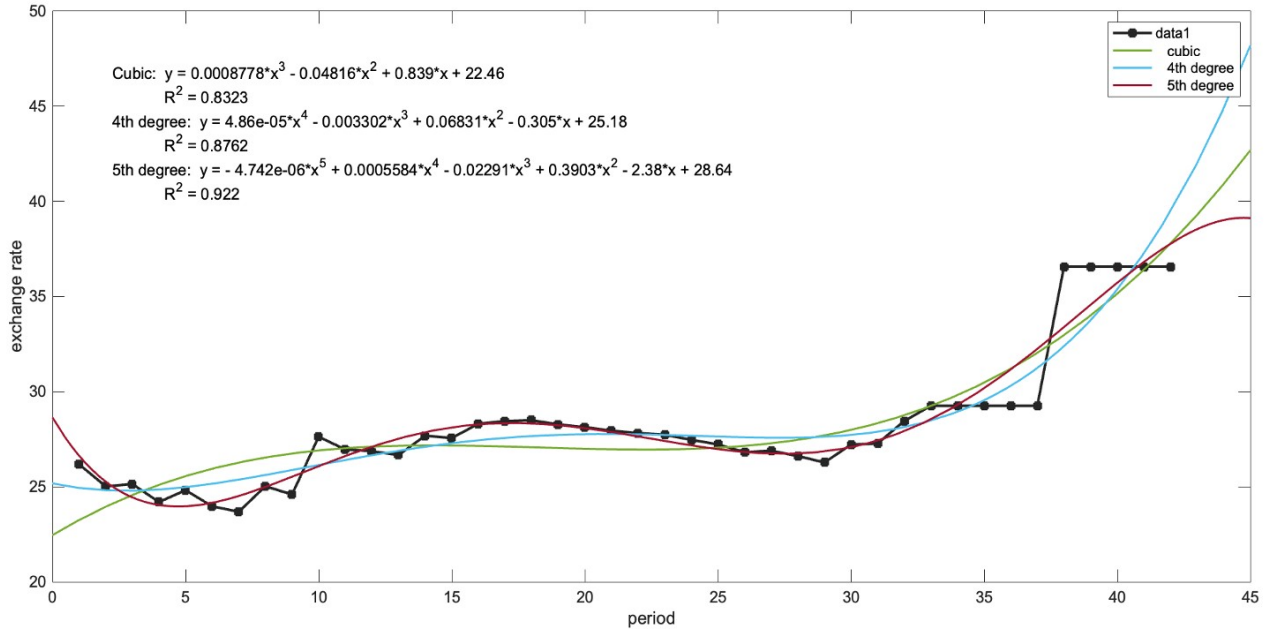


Fig. 2.3.14. Trend models for describing the dynamics of exchange rates

Table 2.9

Exchange rate interpolation results

№	Exchange rate, USD/ UAH (Y)	Polynomial model (3rd degree)		Polynomial model (4th degree)		Polynomial model (6th degree)	
		Predicted value (Y2)	Y-Y2	Predicted value (Y3)	Y-Y2	Пронозоване значення (Y3)	Predicted value (Y2)
1	26,18	23,25	2,93	24,94	1,24	26,63	-0,45
2	25,02	23,95	1,07	24,82	0,20	25,27	-0,25
3	25,14	24,57	0,58	24,79	0,35	24,44	0,71
4	24,20	25,10	-0,90	24,85	-0,66	24,04	0,16
5	24,82	25,56	-0,74	24,98	-0,16	23,97	0,85
6	23,97	25,95	-1,98	25,16	-1,19	24,15	-0,18
7	23,69	26,27	-2,59	25,38	-1,69	24,51	-0,82
8	25,03	26,54	-1,51	25,62	-0,59	24,98	0,05
9	24,59	26,75	-2,16	25,88	-1,29	25,52	-0,93
10	27,63	26,91	0,72	26,15	1,48	26,07	1,56
11	26,96	27,03	-0,07	26,41	0,55	26,60	0,35
12	26,87	27,11	-0,24	26,66	0,21	27,09	-0,23
13	26,67	27,16	-0,49	26,89	-0,23	27,52	-0,85
14	27,68	27,18	0,50	27,11	0,57	27,85	-0,18
15	27,56	27,17	0,39	27,29	0,27	28,10	-0,54
16	28,31	27,15	1,16	27,45	0,86	28,26	0,05

17	28,45	27,12	1,33	27,57	0,88	28,33	0,13
18	28,50	27,08	1,42	27,67	0,83	28,30	0,19
19	28,27	27,04	1,24	27,73	0,54	28,21	0,07
20	28,13	27,00	1,13	27,76	0,37	28,05	0,08
21	27,95	26,97	0,98	27,77	0,17	27,84	0,10
22	27,82	26,96	0,87	27,76	0,07	27,61	0,21
23	27,73	26,96	0,77	27,73	0,01	27,36	0,37
24	27,47	26,99	0,48	27,68	-0,22	27,13	0,34
25	27,23	27,05	0,18	27,64	-0,41	26,93	0,30
26	26,82	27,15	-0,33	27,60	-0,78	26,77	0,05
27	26,89	27,28	-0,39	27,58	-0,68	26,69	0,21
28	26,62	27,46	-0,85	27,58	-0,96	26,69	-0,07
29	26,28	27,70	-1,42	27,63	-1,35	26,79	-0,52
30	27,21	27,99	-0,77	27,72	-0,51	27,01	0,20
31	27,28	28,34	-1,06	27,88	-0,61	27,36	-0,08
32	28,46	28,76	-0,30	28,13	0,33	27,84	0,61
33	29,25	29,25	0,01	28,48	0,78	28,46	0,80
34	29,25	29,81	-0,56	28,94	0,31	29,21	0,05
35	29,25	30,46	-1,21	29,54	-0,29	30,08	-0,83
36	29,25	31,20	-1,95	30,30	-1,05	31,07	-1,81
37	29,25	32,04	-2,78	31,24	-1,98	32,14	-2,89
38	36,57	32,97	3,60	32,38	4,19	33,28	3,29
39	36,57	34,00	2,57	33,75	2,82	34,45	2,12
40	36,57	35,14	1,43	35,36	1,20	35,60	0,97
Coefficients		*p1=*	*0,0008778*	*p1=*	*4,86E-05*	*p1=*	*-4,74E-06*
		p2=	*-0,04816*	*p2=*	*-0,003302*	*92=*	*5,58E-04*
		p3=	*0,839*	*p3=*	*0,06831*	*p3=*	*-2,29E-02*
		p4=	*22,46*	*p4=*	*-0,305*	*p4=*	*3,90E-01*
		R2=	*0,8323*	*p5=*	*25,18*	*p5=*	*-2,38E+00*
				R2=	*0,8762*	*p6=*	*2,86E+01*
						R2=	*9,22E-01*

Based on the correlation coefficient calculated above between the average price of a square meter of an apartment and the exchange rate, which is 0.77, we assume a high degree of dependence of these indicators, therefore, to identify the stochastic relationship between apartment prices and inflation, we will construct a correlation field of indicators and a regression function.

The results of checking the statistical significance of the built power regression equation of the 1st and 2nd degree, polynomial of the 3rd degree in graphic format are shown in figures 2.3.15, 2.3.16, 2.3.17. The results of the relevant calculations are shown in Table 2.10.

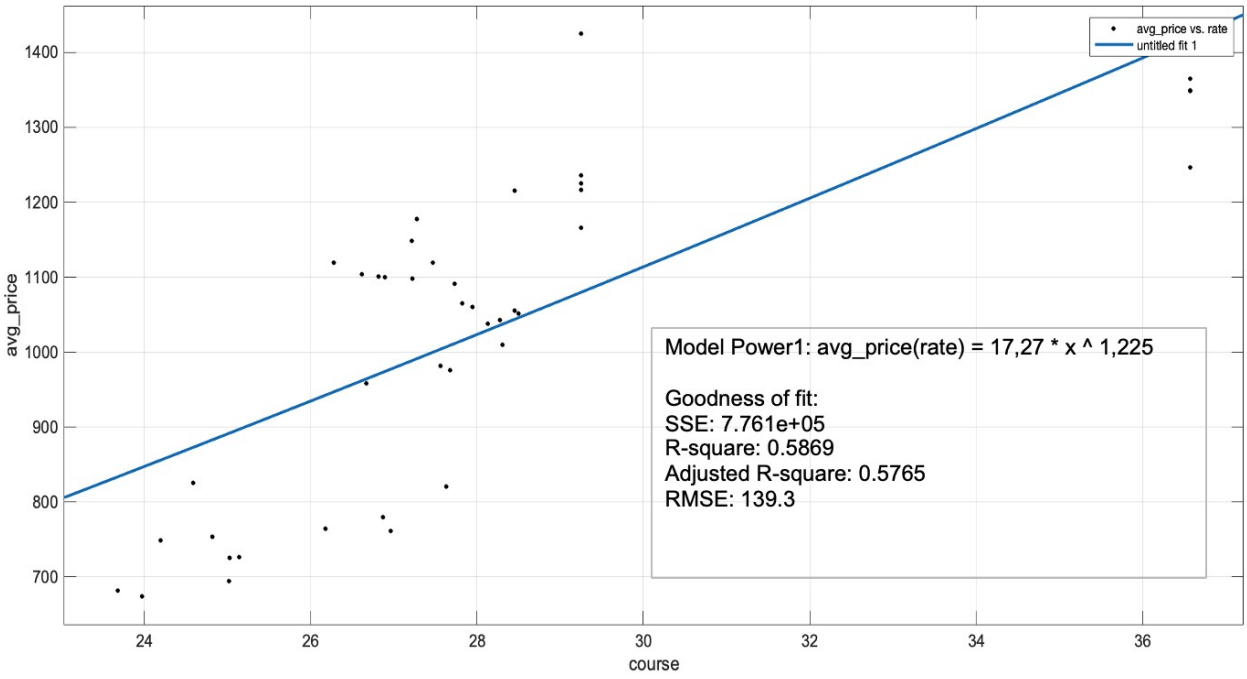


Fig. 2.3.15. Power-law regression (1st degree) of the price of an apartment depending on the exchange rate

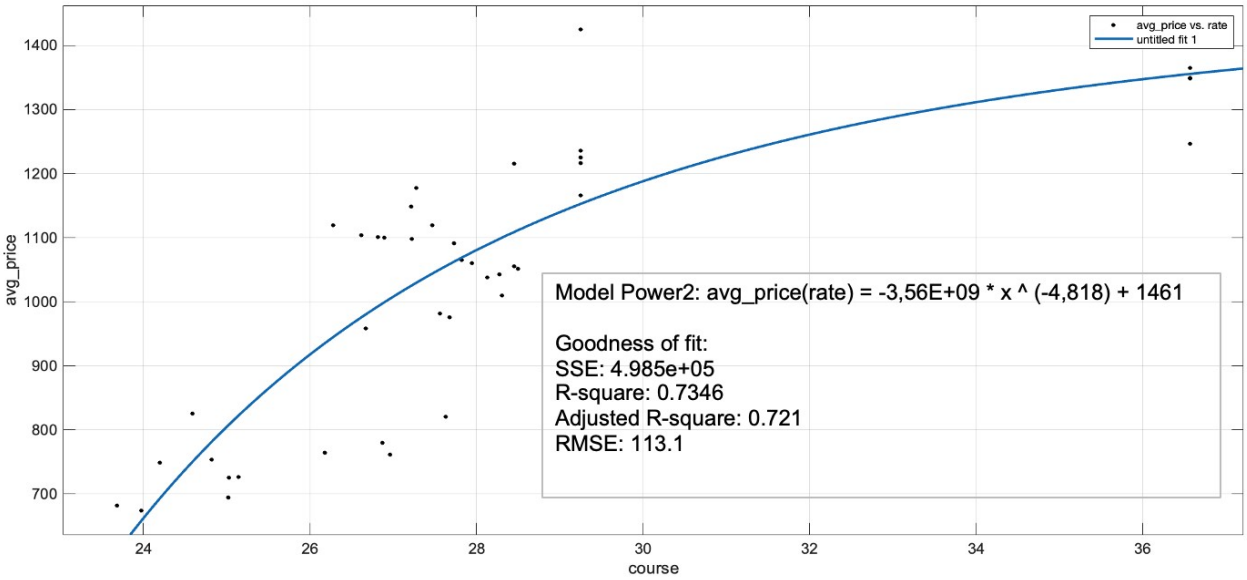


Fig. 2.3.16. Power-law regression (2nd degree) of the price of an apartment depending on the exchange rate

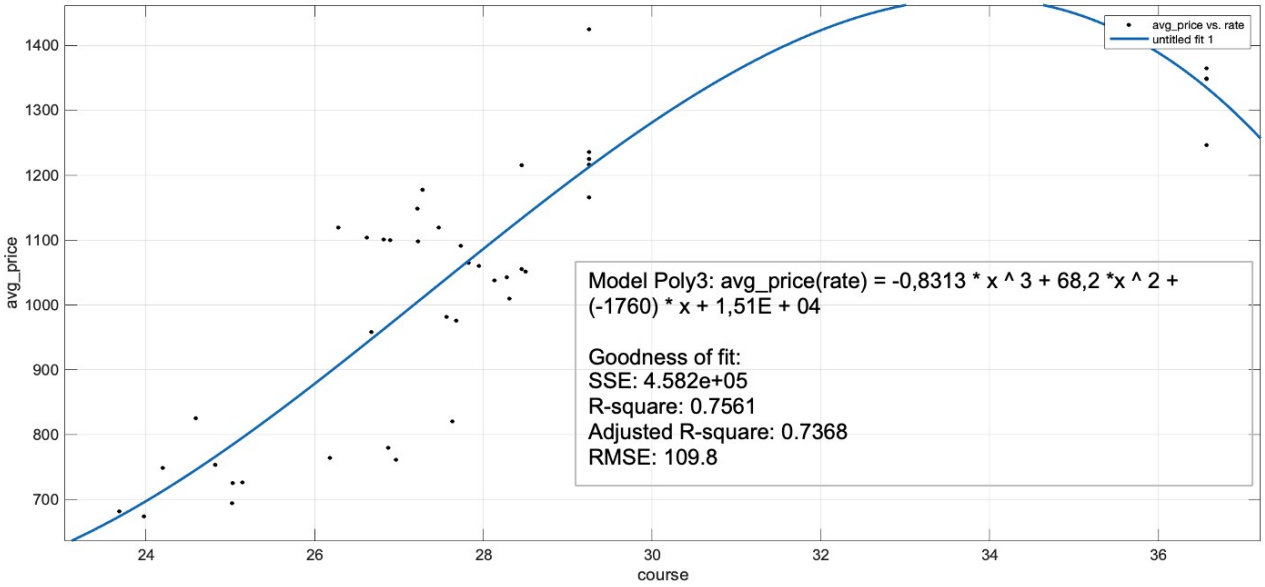


Fig. 2.3.17. Polinomial regression (3rd degree) of the price of an apartment depending on the exchange rate

Table 2.10

Checking the statistical significance of apartment price trend models depending on the exchange rate

№	x	y	X = ln x	Y = ln y	X^2	Y^2	XY	Power-law regression (1st degree)			Power-law regression (2 degree)			Exponential regression		
								Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals
1	26,2	765	3,3	6,6	10,7	44,1	21,7	942,5	177,7	0,2	936,2	171,5	0,2	890,3	125,5	0,2
2	25,0	694	3,2	6,5	10,4	42,8	21,1	891,7	197,5	0,3	808,5	114,3	0,2	777,8	83,6	0,1
3	25,1	727	3,2	6,6	10,4	43,4	21,2	897,1	170,1	0,2	823,8	96,9	0,1	789,2	62,3	0,1
4	24,2	749	3,2	6,6	10,2	43,8	21,1	855,9	106,5	0,1	694,4	-55,0	-0,1	706,9	-42,5	-0,1
5	24,8	754	3,2	6,6	10,3	43,9	21,3	882,9	128,6	0,2	782,6	28,3	0,0	759,6	5,4	0,0
6	24,0	674	3,2	6,5	10,1	42,4	20,7	846,1	171,7	0,3	659,1	-15,3	0,0	689,2	14,8	0,0
7	23,7	682	3,2	6,5	10,0	42,6	20,7	833,8	151,5	0,2	611,3	-70,9	-0,1	668,0	-14,3	0,0
8	25,0	726	3,2	6,6	10,4	43,4	21,2	892,1	166,0	0,2	809,6	83,6	0,1	778,6	52,6	0,1
9	24,6	825	3,2	6,7	10,3	45,1	21,5	872,9	47,7	0,1	751,6	-73,6	-0,1	739,5	-85,7	-0,1
10	27,6	821	3,3	6,7	11,0	45,0	22,3	1006,8	186,2	0,2	1056,3	235,7	0,3	1041,3	220,7	0,3
11	27,0	762	3,3	6,6	10,9	44,0	21,9	977,0	215,3	0,3	1005,6	243,9	0,3	971,0	209,3	0,3
12	26,9	780	3,3	6,7	10,8	44,4	21,9	973,0	192,7	0,2	998,1	217,8	0,3	961,6	181,3	0,2
13	26,7	959	3,3	6,9	10,8	47,1	22,5	964,1	5,3	0,0	981,1	22,3	0,0	940,6	-18,2	0,0
14	27,7	976	3,3	6,9	11,0	47,4	22,9	1009,1	33,2	0,0	1059,9	84,0	0,1	1046,7	70,8	0,1
15	27,6	982	3,3	6,9	11,0	47,5	22,8	1003,9	21,9	0,0	1051,6	69,6	0,1	1034,3	52,3	0,1
16	28,3	1009	3,3	6,9	11,2	47,8	23,1	1037,4	27,9	0,0	1101,2	91,7	0,1	1112,2	102,7	0,1
17	28,5	1055	3,3	7,0	11,2	48,5	23,3	1043,7	-11,8	0,0	1109,6	54,1	0,1	1126,6	71,1	0,1
18	28,5	1051	3,3	7,0	11,2	48,4	23,3	1045,7	-5,6	0,0	1112,3	61,1	0,1	1131,2	79,9	0,1
19	28,3	1043	3,3	6,9	11,2	48,3	23,2	1035,7	-6,8	0,0	1099,0	56,4	0,1	1108,5	66,0	0,1

20	28,1	1038	3,3	6,9	11,1	48,2	23,2	1029,4	-8,2	0,0	1090,1	52,5	0,1	1093,8	56,3	0,1
21	27,9	1060	3,3	7,0	11,1	48,5	23,2	1021,0	-38,9	0,0	1078,0	18,0	0,0	1074,4	14,5	0,0
22	27,8	1065	3,3	7,0	11,1	48,6	23,2	1015,5	-49,9	0,0	1069,7	4,3	0,0	1061,6	-3,8	0,0
23	27,7	1091	3,3	7,0	11,0	48,9	23,2	1011,5	-79,8	-0,1	1063,6	-27,7	0,0	1052,2	-39,1	0,0
24	27,5	1119	3,3	7,0	11,0	49,3	23,3	999,6	-119,8	-0,1	1044,8	-74,7	-0,1	1024,4	-95,1	-0,1
25	27,2	1098	3,3	7,0	10,9	49,0	23,1	989,0	-109,1	-0,1	1026,8	-71,3	-0,1	999,2	-98,9	-0,1
26	26,8	1101	3,3	7,0	10,8	49,1	23,0	970,7	-130,2	-0,1	993,8	-107,1	-0,1	956,2	-144,8	-0,1
27	26,9	1100	3,3	7,0	10,8	49,0	23,1	974,1	-125,9	-0,1	1000,1	-99,8	-0,1	964,1	-135,8	-0,1
28	26,6	1104	3,3	7,0	10,8	49,1	23,0	961,9	-142,1	-0,1	976,7	-127,3	-0,1	935,4	-168,5	-0,2
29	26,3	1119	3,3	7,0	10,7	49,3	22,9	946,8	-172,6	-0,2	945,7	-173,8	-0,2	900,3	-219,1	-0,2
30	27,2	1149	3,3	7,0	10,9	49,7	23,3	988,4	-160,3	-0,1	1025,8	-122,9	-0,1	997,8	-150,8	-0,1
31	27,3	1178	3,3	7,1	10,9	50,0	23,4	991,2	-187,0	-0,2	1030,7	-147,5	-0,1	1004,5	-173,7	-0,1
32	28,5	1216	3,3	7,1	11,2	50,5	23,8	1043,9	-171,8	-0,1	1109,9	-105,7	-0,1	1127,0	-88,6	-0,1
33	29,3	1236	3,4	7,1	11,4	50,7	24,0	1079,9	-155,7	-0,1	1153,8	-81,8	-0,1	1206,4	-29,2	0,0
34	29,3	1425	3,4	7,3	11,4	52,7	24,5	1079,9	-344,9	-0,2	1153,8	-271,0	-0,2	1206,4	-218,4	-0,2
35	29,3	1217	3,4	7,1	11,4	50,5	24,0	1079,9	-136,6	-0,1	1153,8	-62,7	-0,1	1206,4	-10,1	0,0
36	29,3	1166	3,4	7,1	11,4	49,9	23,8	1079,9	-86,1	-0,1	1153,8	-12,2	0,0	1206,4	40,4	0,0
37	29,3	1225	3,4	7,1	11,4	50,6	24,0	1079,9	-145,2	-0,1	1153,8	-71,3	-0,1	1206,4	-18,7	0,0
38	36,6	1247	3,6	7,1	13,0	50,8	25,7	1419,4	172,8	0,1	1356,2	109,6	0,1	1328,5	81,9	0,1
39	36,6	1350	3,6	7,2	13,0	51,9	25,9	1419,4	69,8	0,1	1356,2	6,6	0,0	1328,5	-21,1	0,0
40	36,6	1349	3,6	7,2	13,0	51,9	25,9	1419,4	70,5	0,1	1356,2	7,3	0,0	1328,5	-20,4	0,0
41	36,6	1365	3,6	7,2	13,0	52,1	26,0	1419,4	54,1	0,0	1356,2	-9,2	0,0	1328,5	-36,8	0,0
42	36,6	1365	3,6	7,2	13,0	52,1	26,0	1419,4	54,3	0,0	1356,2	-8,9	0,0	1328,5	-36,6	0,0

However, we remind you that the presence of a time lag of 3 months was determined, which significantly affects the conduct of such a study, that is why we will conduct similar calculations, but taking into account the delay of the reaction.

The results of checking the statistical significance of the constructed power regression equation of the 1st and 2nd degree, polynomial of the 3rd degree in graphic format are shown in figures 2.3.18, 2.3.19, 2.3.20. The results of the corresponding calculations are shown in Table 2.11.

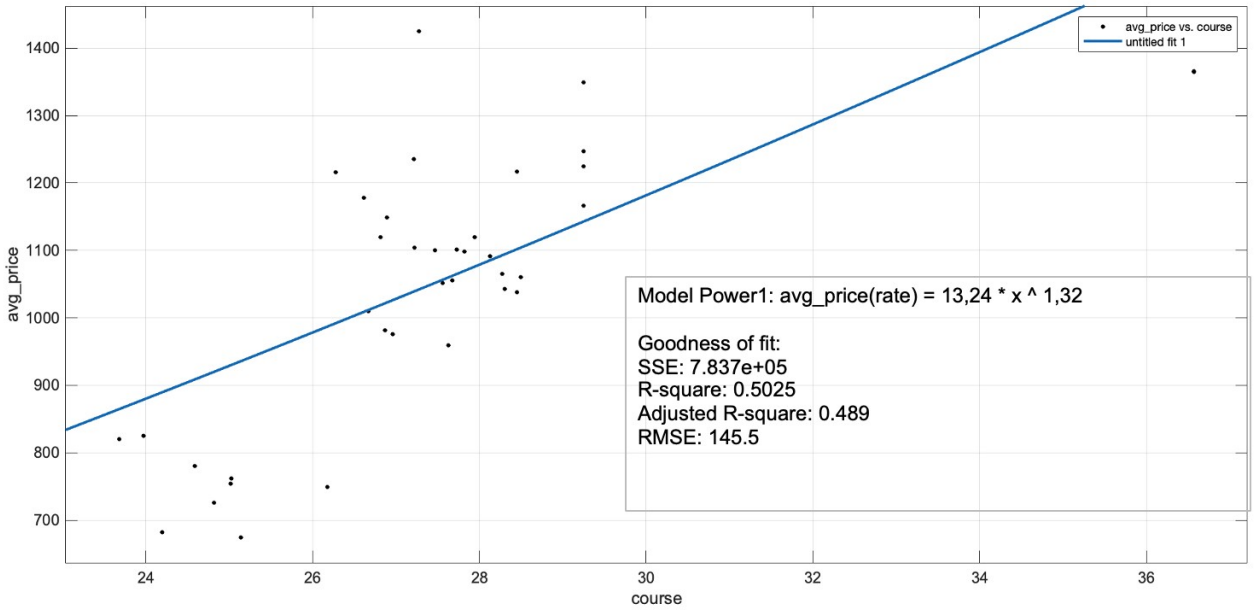


Fig. 2.3.18. Power-law regression (1st degree) of the price of an apartment depending on the exchange rate (time lag – 3 months)

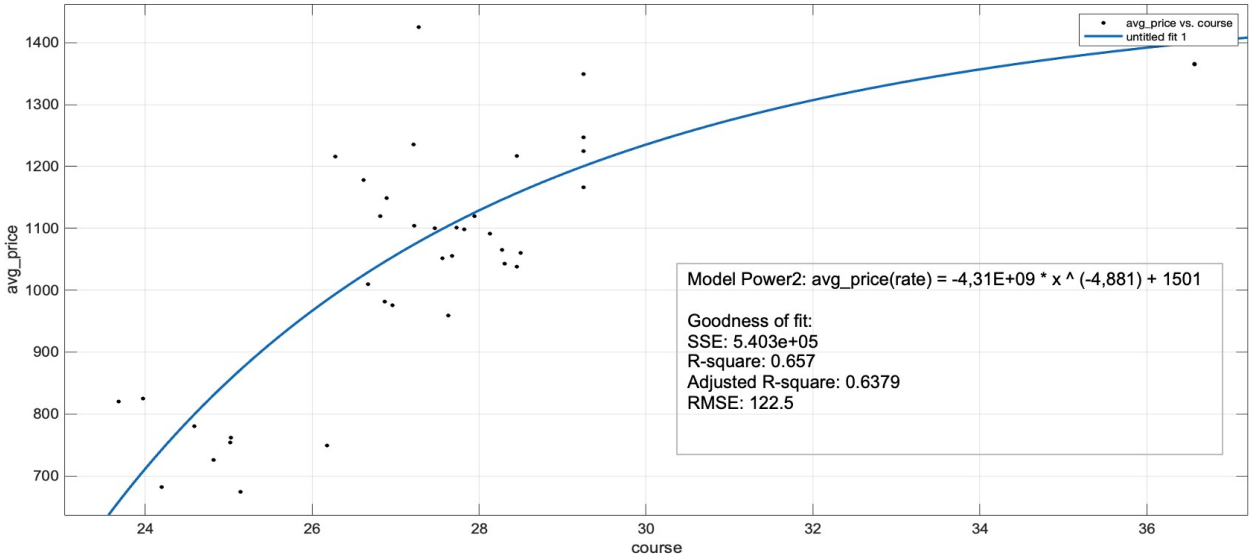


Fig. 2.3.19. Power-law regression (2nd degree) of the price of an apartment depending on the exchange rate (time lag – 3 months)

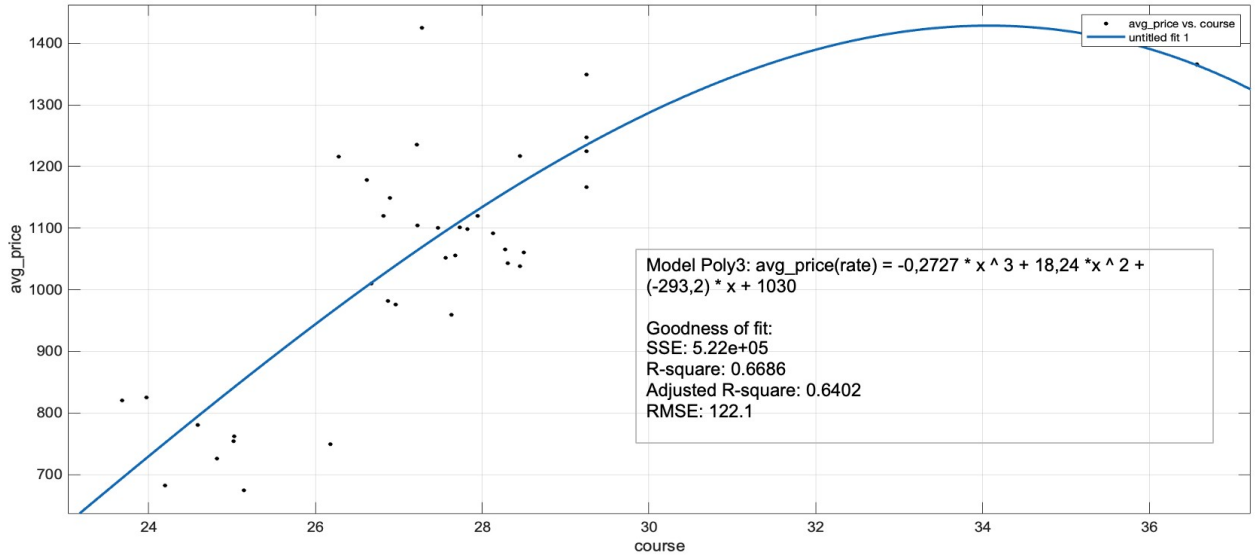


Fig. 2.3.20. Polinomial regression (3rd degree) of the price of an apartment depending on the exchange rate (time lag – 3 months)

Table 2.11

Checking the statistical significance of apartment price trend models depending on the exchange rate, taking into account the time lag

№	x	y	X = ln x	Y = ln y	X^2	Y^2	XY	Power-law regression (1st degree)			Power-law regression (2 degree)			Exponential regression		
								Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals
1	26,18	749	3,26	6,62	10,66	43,81	21,61	985,29	235,90	0,31	984,07	234,68	0,31	962,16	212,77	0,28
2	25,02	754	3,22	6,63	10,37	43,90	21,33	928,21	173,96	0,23	856,43	102,19	0,14	841,30	87,05	0,12
3	25,14	674	3,22	6,51	10,40	42,43	21,00	934,25	259,83	0,39	871,71	197,29	0,29	854,50	180,08	0,27
4	24,20	682	3,19	6,53	10,15	42,58	20,79	888,11	205,88	0,30	742,09	59,86	0,09	751,52	69,29	0,10
5	24,82	726	3,21	6,59	10,31	43,40	21,16	918,34	192,29	0,26	830,46	104,41	0,14	819,55	93,49	0,13
6	23,97	825	3,18	6,72	10,09	45,10	21,33	877,21	51,99	0,06	706,65	-118,58	-0,14	726,56	-98,67	-0,12
7	23,69	821	3,16	6,71	10,02	45,02	21,24	863,42	42,81	0,05	658,70	-161,90	-0,20	694,64	-125,96	-0,15
8	25,03	762	3,22	6,64	10,37	44,03	21,37	928,63	166,92	0,22	857,51	95,80	0,13	842,22	80,51	0,11
9	24,59	780	3,20	6,66	10,25	44,35	21,33	907,17	126,89	0,16	799,41	19,12	0,02	794,64	14,35	0,02
10	27,63	959	3,32	6,87	11,01	47,14	22,79	1058,01	99,22	0,10	1103,73	144,95	0,15	1101,39	142,61	0,15
11	26,96	976	3,29	6,88	10,85	47,38	22,68	1024,29	48,41	0,05	1053,19	77,32	0,08	1039,11	63,24	0,06
12	26,87	982	3,29	6,89	10,83	47,47	22,67	1019,74	37,79	0,04	1045,76	63,81	0,06	1030,40	48,45	0,05
13	26,67	1009	3,28	6,92	10,78	47,85	22,71	1009,69	0,22	0,00	1028,78	19,31	0,02	1010,89	1,43	0,00
14	27,68	1055	3,32	6,96	11,03	48,47	23,12	1060,58	5,09	0,00	1107,29	51,79	0,05	1105,97	50,48	0,05
15	27,56	1051	3,32	6,96	11,00	48,41	23,07	1054,62	3,35	0,00	1098,99	47,72	0,05	1095,32	44,05	0,04
16	28,31	1043	3,34	6,95	11,18	48,29	23,23	1092,59	50,05	0,05	1148,29	105,75	0,10	1160,76	118,22	0,11
17	28,45	1038	3,35	6,94	11,21	48,23	23,25	1099,74	62,19	0,06	1156,69	119,14	0,11	1172,42	134,87	0,13
18	28,50	1060	3,35	6,97	11,22	48,52	23,33	1102,06	42,14	0,04	1159,37	99,44	0,09	1176,16	116,24	0,11

19	28,27	1065	3,34	6,97	11,17	48,60	23,30	1090,77	25,35	0,02	1146,10	80,68	0,08	1157,74	92,33	0,09
20	28,13	1091	3,34	7,00	11,14	48,93	23,34	1083,53	-7,78	-0,01	1137,25	45,94	0,04	1145,67	54,35	0,05
21	27,95	1119	3,33	7,02	11,09	49,29	23,38	1074,04	-45,42	-0,04	1125,23	5,77	0,01	1129,51	10,05	0,01
22	27,82	1098	3,33	7,00	11,06	49,02	23,29	1067,81	-30,29	-0,03	1117,05	18,96	0,02	1118,70	20,60	0,02
23	27,73	1101	3,32	7,00	11,04	49,05	23,27	1063,27	-37,67	-0,03	1110,96	10,02	0,01	1110,73	9,80	0,01
24	27,47	1100	3,31	7,00	10,98	49,04	23,20	1049,85	-50,09	-0,05	1092,20	-7,74	-0,01	1086,71	-13,23	-0,01
25	27,23	1104	3,30	7,01	10,92	49,09	23,15	1037,76	-66,19	-0,06	1074,32	-29,64	-0,03	1064,50	-39,46	-0,04
26	26,82	1119	3,29	7,02	10,82	49,29	23,09	1017,15	-102,30	-0,09	1041,46	-77,99	-0,07	1025,41	-94,05	-0,08
27	26,89	1149	3,29	7,05	10,84	49,65	23,20	1020,96	-127,67	-0,11	1047,77	-100,86	-0,09	1032,74	-115,89	-0,10
28	26,62	1178	3,28	7,07	10,77	50,01	23,21	1007,18	-170,99	-0,15	1024,42	-153,76	-0,13	1005,98	-172,20	-0,15
29	26,28	1216	3,27	7,10	10,68	50,45	23,22	990,20	-225,45	-0,19	993,48	-222,16	-0,18	972,12	-243,53	-0,20
30	27,21	1236	3,30	7,12	10,91	50,68	23,52	1037,09	-198,53	-0,16	1073,30	-162,33	-0,13	1063,25	-172,38	-0,14
31	27,28	1425	3,31	7,26	10,93	52,73	24,01	1040,31	-384,47	-0,27	1078,18	-346,61	-0,24	1069,23	-355,55	-0,25
32	28,46	1217	3,35	7,10	11,21	50,46	23,79	1099,99	-116,54	-0,10	1156,97	-59,55	-0,05	1172,82	-43,71	-0,04
33	29,25	1166	3,38	7,06	11,40	49,86	23,84	1140,96	-25,05	-0,02	1200,49	34,48	0,03	1235,35	69,34	0,06
34	29,25	1225	3,38	7,11	11,40	50,56	24,01	1140,96	-84,16	-0,07	1200,49	-24,63	-0,02	1235,35	10,23	0,01
35	29,25	1247	3,38	7,13	11,40	50,81	24,07	1140,96	-105,63	-0,08	1200,49	-46,10	-0,04	1235,35	-11,24	-0,01
36	29,25	1350	3,38	7,21	11,40	51,95	24,33	1140,96	-208,58	-0,15	1200,49	-149,05	-0,11	1235,35	-114,19	-0,08
37	29,25	1349	3,38	7,21	11,40	51,94	24,33	1140,96	-207,92	-0,15	1200,49	-148,39	-0,11	1235,35	-113,53	-0,08
38	36,57	1365	3,60	7,22	12,95	52,12	25,98	1531,76	166,44	0,12	1399,88	34,56	0,03	1364,23	-1,09	0,00
39	36,57	1365	3,60	7,22	12,95	52,11	25,98	1531,76	166,66	0,12	1399,88	34,78	0,03	1364,23	-0,87	0,00

Similarly, the regression function that was built makes it possible to calculate the forecast values of the average cost of living space for a given value of the exchange rate. After carrying out the calculations, we can say that the

relationship between the indicators is direct and with an increase in the exchange rate, housing prices increase. The figure graphically reflects the concentration of sample values of real estate prices around the regression equation we estimated. Their deviation from the regression line is the result of the action of the random component (the action of all other factors not included in the model).

For the last two factors, the corresponding calculations were made, as for the first three, but we will present only the correlation fields of the dependence of the price on these indicators.

Based on the correlation coefficient calculated above between the average price per square meter of an apartment and the average salary, which is 0.75, we assume a high degree of dependence of these indicators, therefore, to identify the stochastic relationship between apartment prices and salary, we will build a correlation field of indicators and a regression function .

The results of checking the statistical significance of the built power regression equation of the 1st and 2nd degree in graphic format are shown in Figures 2.3.21, 2.3.22. The results of the relevant calculations are shown in Table 2.12.

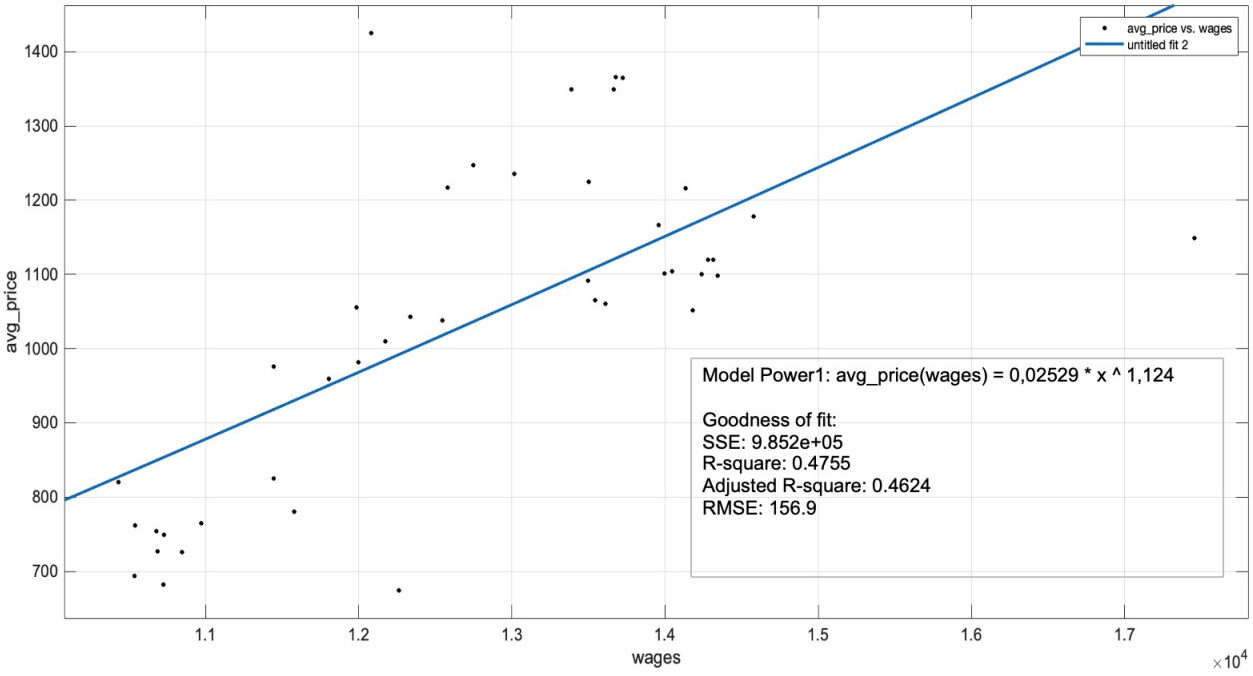


Fig. 2.3.21. Power-law regression (1st degree) of the price of an apartment depending on the average salary

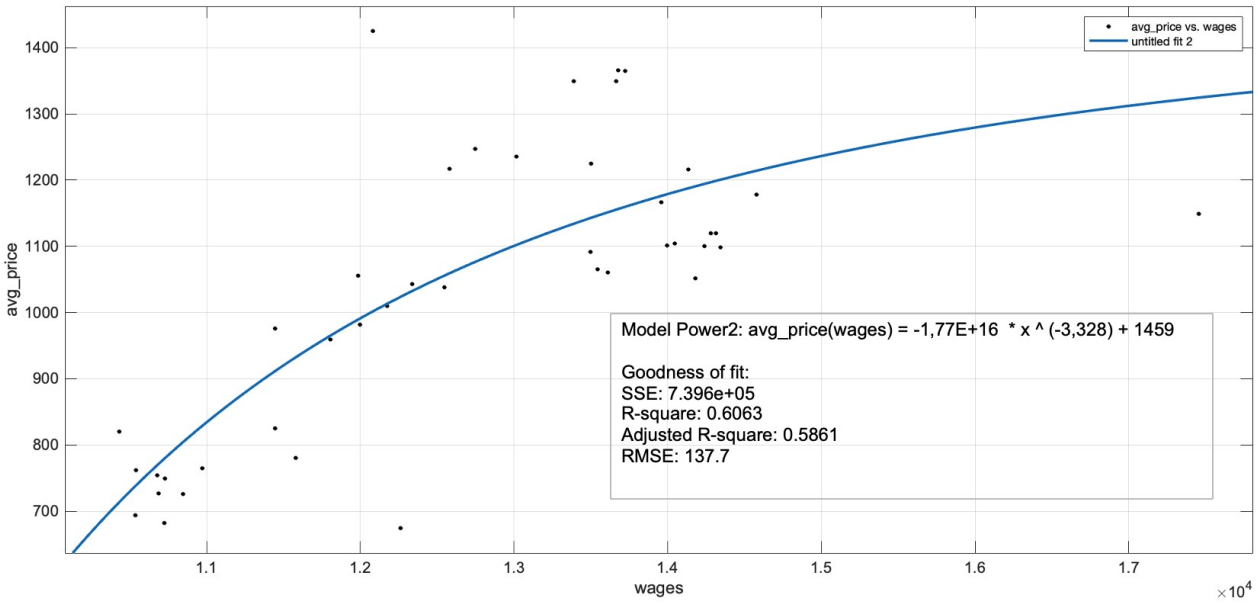


Fig. 2.3.22. Power-law regression (2nd degree) of the price of an apartment depending on the average salary

The figures graphically reflect the concentration of sample values of real estate prices around the regression equation estimated by us. Their deviation from the regression line is the result of the action of the random component (the action of all other factors not included in the model).

Table 2.12

Checking the statistical significance of apartment price trend models depending on the average salary

Period	x	y	X = ln x	Y = ln y	X^2	Y^2	XY	Power-law regression (1st degree)			Power-law regression (2 degree)		
								Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals
1	10970,82	765	9,30	6,64	86,55	44,08	61,77	879,38	114,63	0,15	826,84	62,09	0,08
2	10537,01	694	9,26	6,54	85,80	42,81	60,60	840,39	146,20	0,21	736,00	41,80	0,06
3	10687,06	727	9,28	6,59	86,06	43,41	61,12	853,86	126,93	0,17	769,23	42,30	0,06
4	10727,34	749	9,28	6,62	86,13	43,81	61,43	857,48	108,09	0,14	777,81	28,43	0,04
5	10679,14	754	9,28	6,63	86,05	43,90	61,46	853,15	98,90	0,13	767,53	13,28	0,02
6	12263,61	674	9,41	6,51	88,63	42,43	61,32	996,68	322,26	0,48	1022,66	348,24	0,52
7	10726,94	682	9,28	6,53	86,13	42,58	60,56	857,44	175,21	0,26	777,73	95,50	0,14
8	10847,15	726	9,29	6,59	86,33	43,40	61,21	868,25	142,20	0,20	802,53	76,48	0,11
9	11445,82	825	9,35	6,72	87,34	45,10	62,76	922,29	97,06	0,12	910,01	84,78	0,10
10	10429,80	821	9,25	6,71	85,61	45,02	62,08	830,79	10,18	0,01	710,96	-109,64	-0,13
11	10541,52	762	9,26	6,64	85,80	44,03	61,47	840,80	79,09	0,10	737,02	-24,69	-0,03
12	11578,50	780	9,36	6,66	87,55	44,35	62,31	934,32	154,03	0,20	930,66	150,38	0,19
13	11804,41	959	9,38	6,87	87,91	47,14	64,37	954,83	-3,95	0,00	963,57	4,79	0,00
14	11446,12	976	9,35	6,88	87,34	47,38	64,33	922,32	-53,55	-0,05	910,05	-65,82	-0,07
15	11998,49	982	9,39	6,89	88,22	47,47	64,71	972,49	-9,45	-0,01	989,74	7,79	0,01
16	12173,89	1009	9,41	6,92	88,49	47,85	65,07	988,49	-20,98	-0,02	1011,87	2,40	0,00
17	11986,69	1055	9,39	6,96	88,20	48,47	65,38	971,42	-84,07	-0,08	988,20	-67,29	-0,06
18	14178,85	1051	9,56	6,96	91,38	48,41	66,51	1173,26	121,99	0,12	1189,79	138,53	0,13

19	12336,78	1043	9,42	6,95	88,74	48,29	65,47	1003,37	-39,17	-0,04	1031,22	-11,32	-0,01
20	12548,85	1038	9,44	6,94	89,06	48,23	65,54	1022,77	-14,78	-0,01	1054,81	17,25	0,02
21	13612,21	1060	9,52	6,97	90,61	48,52	66,31	1120,69	60,76	0,06	1150,66	90,74	0,09
22	13543,08	1065	9,51	6,97	90,51	48,60	66,32	1114,29	48,88	0,05	1145,39	79,98	0,08
23	13499,00	1091	9,51	7,00	90,45	48,93	66,53	1110,22	18,90	0,02	1141,97	50,66	0,05
24	14312,85	1119	9,57	7,02	91,56	49,29	67,18	1185,73	66,27	0,06	1198,09	78,63	0,07
25	14345,13	1098	9,57	7,00	91,61	49,02	67,01	1188,73	90,64	0,08	1200,04	101,95	0,09
26	13997,00	1101	9,55	7,00	91,14	49,05	66,86	1156,36	55,42	0,05	1177,98	77,04	0,07
27	14239,30	1100	9,56	7,00	91,47	49,04	66,98	1178,88	78,94	0,07	1193,58	93,64	0,09
28	14044,81	1104	9,55	7,01	91,20	49,09	66,91	1160,80	56,84	0,05	1181,15	77,19	0,07
29	14282,18	1119	9,57	7,02	91,52	49,29	67,16	1182,87	63,42	0,06	1196,22	76,77	0,07
30	17453,23	1149	9,77	7,05	95,40	49,65	68,82	1481,89	333,27	0,29	1324,17	175,54	0,15
31	14577,00	1178	9,59	7,07	91,91	50,01	67,80	1210,35	32,18	0,03	1213,50	35,32	0,03
32	14133,18	1216	9,56	7,10	91,32	50,45	67,88	1169,01	-46,63	-0,04	1186,89	-28,76	-0,02
33	13016,16	1236	9,47	7,12	89,76	50,68	67,45	1065,68	-169,95	-0,14	1101,11	-134,52	-0,11
34	12081,96	1425	9,40	7,26	88,35	52,73	68,26	980,10	-444,69	-0,31	1000,44	-424,34	-0,30
35	12582,42	1217	9,44	7,10	89,11	50,46	67,06	1025,85	-190,68	-0,16	1058,38	-158,14	-0,13
36	13957,63	1166	9,54	7,06	91,08	49,86	67,39	1152,70	-13,31	-0,01	1175,33	9,32	0,01
37	13499,87	1225	9,51	7,11	90,45	50,56	67,63	1110,30	-114,82	-0,09	1142,04	-83,08	-0,07
38	12745,82	1247	9,45	7,13	89,36	50,81	67,38	1040,84	-205,75	-0,17	1075,22	-171,37	-0,14
39	13387,48	1350	9,50	7,21	90,29	51,95	68,49	1099,91	-249,62	-0,18	1133,10	-216,44	-0,16
40	13663,20	1349	9,52	7,21	90,68	51,94	68,63	1125,41	-223,47	-0,17	1154,47	-194,41	-0,14
41	13675,69	1365	9,52	7,22	90,69	52,12	68,75	1126,56	-238,76	-0,17	1155,40	-209,93	-0,15
42	13722,31	1365	9,53	7,22	90,76	52,11	68,77	1130,88	-234,22	-0,17	1158,82	-206,28	-0,15

However, the presence of a time lag of 4 months was again determined, which significantly affects the conduct of the study, which is why we will conduct similar calculations, but taking into account the delay of the reaction.

The results of checking the statistical significance of the built power regression equation of the 1st and 2nd degree in graphic format are shown in figures 2.3.23, 2.3.24. The results of the relevant calculations are shown in Table 2.13.

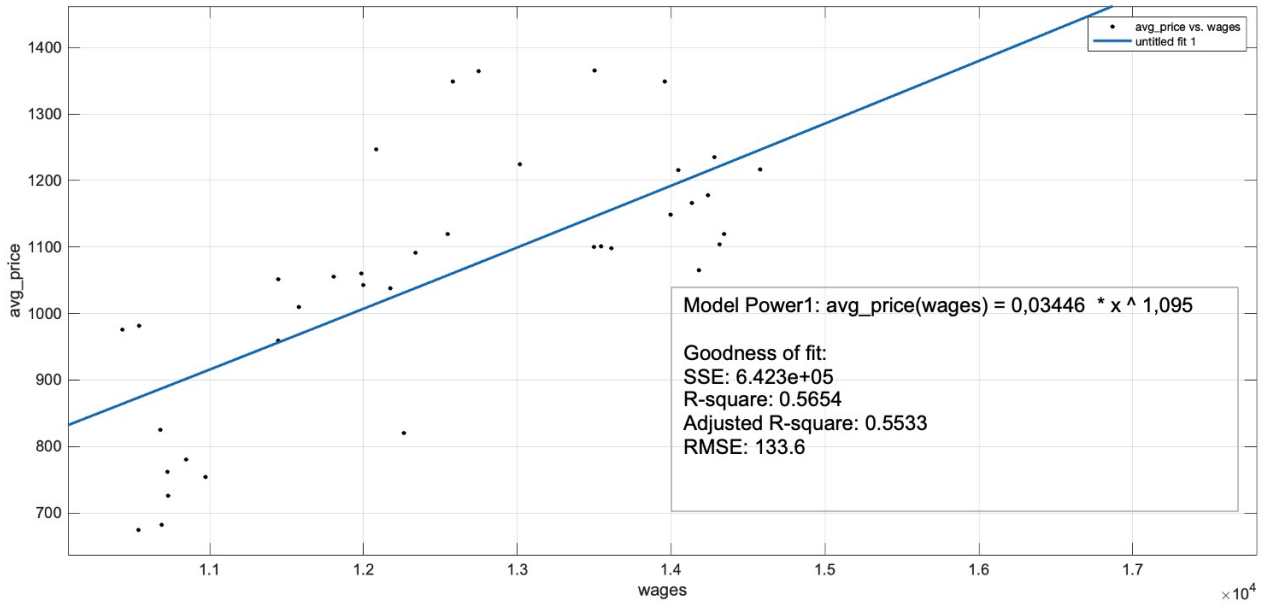


Fig. 2.3.23. Power-law regression (1st degree) of the price of an apartment depending on the average salary (time lag – 4 months)

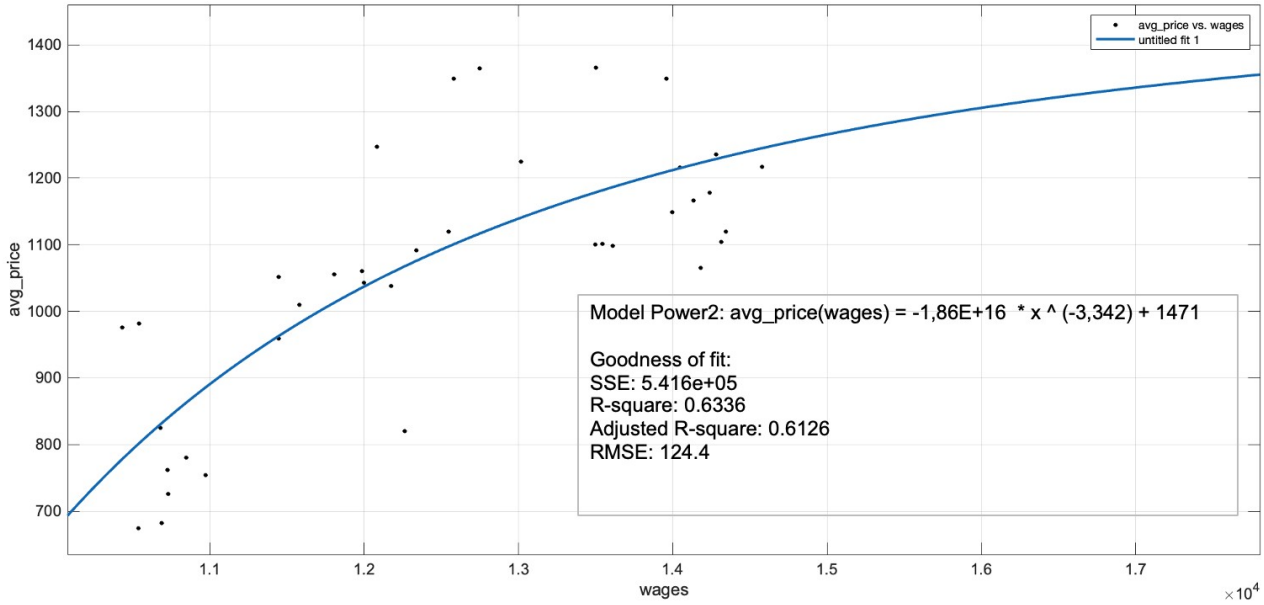


Fig. 2.3.24. Power-law regression (2nd degree) of the price of an apartment depending on the average salary (time lag – 4 months))

Table 2.13

Checking the statistical significance of apartment price trend models depending on the average salary, taking into account the time lag

Period	x	y	X = ln x	Y = ln y	X^2	Y^2	XY	Power-law regression (1st degree)			Power-law regression (2 degree)		
								Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals
1	10970,82	754	9,30	6,63	86,55	43,90	61,64	914,91	160,66	0,21	886,16	131,92	0,17
2	10537,01	674	9,26	6,51	85,80	42,43	60,34	875,37	200,95	0,30	801,75	127,32	0,19
3	10687,06	682	9,28	6,53	86,06	42,58	60,53	889,03	206,80	0,30	832,64	150,41	0,22
4	10727,34	726	9,28	6,59	86,13	43,40	61,14	892,70	166,64	0,23	840,61	114,56	0,16
5	10679,14	825	9,28	6,72	86,05	45,10	62,29	888,31	63,08	0,08	831,05	5,83	0,01
6	12263,61	821	9,41	6,71	88,63	45,02	63,17	1033,60	212,99	0,26	1067,96	247,35	0,30
7	10726,94	762	9,28	6,64	86,13	44,03	61,58	892,66	130,95	0,17	840,53	78,82	0,10
8	10847,15	780	9,29	6,66	86,33	44,35	61,88	903,62	123,33	0,16	863,58	83,30	0,11
9	11445,82	959	9,35	6,87	87,34	47,14	64,16	958,37	-0,41	0,00	963,41	4,62	0,00
10	10429,80	976	9,25	6,88	85,61	47,38	63,69	865,62	-110,25	-0,11	778,48	-197,39	-0,20
11	10541,52	982	9,26	6,89	85,80	47,47	63,82	875,78	-106,17	-0,11	802,70	-179,25	-0,18
12	11578,50	1009	9,36	6,92	87,55	47,85	64,72	970,54	-38,92	-0,04	982,59	-26,88	-0,03
13	11804,41	1055	9,38	6,96	87,91	48,47	65,28	991,30	-64,20	-0,06	1013,13	-42,36	-0,04
14	11446,12	1051	9,35	6,96	87,34	48,41	65,02	958,40	-92,87	-0,09	963,45	-87,81	-0,08
15	11998,49	1043	9,39	6,95	88,22	48,29	65,27	1009,16	-33,38	-0,03	1037,42	-5,12	0,00
16	12173,89	1038	9,41	6,94	88,49	48,23	65,33	1025,32	-12,23	-0,01	1057,94	20,39	0,02
17	11986,69	1060	9,39	6,97	88,20	48,52	65,42	1008,07	-51,85	-0,05	1035,99	-23,93	-0,02
18	14178,85	1065	9,56	6,97	91,38	48,60	66,64	1211,61	146,20	0,14	1222,84	157,43	0,15
19	12336,78	1091	9,42	7,00	88,74	48,93	65,90	1040,35	-50,96	-0,05	1075,89	-15,42	-0,01
20	12548,85	1119	9,44	7,02	89,06	49,29	66,26	1059,95	-59,51	-0,05	1097,77	-21,69	-0,02

21	13612,21	1098	9,52	7,00	90,61	49,02	66,64	1158,69	60,60	0,06	1186,60	88,51	0,08
22	13543,08	1101	9,51	7,00	90,51	49,05	66,63	1152,25	51,31	0,05	1181,72	80,79	0,07
23	13499,00	1100	9,51	7,00	90,45	49,04	66,60	1148,14	48,20	0,04	1178,55	78,61	0,07
24	14312,85	1104	9,57	7,01	91,56	49,09	67,05	1224,15	120,20	0,11	1230,52	126,57	0,11
25	14345,13	1119	9,57	7,02	91,61	49,29	67,20	1227,18	107,72	0,10	1232,33	112,87	0,10
26	13997,00	1149	9,55	7,05	91,14	49,65	67,27	1194,60	45,97	0,04	1211,90	63,27	0,06
27	14239,30	1178	9,56	7,07	91,47	50,01	67,63	1217,27	39,09	0,03	1226,35	48,17	0,04
28	14044,81	1216	9,55	7,10	91,20	50,45	67,83	1199,07	-16,57	-0,01	1214,84	-0,81	0,00
29	14282,18	1236	9,57	7,12	91,52	50,68	68,11	1221,28	-14,35	-0,01	1228,79	-6,84	-0,01
30	17453,23	1425	9,77	7,26	95,40	52,73	70,93	1521,14	96,35	0,07	1347,07	-77,71	-0,05
31	14577,00	1217	9,59	7,10	91,91	50,46	68,11	1248,91	32,39	0,03	1244,78	28,25	0,02
32	14133,18	1166	9,56	7,06	91,32	49,86	67,48	1207,34	41,32	0,04	1220,15	54,14	0,05
33	13016,16	1225	9,47	7,11	89,76	50,56	67,37	1103,25	-121,87	-0,10	1140,70	-84,42	-0,07
34	12081,96	1247	9,40	7,13	88,35	50,81	67,00	1016,85	-229,74	-0,18	1047,35	-199,24	-0,16
35	12582,42	1350	9,44	7,21	89,11	51,95	68,04	1063,06	-286,48	-0,21	1101,09	-248,45	-0,18
36	13957,63	1349	9,54	7,21	91,08	51,94	68,78	1190,92	-157,96	-0,12	1209,45	-139,43	-0,10
37	13499,87	1365	9,51	7,22	90,45	52,12	68,66	1148,22	-217,10	-0,16	1178,62	-186,71	-0,14
38	12745,82	1365	9,45	7,22	89,36	52,11	68,24	1078,18	-286,91	-0,21	1116,70	-248,40	-0,18

After carrying out the calculations, we can say that the relationship between the indicators is direct and with an increase in the wages of citizens, housing prices rise.

The last factor has a lower level of correlation, as a result of which we can assume that they affect the price of apartments to a lesser extent. Reference or marker grades of oil are used to simplify trade operations. The benchmark for world prices is WTI (also known as Texas Light Sweet) and Brent, with WTI used primarily for the Western Hemisphere (and as a benchmark for other crudes in general) and Brent primarily for European and OPEC markets. That is why we used Brent oil indicators in our research.

Based on the correlation coefficient calculated above between the average price of a square meter of an apartment and the world price of oil, which is 0.69, we assume a moderate degree of dependence of these indicators, therefore, in order to identify the stochastic relationship between apartment prices and the price of oil, we will construct a correlation field of indicators and a function regressions The results of checking the statistical significance of the built power regression equation of the 1st and 2nd degree in graphic format are shown in Figures 2.3.25, 2.3.26. The results of the relevant calculations are shown in Table 2.14.

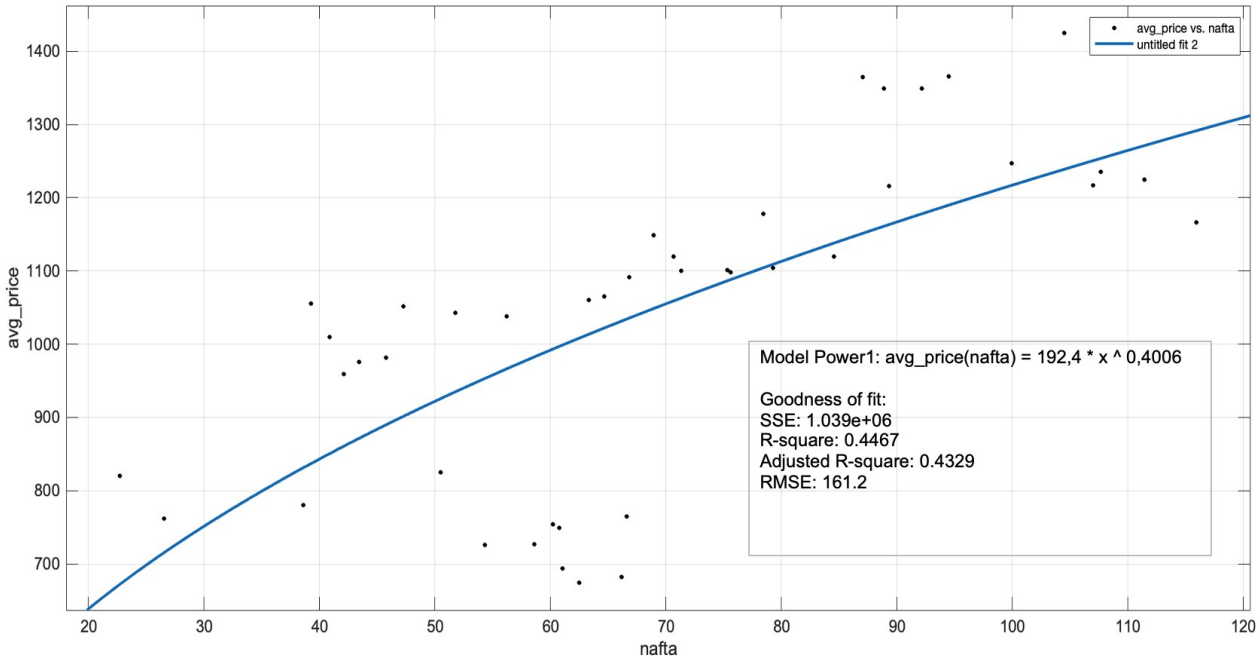


Fig. 2.3.25. Power-law regression (1st degree) of the price of an apartment depending on the world price of oil

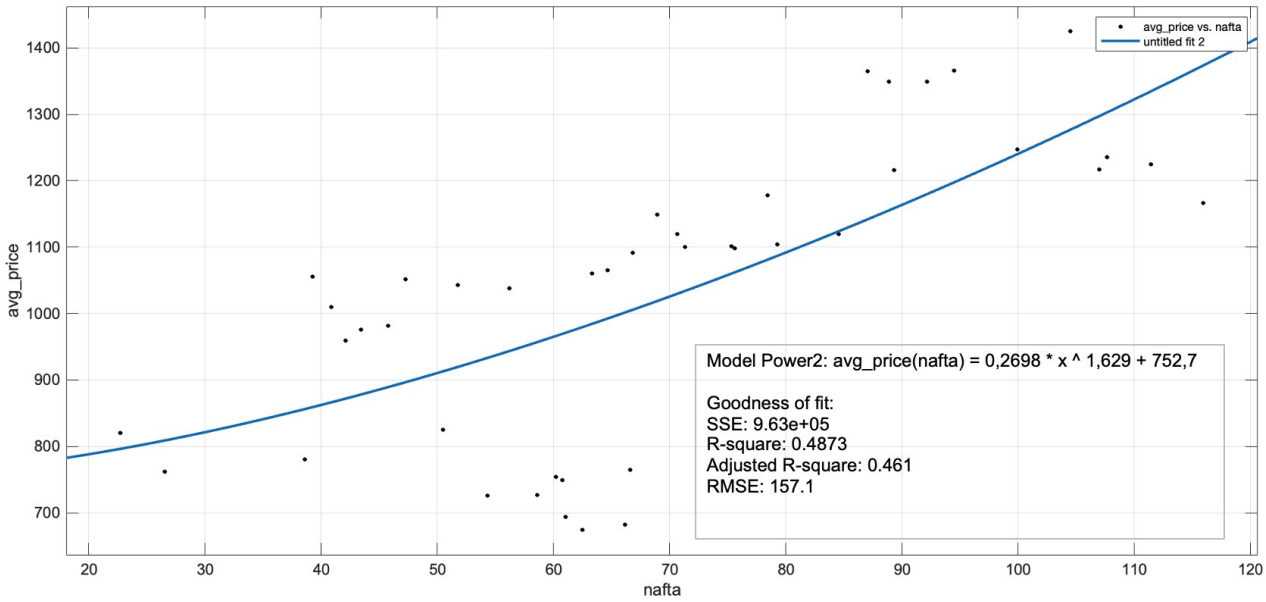


Fig. 2.3.26. Power-law regression (2nd degree) of the price of an apartment depending on the world price of oil

Table 2.14

Checking the statistical significance of apartment price trend models depending on the world oil price

№	x	y	X = ln x	Y = ln y	X^2	Y^2	XY	Power-law regression (1st degree)			Power-law regression (2 degree)		
								Predicted values	Absolute residuals	Relative residuals	Predicted values	Absolute residuals	Relative residuals
1	66,58	764,7	4,20	6,64	17,63	44,08	27,88	1034,28	269,53	0,35	1004,62	239,87	0,31
2	61,02	694,2	4,11	6,54	16,90	42,81	26,90	998,77	304,57	0,44	971,26	277,07	0,40
3	58,61	726,9	4,07	6,59	16,57	43,41	26,82	982,78	255,85	0,35	957,38	230,45	0,32
4	60,78	749,4	4,11	6,62	16,87	43,81	27,19	997,19	247,81	0,33	969,86	220,48	0,29
5	60,20	754,2	4,10	6,63	16,79	43,90	27,15	993,37	239,13	0,32	966,50	212,25	0,28
6	62,47	674,4	4,13	6,51	17,10	42,43	26,93	1008,21	333,79	0,49	979,79	305,37	0,45
7	66,15	682,2	4,19	6,53	17,57	42,58	27,35	1031,60	349,37	0,51	1001,98	319,75	0,47
8	54,31	726,1	3,99	6,59	15,96	43,40	26,32	953,23	227,18	0,31	933,48	207,43	0,29
9	50,50	825,2	3,92	6,72	15,38	45,10	26,34	925,86	100,63	0,12	913,28	88,06	0,11
10	22,72	820,6	3,12	6,71	9,75	45,02	20,96	672,33	-148,28	-0,18	796,42	-24,19	-0,03
11	26,56	761,7	3,28	6,64	10,75	44,03	21,76	715,73	-45,98	-0,06	809,08	47,37	0,06
12	38,61	780,3	3,65	6,66	13,35	44,35	24,33	831,45	51,17	0,07	856,40	76,11	0,10
13	42,09	958,8	3,74	6,87	13,99	47,14	25,68	860,70	-98,08	-0,10	872,05	-86,73	-0,09
14	43,40	975,9	3,77	6,88	14,22	47,38	25,95	871,33	-104,54	-0,11	878,16	-97,71	-0,10
15	45,75	981,9	3,82	6,89	14,62	47,47	26,34	889,93	-92,01	-0,09	889,42	-92,53	-0,09
16	40,87	1009,5	3,71	6,92	13,77	47,85	25,67	850,62	-158,85	-0,16	866,47	-143,00	-0,14
17	39,24	1055,5	3,67	6,96	13,47	48,47	25,55	836,86	-218,63	-0,21	859,17	-196,32	-0,19
18	47,25	1051,3	3,86	6,96	14,86	48,41	26,83	901,51	-149,76	-0,14	896,79	-154,47	-0,15
19	51,73	1042,5	3,95	6,95	15,57	48,29	27,42	934,82	-107,72	-0,10	919,70	-122,84	-0,12

20	56,21	1037,6	4,03	6,94	16,23	48,23	27,98	966,45	-71,10	-0,07	943,90	-93,65	-0,09
21	63,31	1059,9	4,15	6,97	17,21	48,52	28,90	1013,62	-46,30	-0,04	984,78	-75,14	-0,07
22	64,65	1065,4	4,17	6,97	17,38	48,60	29,06	1022,16	-43,25	-0,04	992,84	-72,58	-0,07
23	66,82	1091,3	4,20	7,00	17,66	48,93	29,39	1035,77	-55,54	-0,05	1006,10	-85,21	-0,08
24	70,63	1119,5	4,26	7,02	18,13	49,29	29,89	1059,03	-60,42	-0,05	1030,06	-89,40	-0,08
25	75,61	1098,1	4,33	7,00	18,71	49,02	30,28	1088,34	-9,76	-0,01	1062,62	-35,48	-0,03
26	75,31	1100,9	4,32	7,00	18,68	49,05	30,27	1086,61	-14,33	-0,01	1060,62	-40,32	-0,04
27	71,31	1099,9	4,27	7,00	18,21	49,04	29,88	1063,11	-36,83	-0,03	1034,42	-65,52	-0,06
28	79,24	1104,0	4,37	7,01	19,12	49,09	30,64	1108,98	5,02	0,00	1087,22	-16,73	-0,02
29	84,55	1119,5	4,44	7,02	19,69	49,29	31,15	1138,17	18,72	0,02	1124,50	5,05	0,00
30	68,94	1148,6	4,23	7,05	17,92	49,65	29,83	1048,81	-99,82	-0,09	1019,33	-129,30	-0,11
31	78,41	1178,2	4,36	7,07	19,03	50,01	30,85	1104,31	-73,87	-0,06	1081,53	-96,65	-0,08
32	89,29	1215,6	4,49	7,10	20,18	50,45	31,91	1163,31	-52,33	-0,04	1159,05	-56,60	-0,05
33	107,65	1235,6	4,68	7,12	21,89	50,68	33,31	1253,80	18,18	0,01	1303,75	68,12	0,06
34	104,45	1424,8	4,65	7,26	21,61	52,73	33,76	1238,74	-186,05	-0,13	1277,32	-147,47	-0,10
35	106,97	1216,5	4,67	7,10	21,83	50,46	33,19	1250,63	34,10	0,03	1298,09	81,57	0,07
36	115,90	1166,0	4,75	7,06	22,59	49,86	33,56	1291,45	125,43	0,11	1374,19	208,18	0,18
37	111,44	1225,1	4,71	7,11	22,22	50,56	33,52	1271,30	46,18	0,04	1335,70	110,58	0,09
38	99,93	1246,6	4,60	7,13	21,20	50,81	32,82	1216,98	-29,61	-0,02	1240,84	-5,75	0,00
39	92,17	1349,5	4,52	7,21	20,46	51,95	32,60	1178,20	-171,34	-0,13	1180,62	-168,92	-0,13
40	88,86	1348,9	4,49	7,21	20,13	51,94	32,34	1161,07	-187,82	-0,14	1155,87	-193,02	-0,14
41	94,50	1365,3	4,55	7,22	20,69	52,12	32,84	1190,04	-175,28	-0,13	1198,38	-166,95	-0,12
42	87,05	1365,1	4,47	7,22	19,95	52,11	32,24	1151,53	-213,56	-0,16	1142,57	-222,52	-0,16

After the calculations, we can say that the relationship between the indicators is direct and with an increase in the price of oil, housing prices increase. The figures graphically reflect the concentration of sample values of real estate prices around the regression equation estimated by us. Their deviation from the regression line is the result of the action of the random component (the action of all other factors not included in the model).

2.4. Construction and research of multifactor price models on the secondary market of apartments

As we can see, all the above models are not accurate enough due to the fact that they take into account only one factor that affects the change in the price of an apartment. That is why we came to the conclusion that it is necessary to create a model of multiple regression and approximation of dependence $y_i=f(x_i)$ – constructions of the polynomial form:

$$P_n(x)=a_0\varphi_0(x)+a_1\varphi_1(x)+\ldots+a_n\varphi_n(x),$$

The value of which is in points x_i,i=0,1,…,n sufficiently correspond to the values y_i, i=0, 1, …, n.

Taking into account the calculations carried out in the previous part, the 4 most optimal models were derived.

1. a four-factor model of the dependence of the average cost of a square meter of an apartment on GDP, inflation, exchange rates and world oil prices.

Y = f (x_1, x_2, x_3, x_4), where x_i – relevant factor,

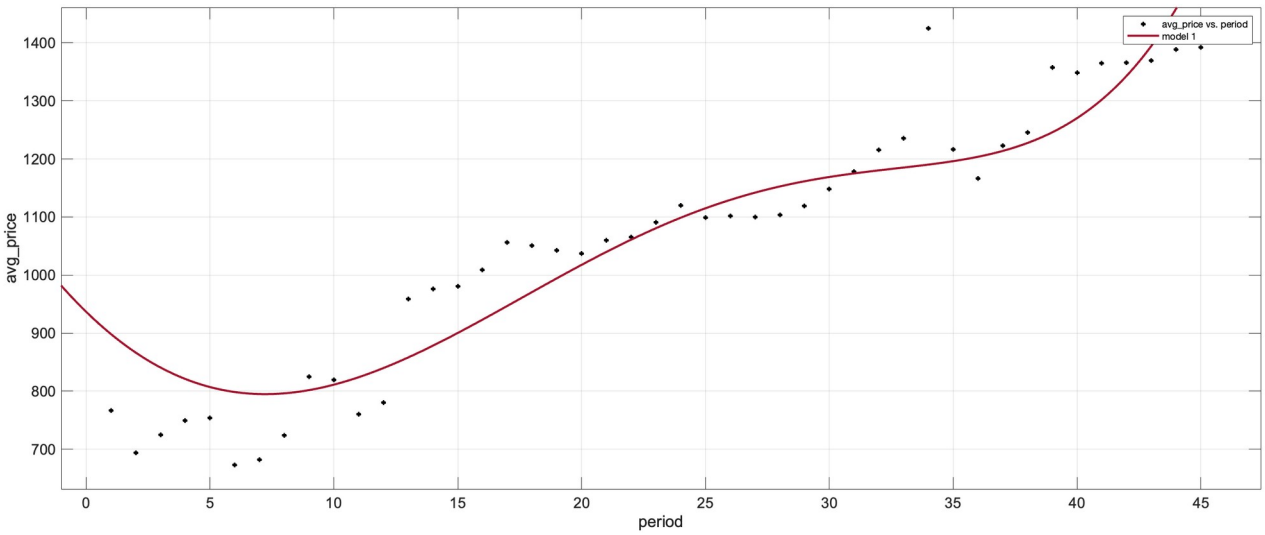


Fig. 2.4.1 The dependence model of apartment pricing №1

Table 2.15

Characteristics of the model №1

Coefficients (with 95% confidence bounds):	SSE 2.8442e+05
a_1 = 0,0011 (0,0007; 0,0016)	R-square 0.8725
a_2 = -31,8815 (19,5251; 44,238)	DFE 41

a_3 = -20,3868 (-37,5426; -3,2311)	Adj R-sq 0.8631
a_4 = -0,2 (-2,7498; 2,3498)	RMSE 83.2891

2. a five-factor model of the dependence of the average price per square meter of an apartment on GDP, inflation, exchange rates, average wages, the world price of oil

$Y = f(x_1, x_2, x_3, x_4, x_5)$, where x_i – relevant factor,

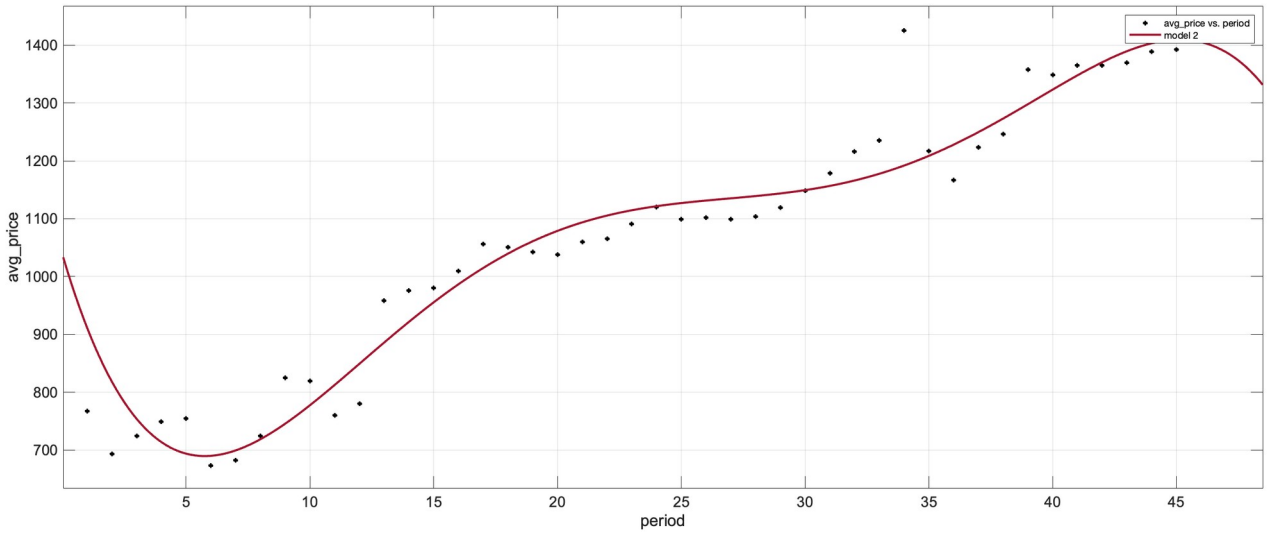


Fig. 2.4.2. The dependence model of apartment pricing №2

Table 2.16

Characteristics of the model №2

Coefficients (with 95% confidence bounds):	SSE 1.5106e+05
a_1 = -0,0031 (-0,0046; -0,0016)	R-square 0.9323
a_2 = -16,7064 (-35,5831; 2,1703)	DFE 40
a_3 = 29,5945 (8,39; 50,7946)	Adj R-sq 0.9255
a_4 = -7,8977 (-11,1224; -4,6729)	SSE 1.5106e+05
a_5 = 0,3445 (0,2273; 0,4617)	

3. a six-factor model of the dependence of the average price per square meter of an apartment on GDP, inflation, exchange rates, average wages, the world price of oil, an indicator of economic sentiment.

$Y = f(x_1, x_2, x_3, x_4, x_5, x_6)$, where x_i – relevant factor,

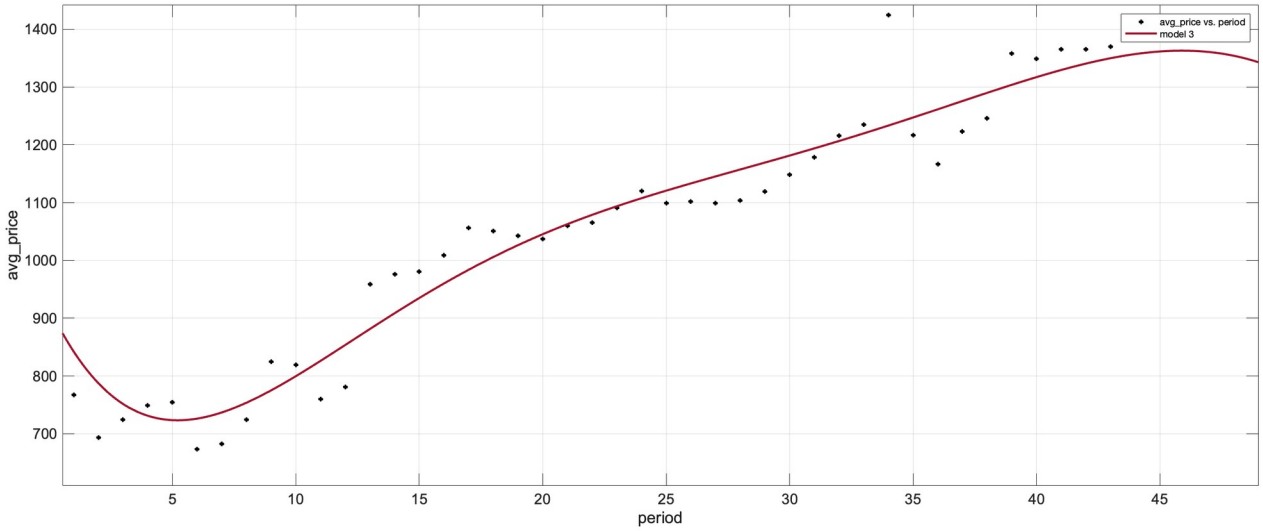


Fig. 2.4.3. The dependence model of apartment pricing №3

Table 2.17

Characteristics of the model №3

Coefficients (with 95% confidence bounds):	SSE 1.2888e+05
a_1 = 0,0152 (-0,068; 0,0984)	R-square 0.9422
a_2 = 31,2415 (-124,2881; 186,7711)	
a_3 = 75,9435 (-285,71; 437,5971)	DFE 38
a_4 = 61,1587 (-272,6474; 394,9649)	
a_5 = -1,1717 (-8,1192; 5,78)	Adj R-sq 0.9331
a_6 = 25,0805 (-148,086; 198,247)	
a_7 = -1,02E+04 (-6,69E+04; 4,64E+04)	RMSE 58.2366

4. a seven-factor model of the dependence of the average price per square meter of an apartment on GDP, inflation, exchange rates, average wages, the world price of oil, an indicator of economic sentiment an unemployment rate.

$Y = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7)$, where x_i – relevant factor,

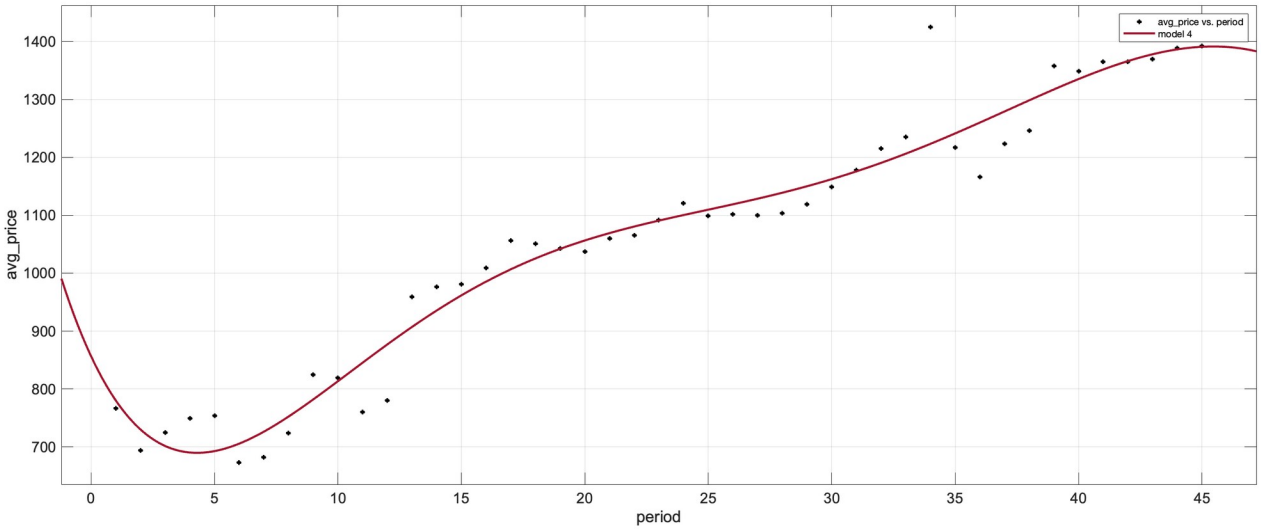


Fig. 2.4.4. The dependence model of apartment pricing №4

Table 2.18

Characteristics of the model №4

Коефіцієнти (with 95% confidence bounds):	SSE 1.0411e+05
a_1 = -0,035 -1,50E+03 1,50E+03	R-square 0.9533
a_2 = 92,4703 -1,03E+06 1,03E+06	
a_3 = -106,946 -5698700,00 5,70E+06	DFE 37
a_4 = -161,4027 -6,48E+06 6481100,0000	
a_5 = 2,1046 -1,02E+05 102160,00	Adj R-sq 0.9445
a_6 = 42,5112 -117,9438 202,9662	
a_7 = 2,49E+03 -6,14E+07 6,14E+07	RMSE 53.0455
a_8 = -365,5374 -4,10E+08 4,10E+08	

When modeling, we are primarily interested in how well the model represents the modeling object. One of the approaches in assessing adequacy is to compare the outputs of the model and the real system at the same input values. Both those and other data (data obtained at the output of the model and data obtained as a result of an experiment with a real system) are statistical. Therefore, methods of statistical theory of evaluation and

hypothesis testing are used to assess adequacy (tables 2.19, 2.20, 2.21, 2.22).

Table 2.19

Comparison of the outputs of model 1 and the real system

period	Yfact	Yexp	Absolute residuals	Predicted values
1	766,97	857,63	90,66	0,12
2	693,67	825,07	131,40	0,19
3	724,41	798,70	74,30	0,10
4	749,48	778,30	28,82	0,04
5	754,25	763,61	9,37	0,01
6	673,07	754,34	81,26	0,12
7	682,13	750,13	68,00	0,10
8	724,32	750,63	26,31	0,04
9	824,92	755,43	-69,49	-0,08
10	819,41	764,12	-55,30	-0,07
11	760,35	776,24	15,89	0,02
12	780,59	791,35	10,76	0,01
13	958,72	809,00	-149,72	-0,16
14	975,92	828,72	-147,21	-0,15
15	980,56	850,04	-130,51	-0,13
16	1009,08	872,53	-136,55	-0,14
17	1056,47	895,75	-160,72	-0,15
18	1050,73	919,27	-131,46	-0,13
19	1042,51	942,70	-99,81	-0,10
20	1037,51	965,66	-71,85	-0,07
21	1059,88	987,84	-72,04	-0,07
22	1065,19	1008,92	-56,27	-0,05
23	1091,29	1028,66	-62,63	-0,06
24	1120,37	1046,85	-73,53	-0,07
25	1099,21	1063,33	-35,88	-0,03
26	1101,43	1078,03	-23,41	-0,02
27	1099,53	1090,90	-8,63	-0,01
28	1103,58	1101,98	-1,59	0,00
29	1119,04	1111,40	-7,64	-0,01
30	1148,64	1119,33	-29,31	-0,03
31	1178,30	1126,06	-52,24	-0,04
32	1215,62	1131,95	-83,66	-0,07
33	1235,26	1137,47	-97,79	-0,08

34	1424,99	1143,15	-281,84	-0,20
35	1216,58	1149,68	-66,91	-0,05
36	1166,39	1157,81	-8,58	-0,01
37	1223,04	1168,44	-54,61	-0,04
38	1246,02	1182,56	-63,46	-0,05
39	1357,71	1201,31	-156,40	-0,12
40	1348,85	1225,94	-122,91	-0,09
41	1365,25	1257,86	-107,39	-0,08
42	1365,41	1298,58	-66,84	-0,05
43	1369,50	1349,78	-19,72	-0,01
44	1388,84	1413,30	24,46	0,02
45	1392,28	1491,11	98,83	0,07

Table 2.20

Comparison of the outputs of model 2 and the real system

period	Yfact	Yexp	Absolute residuals	Predicted values
1	766,97	894,28	127,30	0,17
2	693,67	800,90	107,23	0,15
3	724,41	736,28	11,88	0,02
4	749,48	695,87	-53,61	-0,07
5	754,25	675,53	-78,72	-0,10
6	673,07	671,53	-1,54	0,00
7	682,13	680,55	-1,58	0,00
8	724,32	699,61	-24,71	-0,03
9	824,92	726,10	-98,82	-0,12
10	819,41	757,74	-61,67	-0,08
11	760,35	792,57	32,22	0,04
12	780,59	828,92	48,32	0,06
13	958,72	865,38	-93,34	-0,10
14	975,92	900,84	-75,08	-0,08
15	980,56	934,40	-46,16	-0,05
16	1009,08	965,39	-43,69	-0,04
17	1056,47	993,36	-63,11	-0,06
18	1050,73	1018,02	-32,72	-0,03
19	1042,51	1039,26	-3,25	0,00
20	1037,51	1057,12	19,61	0,02
21	1059,88	1071,78	11,90	0,01
22	1065,19	1083,51	18,32	0,02

23	1091,29	1092,70	1,41	0,00
24	1120,37	1099,79	-20,59	-0,02
25	1099,21	1105,29	6,08	0,01
26	1101,43	1109,75	8,32	0,01
27	1099,53	1113,75	14,22	0,01
28	1103,58	1117,85	14,27	0,01
29	1119,04	1122,59	3,55	0,00
30	1148,64	1128,51	-20,13	-0,02
31	1178,30	1136,07	-42,23	-0,04
32	1215,62	1145,66	-69,96	-0,06
33	1235,26	1157,59	-77,67	-0,06
34	1424,99	1172,04	-252,95	-0,18
35	1216,58	1189,09	-27,50	-0,02
36	1166,39	1208,66	42,27	0,04
37	1223,04	1230,50	7,46	0,01
38	1246,02	1254,20	8,18	0,01
39	1357,71	1279,13	-78,58	-0,06
40	1348,85	1304,45	-44,40	-0,03
41	1365,25	1329,07	-36,17	-0,03
42	1365,41	1351,66	-13,75	-0,01
43	1369,50	1370,61	1,12	0,00
44	1388,84	1384,02	-4,82	0,00
45	1392,28	1389,66	-2,62	0,00

Table 2.21

Comparison of the outputs of model 3 and the real system

period	Yfact	Yexp	Absolute residuals	Predicted values
1	766,97	894,28	127,30	0,17
2	693,67	800,90	107,23	0,15
3	724,41	736,28	11,88	0,02
4	749,48	695,87	-53,61	-0,07
5	754,25	675,53	-78,72	-0,10
6	673,07	671,53	-1,54	0,00
7	682,13	680,55	-1,58	0,00
8	724,32	699,61	-24,71	-0,03
9	824,92	726,10	-98,82	-0,12
10	819,41	757,74	-61,67	-0,08
11	760,35	792,57	32,22	0,04

12	780,59	828,92	48,32	0,06
13	958,72	865,38	-93,34	-0,10
14	975,92	900,84	-75,08	-0,08
15	980,56	934,40	-46,16	-0,05
16	1009,08	965,39	-43,69	-0,04
17	1056,47	993,36	-63,11	-0,06
18	1050,73	1018,02	-32,72	-0,03
19	1042,51	1039,26	-3,25	0,00
20	1037,51	1057,12	19,61	0,02
21	1059,88	1071,78	11,90	0,01
22	1065,19	1083,51	18,32	0,02
23	1091,29	1092,70	1,41	0,00
24	1120,37	1099,79	-20,59	-0,02
25	1099,21	1105,29	6,08	0,01
26	1101,43	1109,75	8,32	0,01
27	1099,53	1113,75	14,22	0,01
28	1103,58	1117,85	14,27	0,01
29	1119,04	1122,59	3,55	0,00
30	1148,64	1128,51	-20,13	-0,02
31	1178,30	1136,07	-42,23	-0,04
32	1215,62	1145,66	-69,96	-0,06
33	1235,26	1157,59	-77,67	-0,06
34	1424,99	1172,04	-252,95	-0,18
35	1216,58	1189,09	-27,50	-0,02
36	1166,39	1208,66	42,27	0,04
37	1223,04	1230,50	7,46	0,01
38	1246,02	1254,20	8,18	0,01
39	1357,71	1279,13	-78,58	-0,06
40	1348,85	1304,45	-44,40	-0,03
41	1365,25	1329,07	-36,17	-0,03
42	1365,41	1351,66	-13,75	-0,01
43	1369,50	1370,61	1,12	0,00
44	1388,84	1384,02	-4,82	0,00
45	1392,28	1389,66	-2,62	0,00

Table 2.22

Comparison of the outputs of model 4 and the real system

period	Yfact	Yexp	Absolute residuals	Predicted values

1	766,97	760,86	-6,11	-0,01
2	693,67	710,45	16,78	0,02
3	724,41	681,54	-42,87	-0,06
4	749,48	669,95	-79,54	-0,11
5	754,25	672,02	-82,23	-0,11
6	673,07	684,58	11,51	0,02
7	682,13	704,90	22,77	0,03
8	724,32	730,66	6,34	0,01
9	824,92	759,88	-65,04	-0,08
10	819,41	790,98	-28,44	-0,03
11	760,35	822,62	62,27	0,08
12	780,59	853,79	73,20	0,09
13	958,72	883,70	-75,02	-0,08
14	975,92	911,78	-64,14	-0,07
15	980,56	937,67	-42,88	-0,04
16	1009,08	961,16	-47,92	-0,05
17	1056,47	982,20	-74,27	-0,07
18	1050,73	1000,83	-49,90	-0,05
19	1042,51	1017,22	-25,29	-0,02
20	1037,51	1031,60	-5,91	-0,01
21	1059,88	1044,28	-15,60	-0,01
22	1065,19	1055,58	-9,61	-0,01
23	1091,29	1065,87	-25,42	-0,02
24	1120,37	1075,52	-44,86	-0,04
25	1099,21	1084,89	-14,33	-0,01
26	1101,43	1094,33	-7,10	-0,01
27	1099,53	1104,16	4,63	0,00
28	1103,58	1114,67	11,10	0,01
29	1119,04	1126,09	7,05	0,01
30	1148,64	1138,59	-10,05	-0,01
31	1178,30	1152,30	-26,00	-0,02
32	1215,62	1167,25	-48,37	-0,04
33	1235,26	1183,43	-51,82	-0,04
34	1424,99	1200,75	-224,24	-0,16
35	1216,58	1219,04	2,45	0,00
36	1166,39	1238,04	71,66	0,06
37	1223,04	1257,45	34,41	0,03
38	1246,02	1276,89	30,86	0,02
39	1357,71	1295,88	-61,83	-0,05
40	1348,85	1313,93	-34,92	-0,03
41	1365,25	1330,46	-34,79	-0,03
42	1365,41	1344,85	-20,56	-0,02

43	1369,50	1356,45	-13,05	-0,01
44	1388,84	1364,57	-24,27	-0,02
45	1392,28	1368,51	-23,77	-0,02

The adequacy of the studied model can be checked by the variances of the deviations of the model outputs from the average value of the system outputs. Comparison of variances is carried out using the F-test (Fisher's test). The obtained results regarding the specified models are given below (Table 2.23, 2.24, 2.25, 2.26)

Table 2.23

F-test for model 1

	Yfact	*Yexp*
Average	1057,05	1011,59
Dispersion	50687,58	39380,19
Number of observations	45	45
df	41	41
F	1,2871	
P(F<=f)	0,2029	
F critical	1,6509	

Table 2.24

F-test for model 2

	Yfact	*Yexp*
Average	1057,05	1037,37
Dispersion	50687,58	46425,36
Number of observations	45	45
df	41	41
F	1,0918	
P(F<=f)	0,3861	
F critical	1,6509	

Table 2.25

F-test for model 3

	Yfact	*Yexp*
Average	1057,05	1085,96
Dispersion	50687,58	44462,22
Number of observations	45	45
df	41	41

F	1,1400
P(F<=f)	0,3329
F critical	1,6509

Table 2.26

F-test for model 4

	Yfact	*Yexp*
Average	1057,05	1034,27
Dispersion	50687,58	48197,99
Number of observations	45	45
df	41	41
F	1,0517	
P(F<=f)	0,4340	
F critical	1,6509	

Based on the results of modeling and comparison of the obtained calculation results, model №4 was selected as the most optimal with the best statistical characteristics. The results obtained using it are almost identical to those obtained using model №3. Based on these conclusions, forecast values were calculated for the next 6 periods – six months, that is, until April 2023 using models №1, 2 and 4 (Fig. 2.4.5).

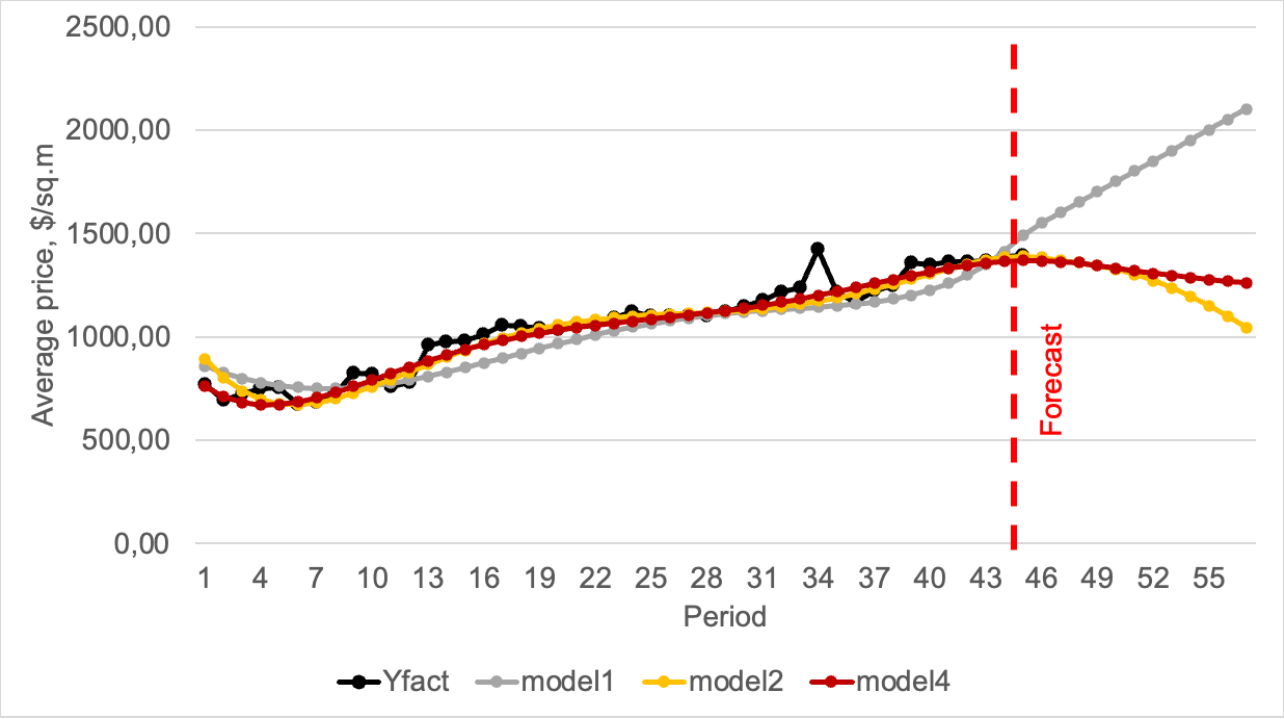


Fig. 2.4.5. Apartment price forecast for 12 months (until March 2024)

In such a way, we see two possible scenarios:

1. based on the first model, the average price per square meter on the apartment market will steadily increase;

2. according to the results of the fourth model, the market will initially experience relative stabilization, followed by a drop in prices;

3. the second model also predicts a fall, but more significant.

However, the specified methodology does not take into account the significance of each of the factors in accordance with the calculated correlation coefficients. When considering the values of correlation coefficients in multivariate regression, the so-called multiple correlation method is usually used. This method uses the multiple correlation coefficient (R) to determine the overall relationship between the dependent variable and all independent variables. The R value is found by calculating the correlation between the observed values of the dependent variable and those predicted by all the independent variables.

In addition, in multivariate regression, the so-called technique of standardized regression coefficients can be used to identify the importance of each of the independent variables. This method allows you to compare the effects of different variables on the dependent variable, if they have different scales and units of measurement. It consists in the fact that each variable (both dependent and independent) is standardized by subtracting the mean value from each of the values of the variable and dividing by its standard deviation. As a result of standardization, all variables will have a mean of 0 and a standard deviation of 1.

Standardized regression coefficients allow you to compare the influence of different variables on the dependent variable in standardized units. The values of the standardized coefficients can be compared with each other without the need to consider the difference in the scale of measurement of the variables. Standardized regression coefficients can also be used to determine the effect of each of the independent variables on the dependent variable.

Based on this, another model is proposed (Fig. 2.4.6), which considers 7 the most influential parameters and the level of their correlation with the average price of an apartment.

Characteristics of the model №5

Number of observations: 45, Error degrees of freedom: 38
Root Mean Squared Error: 52.3
R-squared: 0.953, Adjusted R-Squared: 0.946
F-statistic vs. constant model: 129, p-value = 9.7e-24MLR_avg_price =
MLR_avg_price = Linear regression model:
avg_price ~ [Linear formula with 7 terms in 6 predictors]
Coefficients of the model №5

Beta(Inf) -5.0287
Beta(exchange) -12.7892
Beta(gdp) -0.0075
Beta(iem) -30.6495
Beta(oil) -35.4081
Beta(wages) 0.7302

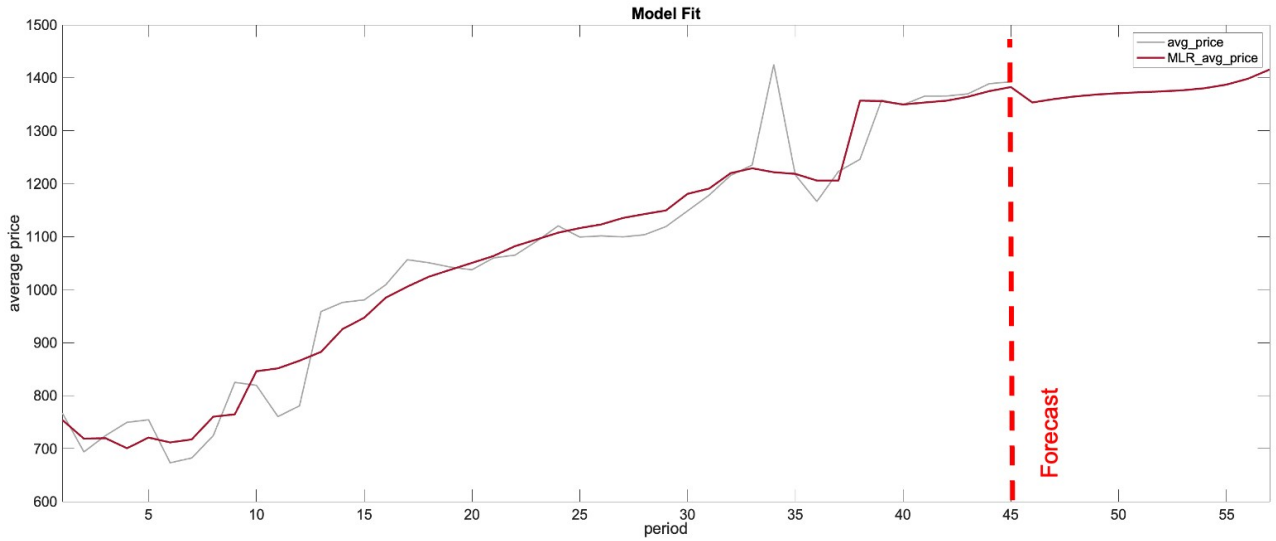


Fig. 2.4.4. The dependence model of apartment pricing №5

According to such a model, the market will expect gradual growth, which will take place at a stable pace. After reaching the peak price, it will start to decrease. Such trends may be caused by the prospective recovery of GDP, exchange rate fluctuations and inflationary expectations.

With the use of the specified methodology, trends and possible options for the future development of sub-segments of the secondary market of apartments in Ukraine were also analyzed. Thus, under the condition of segmentation by the number of rooms in the apartment, models were proposed and further development was predicted for the next six months (Fig. 2.4.7). The main characteristics of the models are given in table 2.27.

Table 2.27

The main characteristics of models of apartment pricing with different number of rooms

1-room	**2- room**
SSE 7.2435e+04 R-square 0.9636 DFE 37 Adj R-sq 0.9567 RMSE 44.2459	SSE 1.1954e+05 R-square 0.9434 DFE 41 Adj R-sq 0.9392 RMSE 53.9960
3- room	**4- room**
SSE 1.3628e+05	SSE 276530,00

R-square 0.9450 DFE 41 Adj R-sq 0.9409 RMSE 57.6539	R-square 0,93 DFE 41 Adj R-sq 0,93 RMSE 82,13
5- room (and more) SSE 330160,00 R-square 0,89 DFE 39 Adj R-sq 0,88 RMSE 92,01	

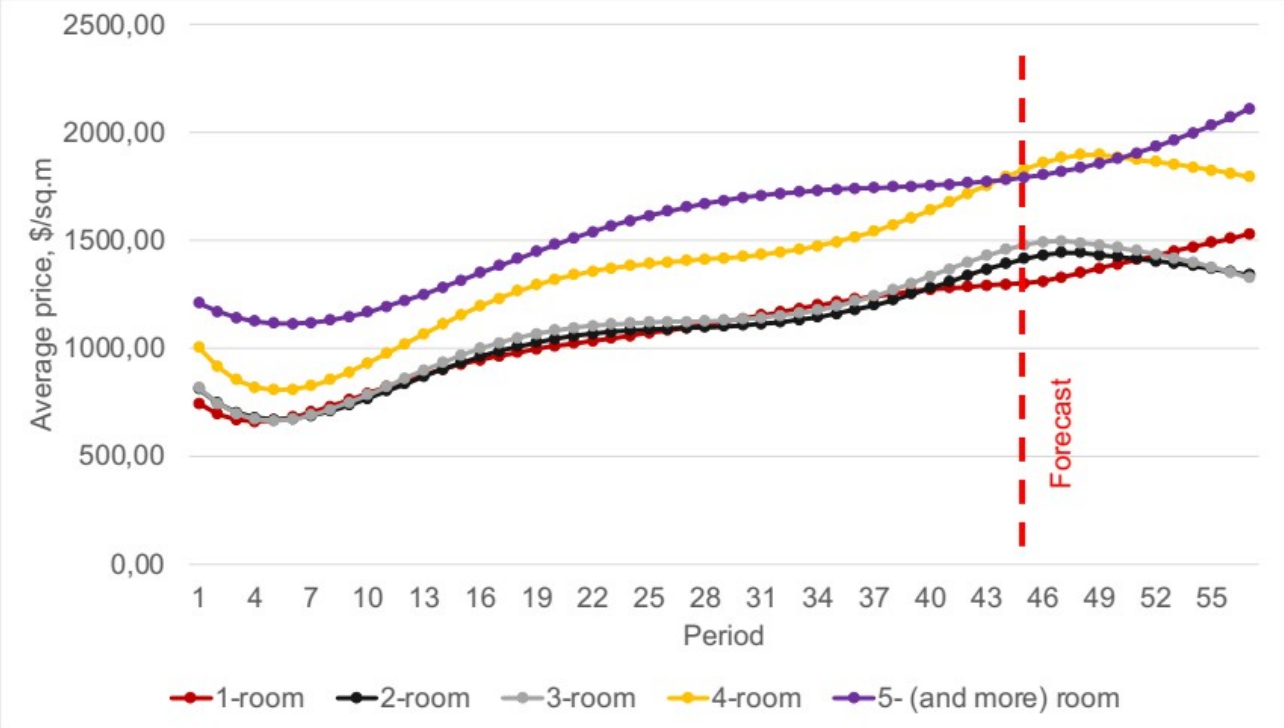


Fig. 2.4.7. Forecasting the price of apartments with different number of rooms for 12 months (until March 2024)

As we can see, a significant decline in prices for 2-room and multi-room apartments is expected, which may be associated with a significant decrease in purchasing power, while stability and confident growth is expected for 1-room apartments, given that these options are always in the most demand as the most optimal for people with an average income. A significant increase will affect 5-room apartments, which can be explained by the fact that the market is recovering from the shock and such offers are returning to normal.

In the context of the largest cities in today's conditions, the dynamics are not so obvious. The main characteristics and graphical representation of the built models are given below (Fig. 2.4.8, Table 2.28).

Table 2.28

The main characteristics of the price formation models for apartments in the largest cities of Ukraine

Kyiv SSE 142050,00 R-square 0,97 DFE 39 Adj R-sq 0,97 RMSE 60,35	**Odesa** SSE 39301,00 R-square 0,93 DFE 41 Adj R-sq 0,93 RMSE 30,96
Kharkiv SSE 56188,00 R-square 0,87 DFE 41 Adj R-sq 0,86 RMSE 37,02	**Dnipro** SSE 19362,00 R-square 0,97 DFE 39 Adj R-sq 0,97 RMSE 22,28
Lviv SSE 22695,00 R-square 0,99 DFE 37 Adj R-sq 0,98 RMSE 24,77	

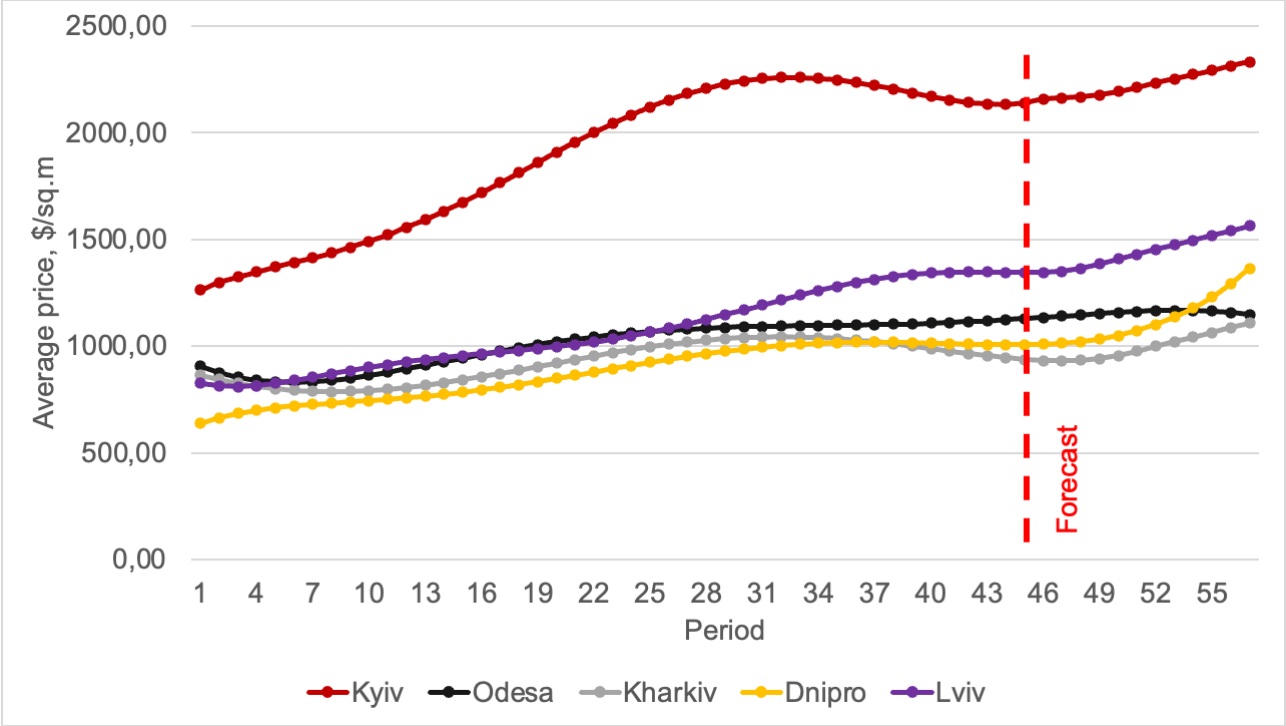


Fig. 2.4.8. Forecasting the price of apartments in the largest cities of Ukraine for 12 months (until March 2024)

As we can see, it will not be the best of times for such cities as Dnipro and Kharkiv in terms of the secondary market of apartments, although we can see that the market recovery and a gradual increase in prices are expected in the future. The impact of power problems, the threat of repeated attacks and shelling will be reflected. In general, prices for secondary apartments in Kyiv, Dnipro and various cities in the center of Ukraine have fallen by 20-30% in the last months of the war. Although in some cities, such as Lviv, where, according to various sources, a lot of internally displaced people came, housing on the secondary market has become more expensive. In Odesa, we note the relative stability and preservation of a positive trend, which is explained by the constant demand for real estate. We can expect the market to recover and prices to rise in Kyiv. In Lviv, positive trends and the continuation of the growing trend due to the new influx of refugees from the eastern and southern regions are likely.

In order to make objective and well-founded conclusions about the further development of the apartment market, all the obtained forecast models in fig. 2.4.9. Model 0 is built on the basis of an ordinary polynomial of degree 4, which describes the trend of the dynamics of the average price of apartments. Models 1, 2 and 4 are multivariate, which were defined as the most optimal above. Model 5 also takes into account the importance of each of the factors when determining the coefficients.

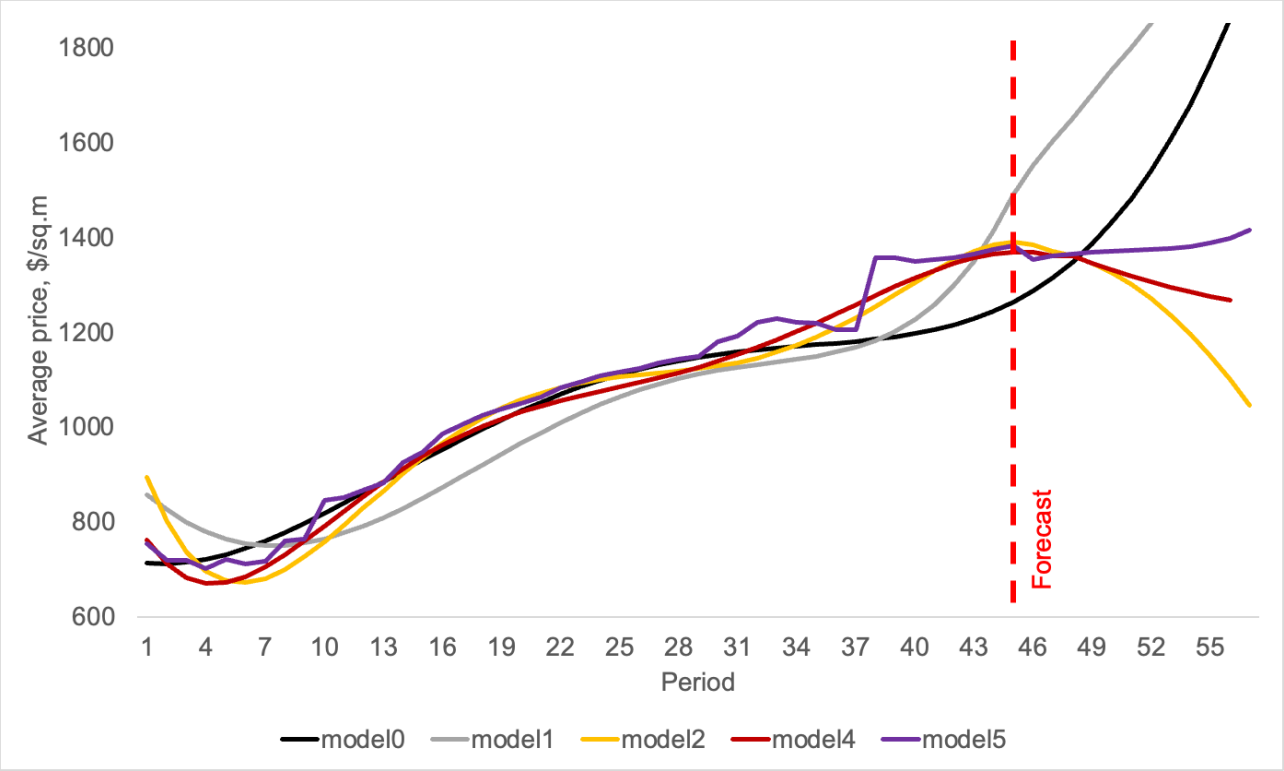


Fig. 2.4.9. Forecasting the price of apartments for 12 months (until March 2024) using different methods

Thus, it is entirely possible that apartment prices will continue to rise. The reason is not only the depreciation of the national currency, but also the destruction of the logistics system, internal agreements, problems with metal. Also, earlier Ukraine bought most of the glass from Russia and Belarus - now it has to be ordered from Europe. However, it is also worth considering that most developers are currently returning to work, which may bring another option closer to reality - the relative stabilization of prices for apartments both on the secondary market and on the primary market.

3. THE DEPENDENCE MODEL OF LAND PLOTS PRICING

The next step of the research is to extend the use of the methodology described in the previous section to different market segments, in particular the land market and the home ownership market. Let's start with the land market consider the dynamics of price changes over time (Fig. 3.1).

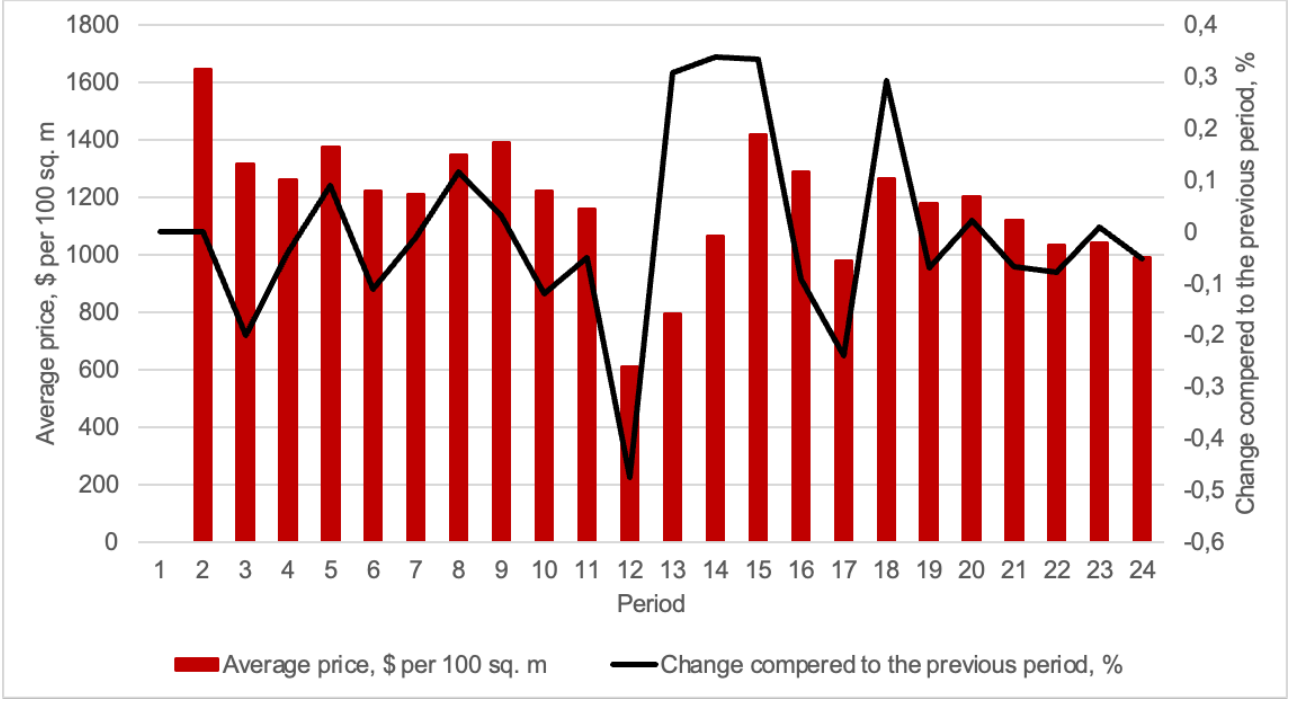


Fig. 2.1. Dynamics of the average value of a land plot (USD/100 m^2) on the real estate market of Ukraine for April 2021 - March 2023

The monthly indicators of the average value on the land market in Ukraine for the period of 2021-2023 dynamically characterize the overall picture, taking into account the influence of various factors that restrained or, on the contrary, revived market activity. We should note the clearly expressed seasonality characteristic of this segment, as well as the fact that the average price actually fluctuates around a fixed average. This makes it difficult to build a regression model.

However, for the land market, we can take the predicted median value of an acre of land (Fig. 3.2), because such a time series will show a non-stationary character.

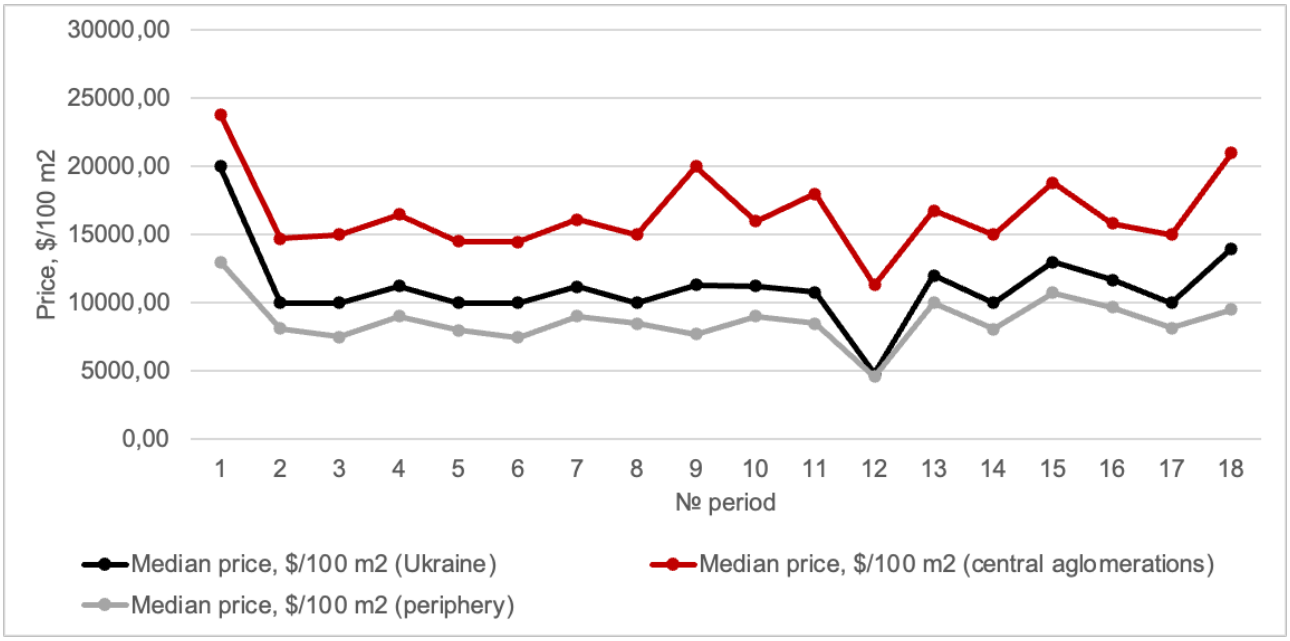


Fig. 3.2. Dynamics of the median value of a land plot (USD/100 m^2) on the real estate market of Ukraine for April 2021 - March 2023.

With the opening of the agricultural land market from July 1, 2021, a rapid growth of this category of land plots in the general information base of the land market was expected. The analysis of the mentioned indicators confirms this, showing a rapid growth in the third quarter of 2021. It is clear that in the second quarter of 2022, the market largely reflected a full-scale war: which caused a shock situation and a significant drop, both in terms of quantitative and value results. Nevertheless, the third quarter has shown a tendency to recovery. During the entire considered period, the price of land plots in the central agglomerations exceeded the price in the periphery.

We note that in the following stages of work, we will divide the market of land plots in accordance with their intended purpose into three subdivisions:

- Land plots for residential and public buildings;
- Agricultural plots of land;
- Land plots for industrial development.

Next, it is necessary to check the presence of a connection (dependence or interdependence) between the indicators. According to the average monthly data for the period from March 2021 to March 2023, a correlation-regression analysis was performed and paired correlation coefficients were obtained, which determine the closeness of the relationship between the variables. As a result, it was determined:

- For the market of land plots for residential and public development, the most influential factors are inflation, average wages and the unemployment rate;
- For the agricultural land market - exchange rate, inflation and world oil prices;

• For the industrial land market - inflation, global oil prices and an economic sentiment indicator.

Considering these conclusions, models were built for each sub-segment of the market and the adequacy of the model was tested using Fisher's test.

1. Land plots for residential and public buildings

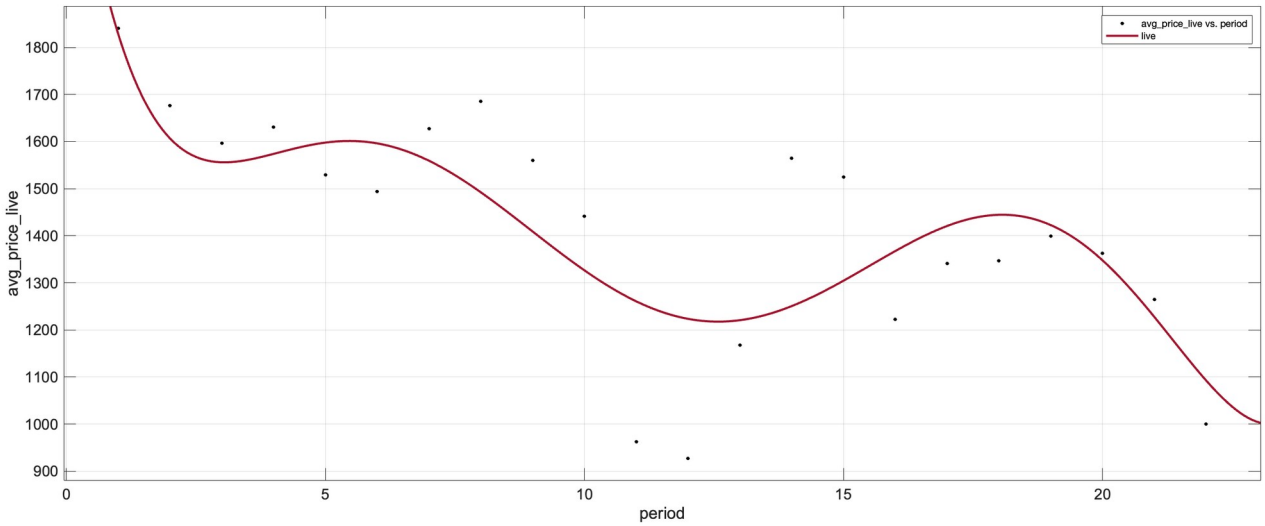


Fig. 3.3. The dependence model of land plots for residential and public buildings pricing (№1)

Characteristics of the model №1

SSE: 3.281e+05

R-square: 0.7229

Adjusted R-square: 0.6068

RMSE: 158.9

Table 3.1

F-test for model 1

	Yfact	*Yexp*
Average	1417,196637	1464,601619
Dispersion	72806,0368	29996,34631
Number of observations	20	20
df	19	19
F	2,427163497	
P(F<=f)	0,03020513	

	1
	2,16825160
F critical	1

2. Agricultural plots of land

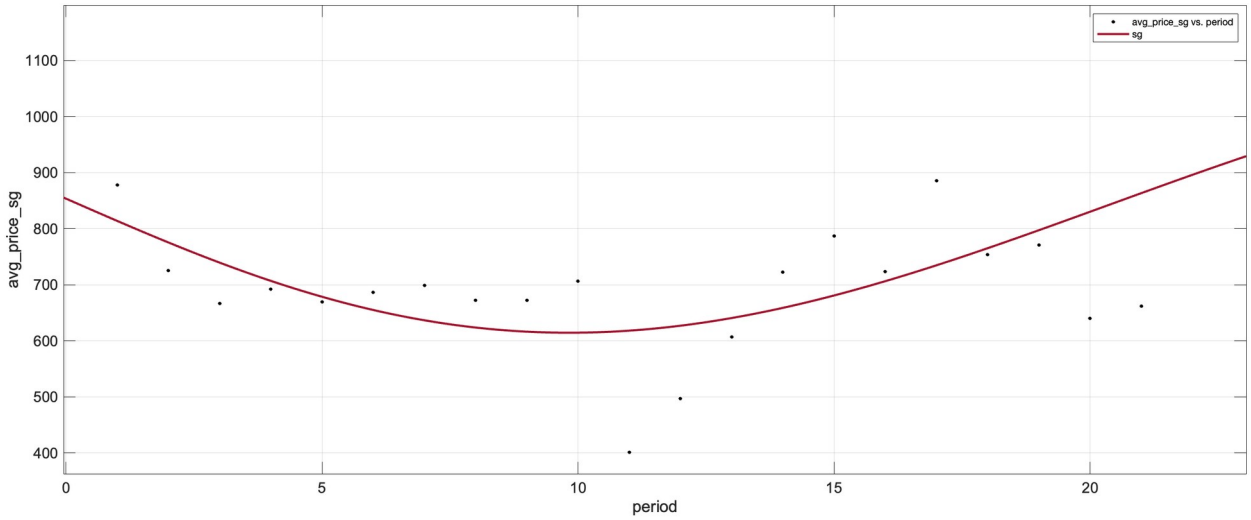


Fig. 3.4. The dependence model of agricultural plots of land pricing (№2)

Characteristics of the model №2

SSE: 5.622e+04

R-square: 0.6646

Adjusted R-square: 0.4298

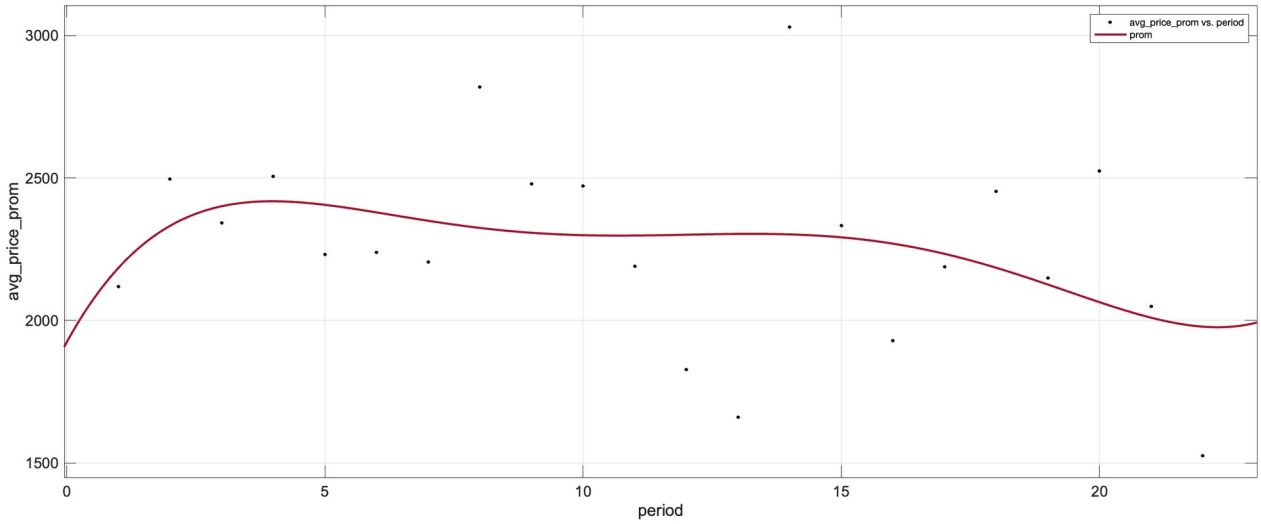
RMSE: 74.98

Table 3.2

F-test for model 2

	Yfact	*Yexp*
Average	686,5626842	683,8023497
Dispersion	18472,69702	10423,37276
Number of observations	20	20
df	19	19
F	1,772237974	
P(F<=f)	0,110713054	
F critical	2,168251601	

3. Plots of land for industrial purposes



Puc. 3.5. The dependence model of land plots for industrial development pricing (№3)

Characteristics of the model №3

SSE: 7.776e+05

R-square: 0.1246

Adjusted R-square: -0.0813

RMSE: 254.6

Table 3.3

F-test for model 3

	Yfact	*Yexp*
Average	2331,451119	2322,345105
Dispersion	232282,3352	6410,977391
Number of observations	20	20
df	19	19
F	36,23196918	
P(F<=f)	4,58094E-11	
F critical	2,168251603	

After analyzing the obtained results, we conclude that the selected models are the most optimal with the best statistical characteristics. Taking into account the fact that the coefficients of determination in each of them indicate that they are satisfactory. To obtain more reliable results, further accumulation of information on the real estate market and expansion of the database is necessary. Based on such conclusions, forecast values were calculated for the next 6 periods - six months, that is, until September 2023 (Figure 3.6).

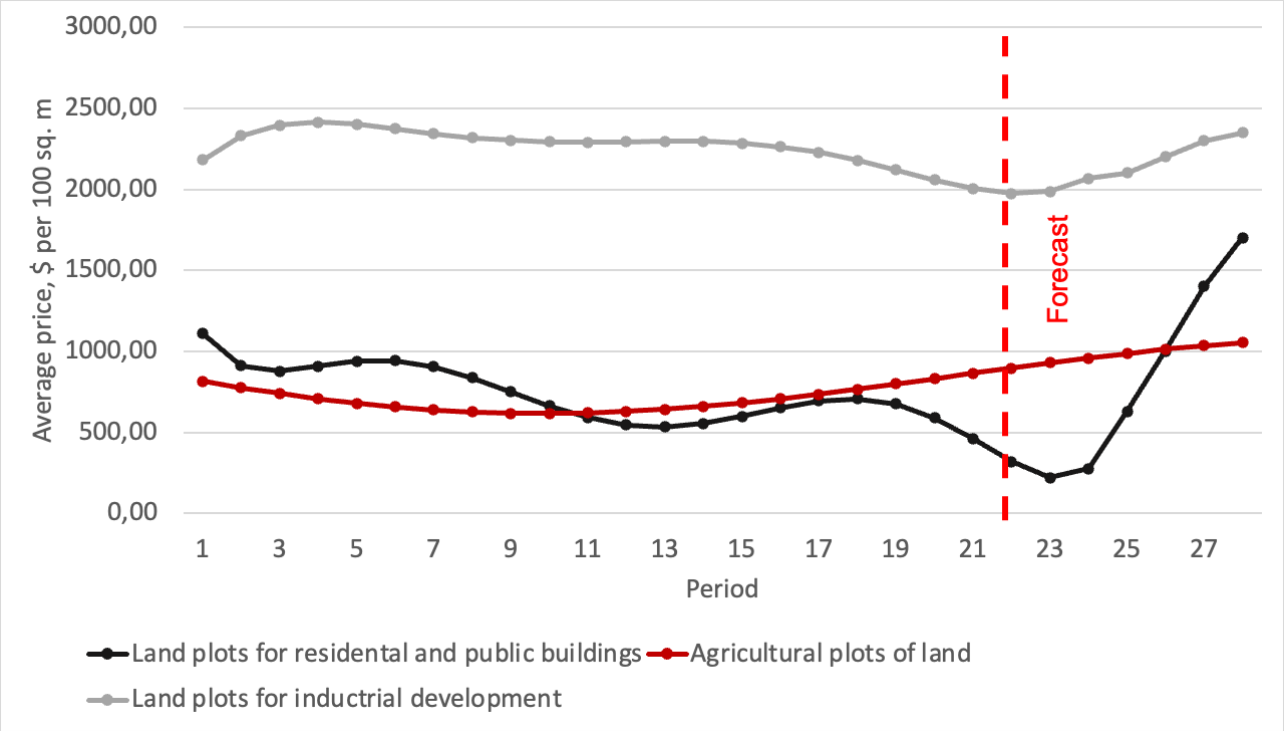


Fig. 3.6. Forecasting the price of land plots in Ukraine for 6 months (until September 2023)

As we can see, the land market for industrial development, which is connected with the active conduct of hostilities, will be most affected by hostilities. Agricultural land and areas for residential and public development will continue the growth that began in the pre-war period, however, it is clear that this pattern applies to areas that are distant from the places of hostilities.

4. THE DEPENDENCE MODEL OF HOUSEHOLD PRICING

Trends in the household market were also analyzed using the approaches described above. First of all, we should consider the general price dynamics for the period from March 2021 to October 2022 (Fig. 4.1).

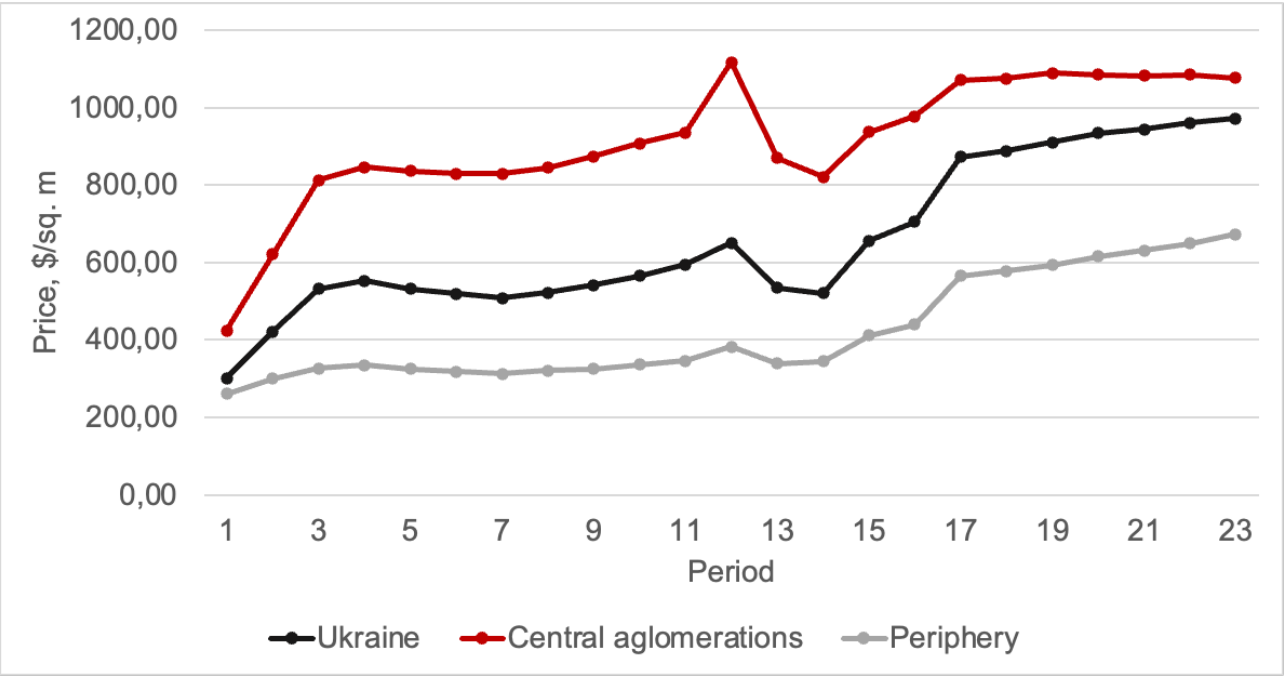


Fig. 3.1. Evolution of the average cost of housing (USD/m2) in the real estate market of Ukraine for March 2021 – March 203.

As we can see from the graph, in the central agglomerations the average price per square meter of housing is significantly higher than the average price in the periphery. Indicators of market volume in Ukraine for the period 2021-2023 in dynamics allow to analyze how certain factors influenced market activity. Since the beginning of 2022, there has been a decline, which is associated with political and economic instability in the country. We see that March 2022 has become the most critical in terms of value results. It is obvious that the reason was the beginning of a full-scale war, which shook the market. Currently, relative stabilization and gradual growth is observed.

An important stage of the analysis is the verification of the assumption about the existence of a relationship (dependence or interdependence between indicators). According to the average monthly data for the period from March 2021 to March 2023, a correlation-regression analysis was performed and paired correlation coefficients were obtained, which determine the closeness of the relationship between the variables. As a result, a matrix of paired correlation coefficients was obtained (table 4.1).

Table 4.1

Correlation matrix of the relationship between the price of housing and macroeconomic indicators

	avg	*gdp*	*course*	*inf*	*nafta*	*wages*	*iemm*
avg	1,00000						
gdp	-0,86095	1,00000					
course	0,87409	-0,96738	1,00000				
inf	0,81824	-0,95882	0,90112	1,00000			
nafta	0,34053	-0,58534	0,38501	0,65997	1,00000		
wages	-0,29801	0,41731	-0,38611	-0,41524	-0,49968	1,00000	
iemm	-0,72465	0,91283	-0,78614	-0,92362	-0,81717	0,36960	1,00000

The following designations were used: avg - average price per square meter. m of home ownership, gdp – GDP, course – dollar exchange rate, inf – inflation rate, nafta – world oil price, wages – average monthly wage in Ukraine, iemm – economic sentiment indicator, non-working – unemployment rate.

Based on the correlation matrix, we can see that the exchange rate (r=0.87), inflation (r=0.81) have the greatest influence on the average price of home ownership, and world oil prices have a much smaller influence (r=0.34). At the same time, the average wage has almost no effect (r=-0.29). At the same time, the correlations with GDP and economic sentiment indicator are negative, which is directly related to the fact that the reviewed period falls on crisis moments, when GDP dynamics were unstable, while at the same time the level of home ownership prices showed increasing trends.Thus, 3 main factors for building models were determined.

The methodology remained unchanged, so our goal was approximation of dependence $y_i=f(x_i)$ – constructions of the polynomial form:

$$P_n(x)=a_0\varphi_0(x)+a_1\varphi_1(x)+\ldots+a_n\varphi_n(x),$$

The value of which is in points x_i,i=0,1,…,n sufficiently correspond to the values y_i, i=0, 1, …, n.

Considering the calculations regarding the most influential factors, the 3 most optimal models were derived. The coefficients of determination in each of them indicate that they are satisfactory. To obtain more reliable results, further accumulation of information on the real estate market and expansion of the database is necessary.

1. Three-factor model of the dependence of the average cost of a square meter of an apartment on inflation, exchange rates and average wagees.

$$Y = f(x_1, x_2, x_3), \text{ where } x_i - \text{relevant factor},$$

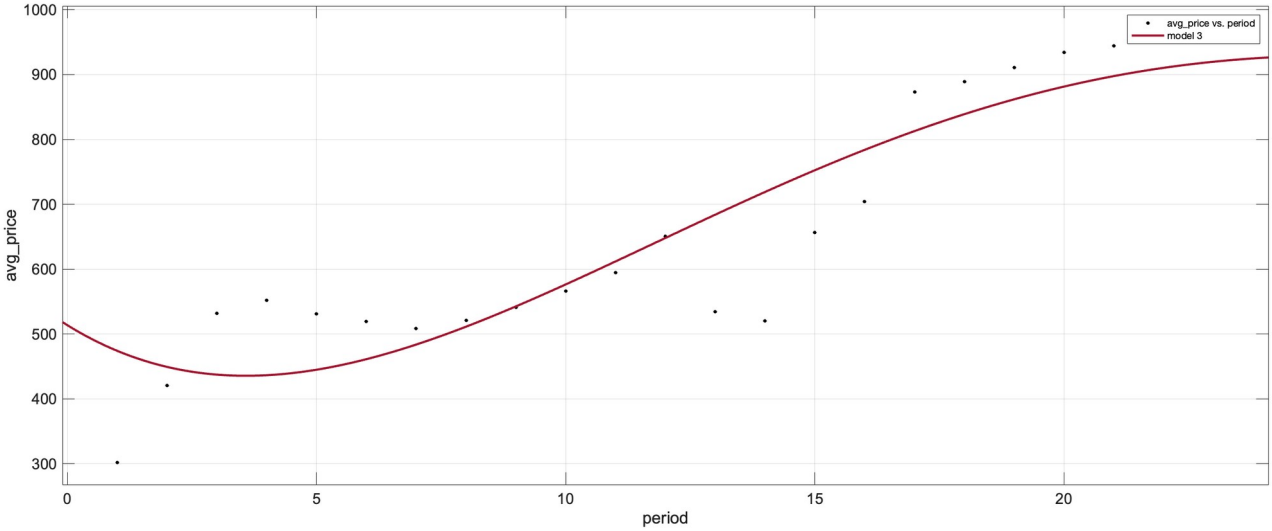


Fig. 4.2. The dependence model of household pricing №1

Table 4.2

Characteristics of model №1

Coefficients (with 95% confidence bounds):	SSE 1.6099e+05
a_1 = 0,002 (0,0015; 0,0024)	R-square 0.8131
a_2 = 21,97 (4,4581; 39,4906)	
a_3 = -1660,30 (-2,18E+03; -1,14E+03)	Adj R-sq 0.7944
	RMSE 89.7199

2. Four-factor model of the dependence of the average cost per square meter of an apartment on inflation, exchange rates, average wages and the world price of oil.

$$Y = f(x_1, x_2, x_3, x_4), \text{ where } x_i - \text{relevant factor},$$

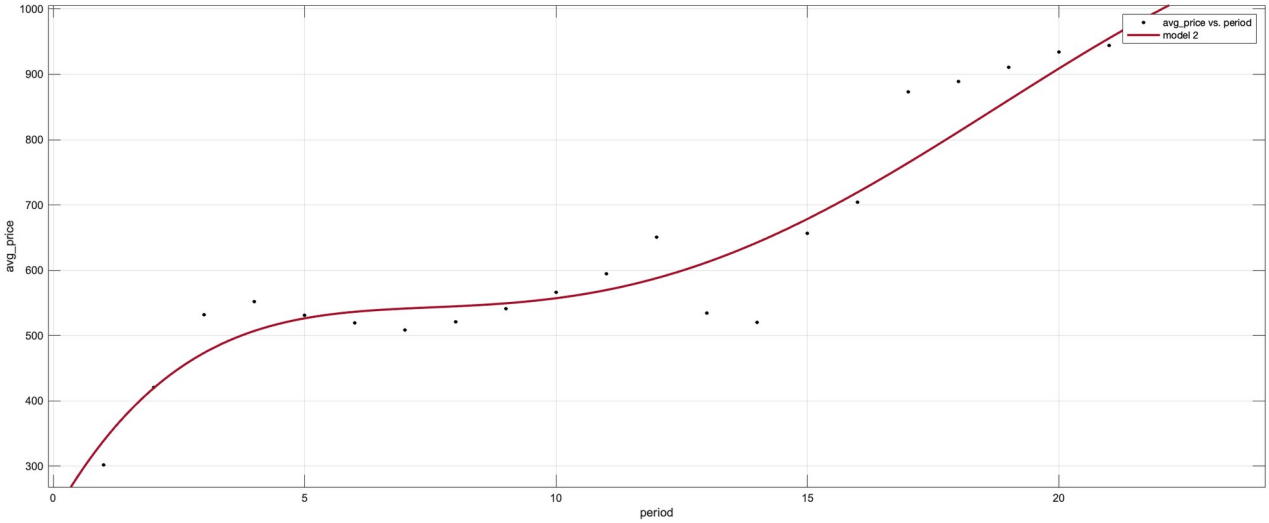


Fig. 4.3. The dependence model of household pricing №2

Table 4.3

Characteristics of model №2

Coefficients (with 95% confidence bounds):	SSE 6.1577e+04
a_1 = 0,0037 (0,0031; 0,0043)	R-square 0.9285
a_2 = 92,5475 (65,7138; 119,3811)	
a_3 = -126,2453 (-153,47; -99,0207)	Adj R-sq 0.9172
a_4 = -11,3082 (-16,6571; -5,9593)	
	RMSE 56.9289

3. Five-factor model of the dependence of the average price per square meter of an apartment on inflation, exchange rates, world oil prices, GDP and the index of business expectations.

$Y = f(x_1, x_2, x_3, x_4, x_5)$, where x_i – relevant factor,

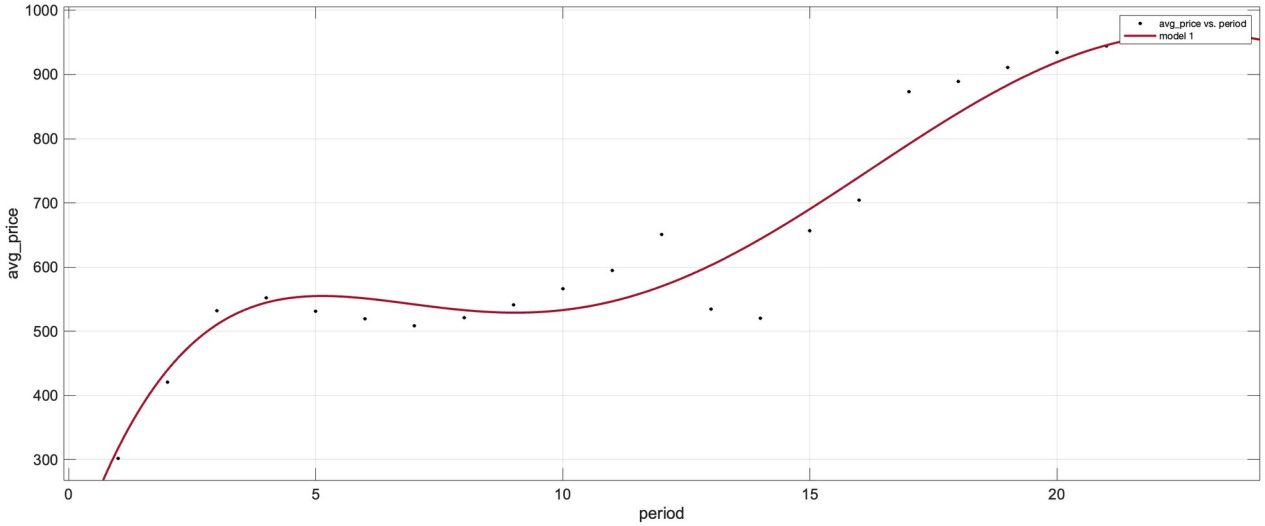


Fig. 4.4. The dependence model of household pricing №3

Table 4.4

Characteristics of model №3

Coefficients (with 95% confidence bounds):	SSE 4.6524e+04
a_1 = 0,0099 (0,0042; 0,0156)	R-square 0.9460
a_2 = 1,27E+03 (229,7306; 2,31E+03)	
a_3 = -893,016 (-1,57E+03; -212,0393)	Adj R-sq 0.9340
a_4 = -260,6262 (-480,5916; -40,6608)	
a_5 = 2,04E+04 (2,45E+03; 3,84E+04)	RMSE 50.8396

Invariably, when modeling, we are first of all interested in how well the model represents the modeling object. Therefore, methods of statistical theory of evaluation and hypothesis testing are used to assess adequacy (tables 4.5, 4.6, 4.7).

Table 4.5

Comparison of the outputs of model №1 and the real system

period	Yfact	Yexp	Absolute residuals	Predicted values
1	301,68	515,04	213,36	0,71
2	421,06	490,90	69,84	0,17
3	531,57	479,64	-51,93	-0,10
4	552,36	479,44	-72,92	-0,13
5	531,2	488,61	-42,59	-0,08

6	519,6	505,58	-14,02	-0,03
7	508,76	528,88	20,12	0,04
8	521,52	557,15	35,63	0,07
9	541,52	589,15	47,63	0,09
10	565,93	623,74	57,81	0,10
11	595,11	659,89	64,78	0,11
12	650,83	696,66	45,83	0,07
13	534,13	733,22	199,09	0,37
14	520,4	768,84	248,44	0,48
15	656,56	802,88	146,32	0,22
16	704,62	834,80	130,18	0,18
17	873,24	864,14	-9,10	-0,01
18	888,81	890,55	1,74	0,00
19	910,69	913,74	3,05	0,00
20	934,08	933,55	-0,53	0,00
21	944,09	949,85	5,76	0,01
22	961,63	962,64	1,01	0,00
23	972,21	971,96	-0,25	0,00

Table 4.6

Comparison of the outputs of model №2 and the real system

period	Yfact	Yexp	Absolute residuals	Predicted values
1	301,68	370,87	69,19	0,23
2	421,06	452,28	31,22	0,07
3	531,57	506,63	-24,94	-0,05
4	552,36	540,78	-11,58	-0,02
5	531,2	560,62	29,42	0,06
6	519,6	571,21	51,61	0,10
7	508,76	576,77	68,01	0,13
8	521,52	580,75	59,23	0,11
9	541,52	585,89	44,37	0,08
10	565,93	594,27	28,34	0,05
11	595,11	607,35	12,24	0,02
12	650,83	626,07	-24,76	-0,04
13	534,13	650,85	116,72	0,22
14	520,4	681,66	161,26	0,31
15	656,56	718,10	61,54	0,09
16	704,62	759,42	54,80	0,08
17	873,24	804,58	-68,66	-0,08
18	888,81	852,33	-36,48	-0,04
19	910,69	901,23	-9,46	-0,01

20	934,08	949,72	15,64	0,02
21	944,09	996,20	52,11	0,06
22	961,63	1039,01	77,38	0,08
23	972,21	1076,56	104,35	0,11

Table 4.7

Comparison of the outputs of model №3 and the real system

period	Yфакт	Yексп	Абсолютні залишки	Відносні залишки
1	301,68	304,08	2,40	0,01
2	421,06	426,09	5,03	0,01
3	531,57	496,69	-34,88	-0,07
4	552,36	530,77	-21,59	-0,04
5	531,2	540,79	9,59	0,02
6	519,6	536,95	17,35	0,03
7	508,76	527,36	18,60	0,04
8	521,52	518,25	-3,27	-0,01
9	541,52	514,12	-27,40	-0,05
10	565,93	517,91	-48,02	-0,08
11	595,11	531,24	-63,87	-0,11
12	650,83	554,51	-96,32	-0,15
13	534,13	587,16	53,03	0,10
14	520,4	627,77	107,37	0,21
15	656,56	674,31	17,75	0,03
16	704,62	724,28	19,66	0,03
17	873,24	774,90	-98,34	-0,11
18	888,81	823,30	-65,51	-0,07
19	910,69	866,68	-44,01	-0,05
20	934,08	902,51	-31,57	-0,03
21	944,09	928,69	-15,40	-0,02
22	961,63	943,77	-17,86	-0,02
23	972,21	947,06	-25,15	-0,03

The adequacy of the studied model is checked by the variances of the deviations of the model outputs from the average value of the system outputs (comparison of variances using the Fisher test) (tables 4.8, 4.9, 4.10).

Table 4.8

F-test for model 1

	Yfact	*Yexp*
Average	658,3304	706,1239
Dispersion	39151,0497	33164,6239
Number of observations	23	23
df	22	22
F	1,1805	
P(F<=f)	0,3503	
F critical	2,0478	

Table 4.9

F-test for model 2

	Yfact	*Yexp*
Average	658,3304	695,7894
Dispersion	39151,0497	37443,3774
Number of observations	23	23
df	22	22
F	1,0456	
P(F<=f)	0,4588	
F critical	2,0478	

Table 4.10

F-test for model 3

	Yfact	*Yexp*
Average	658,3304	643,4426
Dispersion	39151,0497	33721,5598
Number of observations	23	23
df	22	22
F	1,1610	
P(F<=f)	0,3647	
F critical	2,0478	

After comparing the obtained results, we choose model №1 as the most optimal with the best statistical characteristics. Based on these conclusions, forecast values were calculated for the next 6 periods – six months, that is, until March 2023 using three models (Fig. 4.5) and 3 probable options for price changes in the housing market are identified:

1. Model №1 predicts relative stability and a very slight price increase in the near future;

2. Model №2 corresponds to the scenario when the market will initially grow, which will be accompanied by a drop in price in subsequent periods;
3. Model №3 predicts a certain fall in the near future, but with the prospect of price growth.

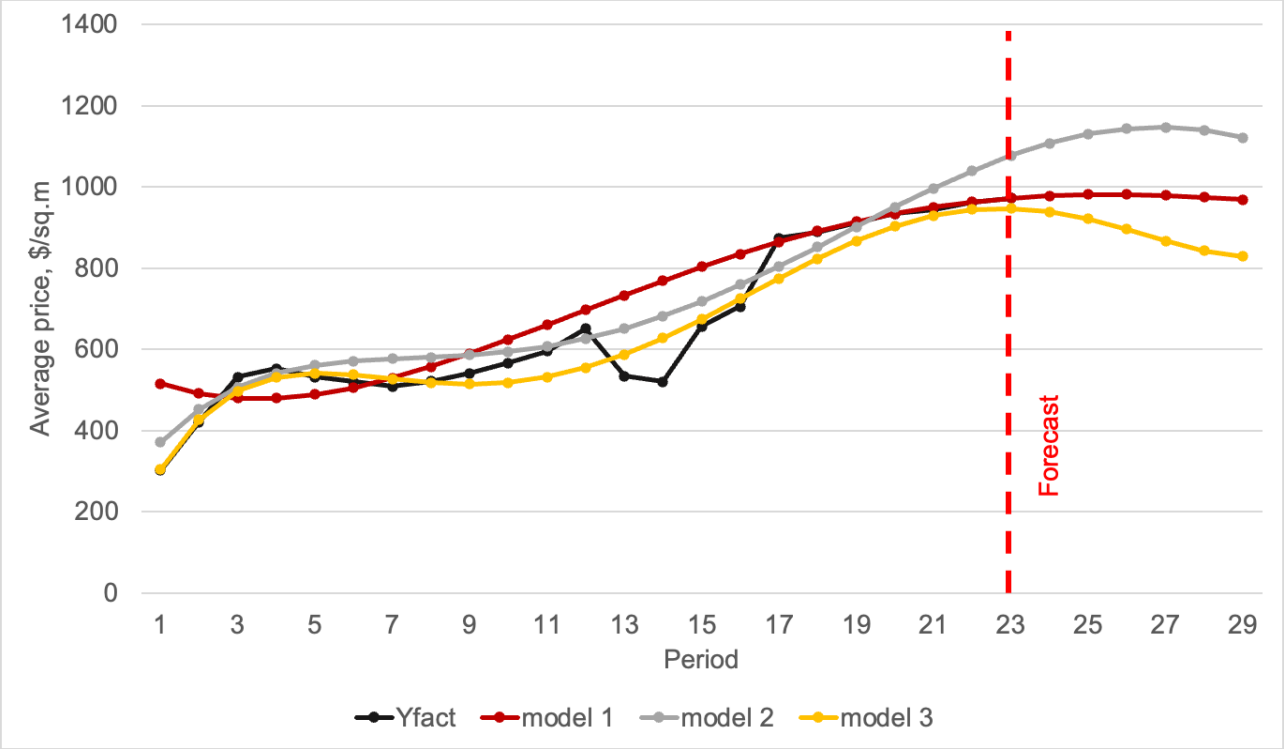


Fig. 4.5. Household price forecast in Ukraine for 6 months (until September 2023)

The following home ownership price model takes into account the importance of each of the factors in accordance with the calculated correlation coefficients (Fig. 4.6).

Characteristics of model №4

Number of observations: 23, Error degrees of freedom: 18
Root Mean Squared Error: 84.7
R-squared: 0.85, Adjusted R-Squared: 0.817
F-statistic vs. constant model: 25.5, p-value = 3.3e-07
Coefficients of model №4
Beta{Inf} 15.7711
Beta{gdp} -0.0017
Beta{oil} -6.7657

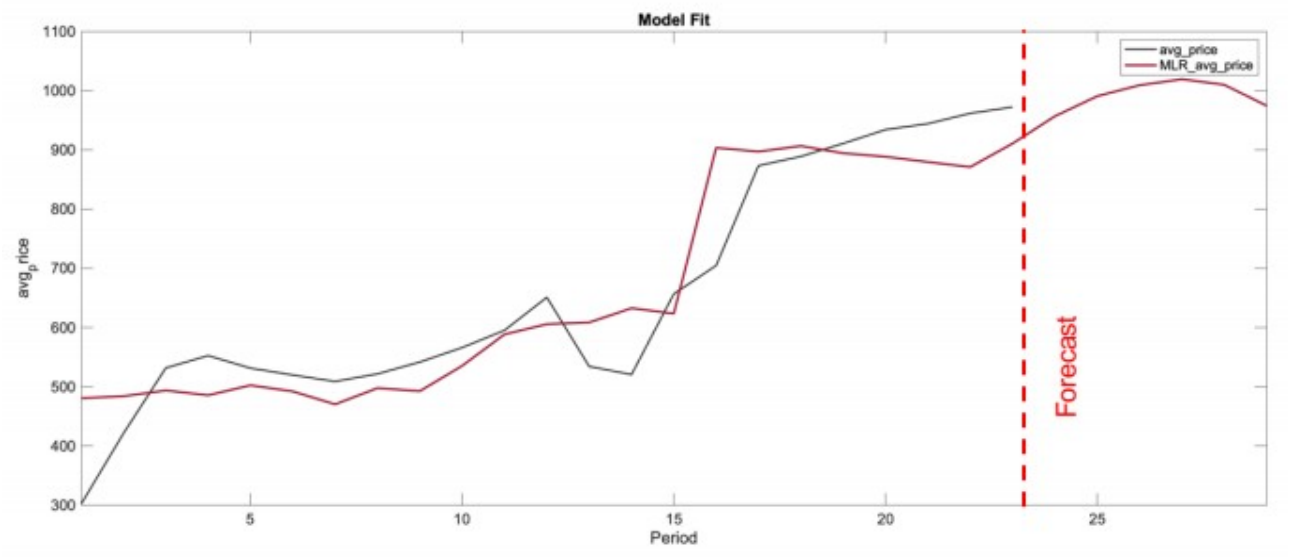


Fig. 4.6. The dependence model of household pricing №4

Trends and possible options for the future development of sub-segments of the secondary household market of Ukraine were also analyzed. Thus, in the context of dividing the market into central agglomerations and periphery in today's conditions, the main characteristics (Table 4.11) and a graphic representation of the constructed models (Figure 4.7) are given below.

Table 4.11

Main characteristics of household price formation models in different regions of Ukraine

Central aglomerations	**Periphery**
SSE: 9.5488e+04 R-square: 0.8459 Adjusted R-square: 0.8216 RMSE: 70.8920	SSE: 1.2548e+04 R-square: 0.9693 Adjusted R-square: 0.9625 RMSE: 26.4025

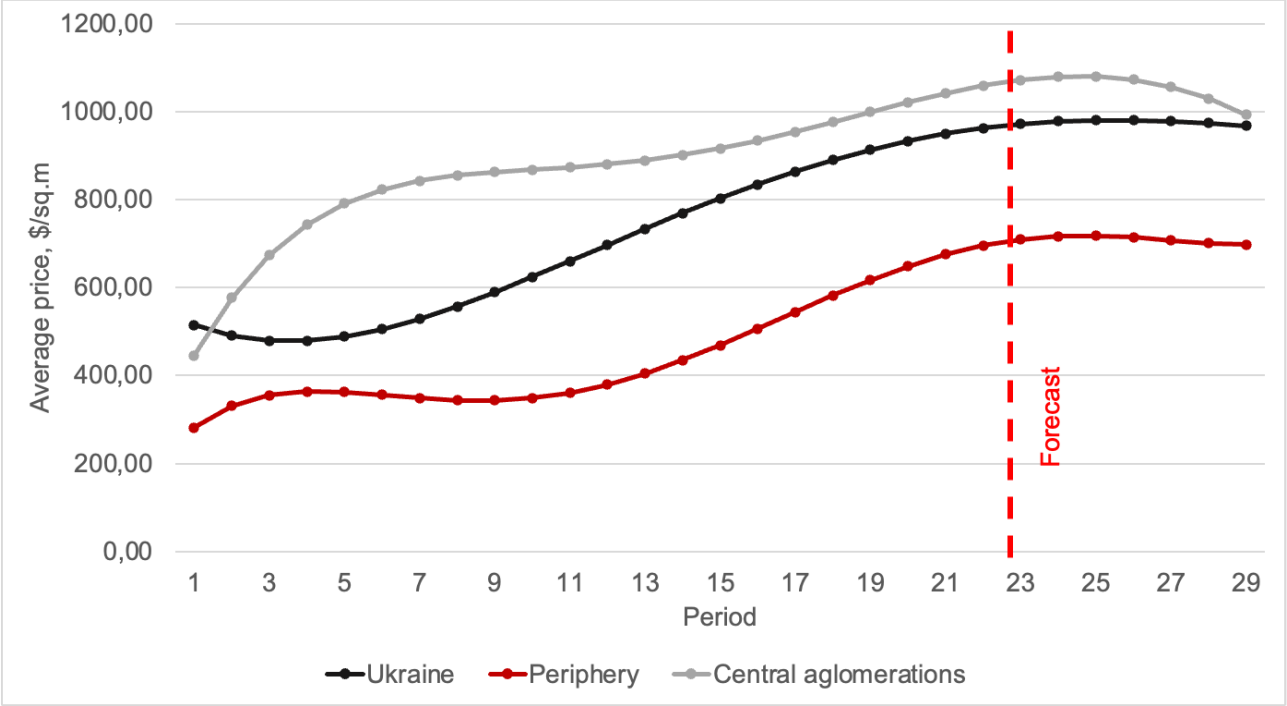


Fig. 4.7. Forecasting the price of home ownership in different regions of Ukraine for 6 months (until March 2023)

Thus, it is entirely possible that prices will remain relatively stable in the near future, as has been demonstrated in all models. The reason is that demand in the home ownership market has increased significantly in the fall of 2022, and now it is returning to normal values. At the moment, the most popular options are houses with a generator, a basement and a private well. This is due to the desire to protect against large-scale attacks on infrastructure and a possible blackout. It is interesting that the price of housing in the periphery has more positive trends than in the central regions. An important point here is that buyers will prefer those homes that are more distant from the places of hostilities.

5. VERIFICATION OF FORECAST VALUES IN PREVIOUS PERIODS WITH THE REALITY

In order to analyze the effectiveness of modeling and forecasting the real estate market using regression models, the study was conducted starting from the 3rd quarter of 2022, so we can currently compare the results obtained during modeling (Fig. 5.1) and real values.

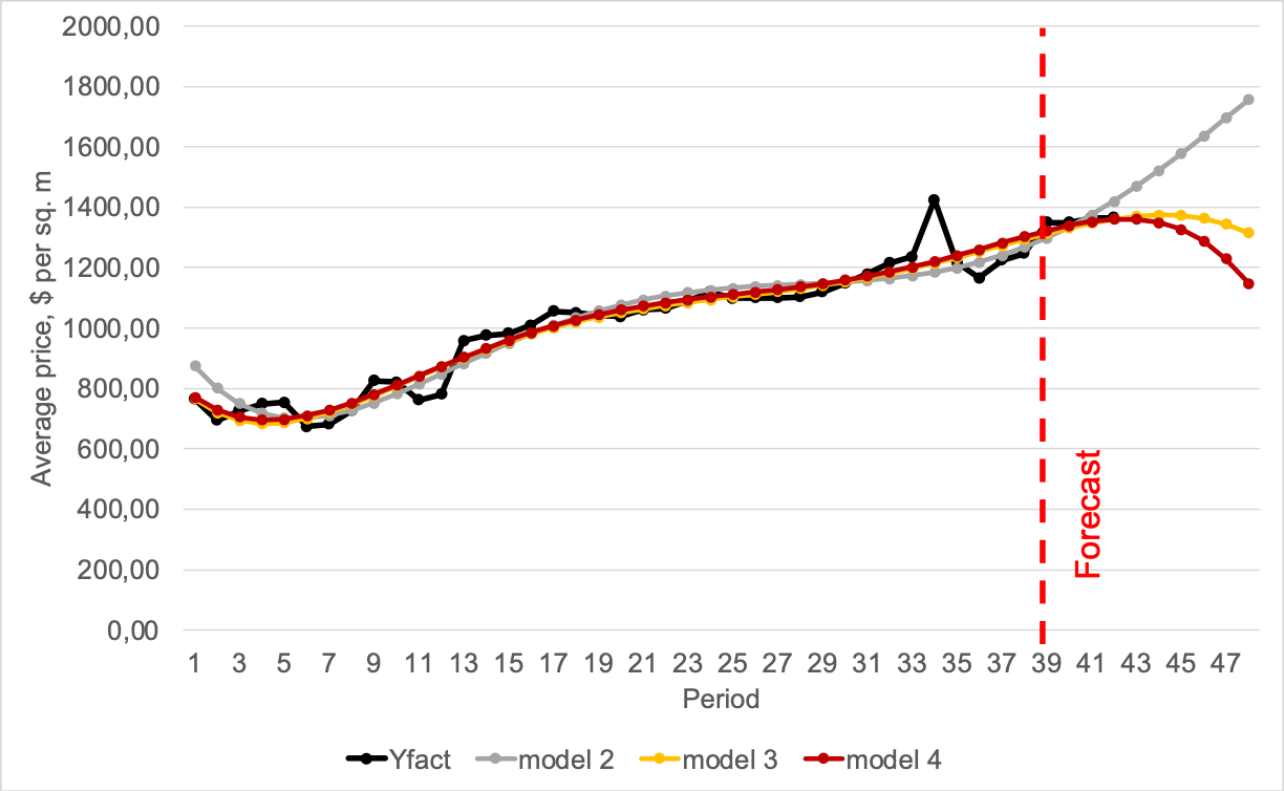


Fig. 5.1. Initial model of forecasting apartment prices (until April 2023)

If we compare the indicators with the above market dynamics, we can see that models №3 and №4, which demonstrated relative price stabilization, are quite accurate for the first forecast periods. At the same time, model №3 indicates correct trends almost throughout the entire forecast period. Only in the last 2 months, the market prices did not correspond to the modeling results, which is acceptable and indicates the direction of further development of the methodology. It should be noted that the analysis of the received forecasts indicated that model №2 is very optimistic and is the least likely to be implemented.

Figure 5.2 shows the model and forecast of the price of home ownership until April 2023. Similarly, let's compare the obtained values with the real price on the market.

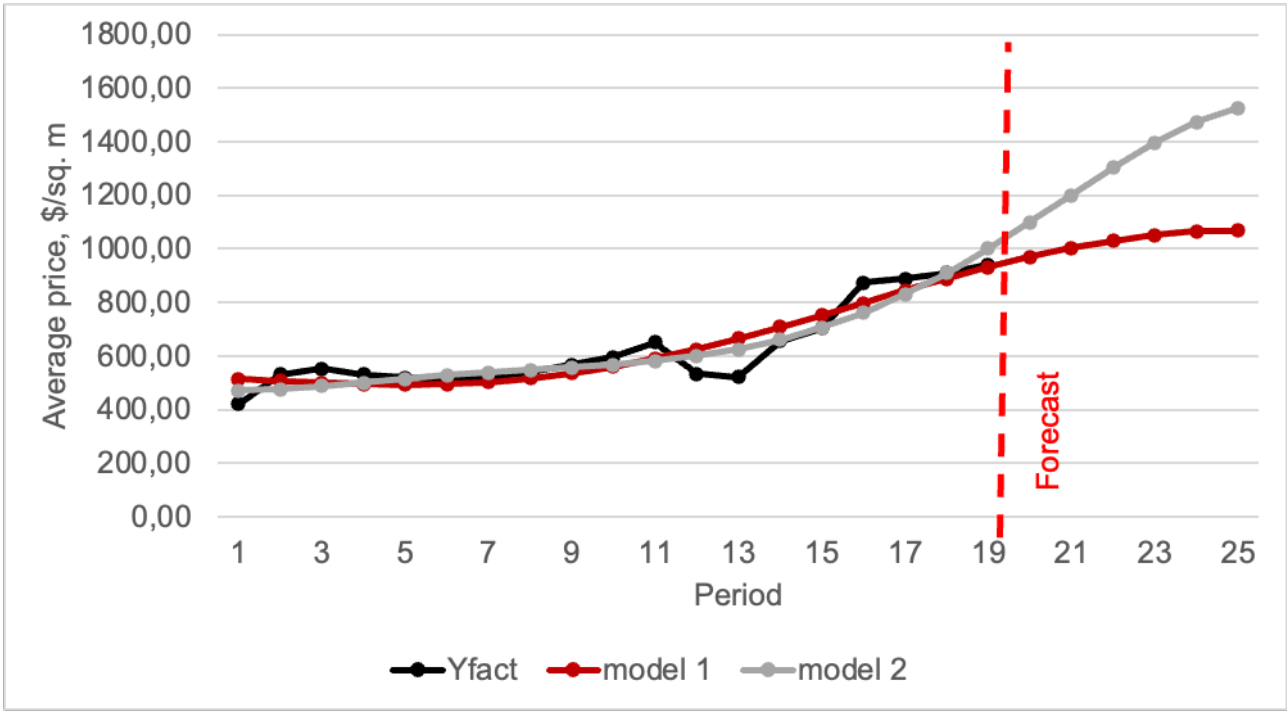


Fig. 5.2. Initial model of forecasting household prices (until April 2023)

Obviously, the forecast was less accurate than in the apartment segment, which is explained by the much smaller amount of accumulated data on home ownership. Nevertheless, we note that model №1 reflected the real trends that were inherent in the housing market in the post-forecast periods. According to real market indicators, we observe a gradual increase in prices, which is reflected in the models. As for model №2, it characterizes a more rapid increase in prices, which is inherent in certain sub-segments of the housing market, which was discussed above.

Thus, the methodology showed a good result in practice, which will be improved through the accumulation of data and the use of updated tools in subsequent periods. Taking into account the fact that approximation by polynomials of a high degree does not allow building a model that is 100% true, in order to increase the accuracy of the received forecasts in the future, other types of dependencies based on a wider list of macroeconomic factors will be used. Also, by accumulating data, we will be able to observe real dynamics and draw conclusions based on this.

CONCLUSIONS

Thus, a correlation-regression analysis of apartment prices was conducted and revealed:

1. Structural shifts in the offer of residential real estate on the secondary market of apartments are caused by the deterioration of the market situation due to the war and the pandemic. The nature of changes in the supply structure during the economic downturn confirms the investment motives for purchasing new housing in previous years.

2. On the basis of connection graphs and structural regression equations, groups of macroeconomic level factors that simultaneously affect the demand and supply of residential real estate are outlined:

a. The active development of the economy, on the one hand, helps to increase the level of employment and incomes of the population, and thus expands the solvent demand for housing, on the other hand, by increasing the volume of housing construction, it expands the supply of housing.

b. The increase in production and consumer prices causes an increase in the cost of new housing construction, while inflationary expectations force the population to look for alternative means of saving their own savings and income and, in the conditions of an underdeveloped securities market and mistrust of financial and banking institutions, to invest in residential real estate.

3. Price dynamics in the residential real estate market is a complex structure of cycles of different lengths. Monthly average price trends were approximated using multivariate models and short- and medium-term trends were forecast.

4. A study of the general dynamics of real estate prices for June 2019 - March 2023 was conducted, which shows an average growing trend. As an anomalous phenomenon from the point of view of the general dynamics that have developed in the real estate market over the past 12 years, the behavior of prices during periods of crises caused by extraordinary events and conditions (pandemic and war) observed in 2020 and in the current year 2023 is of particular interest.

5. Analysis of the possibility of interpolation of the studied time series by a trend line represented by a polynomial of a fairly high degree showed that it still cannot fully approximate changes in the indicator. A good interpolation of the time series using a high-order polynomial, which does not reflect the internal mechanisms of price movement, does not guarantee a high accuracy of the forecast of further price behavior.

6. From the point of view of making investment decisions, the most important task is to identify harbingers that indicate that a change in trends

should occur in the near future. Usually, such predictors are considered to be factors that to one degree or another influence the processes of pricing in the real estate market.

7. The relationship between the real estate price and each individual factor was investigated. After the calculations, we can say that in most cases the relationship between the indicators is direct and with an increase in the indicators, housing prices increase. The figures graphically reflect the concentration of sample values of real estate prices around the regression equation estimated by us. Their deviation from the regression line is the result of the action of the random component (the action of all other factors not included in the model).

8. Multifactor models of apartment price dependence on macroeconomic indicators were built and three possible scenarios were identified:

i. the average price per square meter on the apartment market will steadily increase;

ii. at first, the market will be relatively stabilized, followed by a slight drop in prices;

iii. the third scenario also predicts a fall, but more significant.

9. Using a similar methodology, a study of the land market was conducted, which showed that the land market for industrial development will be most affected by hostilities, which is connected with the active conduct of hostilities. Agricultural land and areas for residential and public development will continue the growth that began in the pre-war period, however, it is clear that this pattern applies to areas that are distant from the places of hostilities.

10. In the context of the housing market was noted the situation that the price of housing in the periphery has more positive trends than in the central regions, and identified 3 possible options for price changes in the housing market:

i. Model №1 predicts relative stability and a very small price increase in the near future;

ii. Model №2 corresponds to the scenario when the market will initially grow, followed by a fall in price in subsequent periods;

iii. Model №3 predicts a certain decline in the near term, but with the prospect of rising prices.

11. The methodology showed a good result in practice, which will be improved through the accumulation of data and the use of updated tools in subsequent periods.

12. Thus, we came to the conclusion that the use of multifactor models is absolutely justified for identifying trends and forecasting prices in the real estate market in the short- and medium-term perspective.