Comparative analysis of different approaches to the Ukrainian residential property market evolution modelling and its forecast for the years 2019–2024

Valery Yakubovsky
Institute of International Relations, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine and School of Business, University of Leicester, Leicester, UK, and
Kateryna Zhuk
Faculty of Economics, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

Abstract
Purpose – This study aims to provide a comprehensive analysis of various approaches to the residential property market evolution modelling and to examine the macroeconomic fundamentals that have shaped this market development in Ukraine in recent years.

Design/methodology/approach – The study uses a comprehensive data set encompassing relevant macroeconomic indicators and historical apartment prices. Multifactor linear regression (MLR) and ridge regression (RR) models are constructed to identify the impact of multiple predictors on apartment prices. Additionally, the ARIMAX model integrates time series analysis and external factors to enhance modelling and forecasting accuracy.

Findings – The investigation reveals that MLR and RR yield accurate predictions by considering a range of influential variables. The hybrid ARIMAX model further enhances predictive performance by fusing external indicators with time series analysis. These findings underscore the effectiveness of a multidimensional approach in capturing the complexity of housing price dynamics.

Originality/value – This research contributes to the real estate modelling and forecasting literature by providing an analysis of multiple linear regression, RR and ARIMAX models within the specific context of property price prediction in the turbulent Ukrainian real estate market. This comprehensive analysis not only offers insights into the performance of these methodologies but also explores their adaptability and robustness in a market characterized by evolving dynamics, including the significant influence of external geopolitical factors.

Keywords Multiple linear regression, Ridge regression, ARIMAX, Housing prices, Macroeconomic indicators, Forecasting, Real estate market, Ukraine

Paper type Research paper

The final stage of this paper preparation has been fulfilled with the kind support of the Leicester University School of Business, UK, under the British Academy-funded project “Researchers at Risk”. Appearance of presented summarized results on the comparison of different approaches to Ukrainian residential property market evolution modelling and the forecast could not have been possible without such valuable support.
1. Introduction
The Ukrainian real estate market is currently grappling with a crisis brought about by a confluence of adverse factors including full-scale Russian aggression, energy resource imports dependence and the repercussions of the coronavirus pandemic. The interplay of these crisis phenomena further amplifies the complexity of forecasting market parameters, necessitating a thorough examination of various factors and their interdependencies. The effectiveness of decision-making for the efficient restoration of the national economy relies on considering this forecasting problem and analysing its impact on the future.

A prior analysis of the Ukrainian property market conducted during the COVID-19 pandemic and war revealed a remarkable display of resilience and growth, even in the face of considerable challenges (Yakubovsky et al., 2023). Nevertheless, it is important to emphasize that the Ukrainian property market continues to be impacted by the ongoing conflict. Looking forward, the market’s dynamics are poised for potential shifts contingent upon the unfolding developments in Ukraine and the broader international context.

This period is marked by heightened uncertainty, posing a challenge in accurately predicting the behaviour of specific market indicators. The fluid nature of the situation underscores the need for ongoing vigilance and adaptive strategies to navigate the complexities of the Ukrainian property market.

Forecasting the Ukrainian property market holds significant importance for various reasons. It plays a crucial role in navigating the impact of the conflict and reconstruction efforts on different property segments. This understanding empowers individuals and businesses to adjust their strategies accordingly. The reconstruction and revitalization of areas affected by the conflict necessitate a comprehensive grasp of evolving market dynamics, infrastructure development, housing needs and investment opportunities.

Accurate assessment of property damage and reconstruction costs is essential for efficient resource allocation and prioritization during the rebuilding process. Additionally, anticipating future housing demand and supply trends is vital to ensure that people have access to safe and affordable housing both during and after the war. Forecasts serve as valuable tools to inform policies and initiatives aimed at addressing housing shortages and supporting displaced individuals.

Consequently, drawing accurate conclusions necessitates a comprehensive analysis of various factors that influence the value of the forecasted indicators. The foundation of market forecasting typically relies on analysing the historical evolution of market processes, identifying and studying the relationships between phenomena and fundamental indicators, describing their quantitative and qualitative characteristics and discerning stable patterns.

The findings of this comprehensive analysis can serve as a foundation for forecasting the future development of the real estate market, contributing to informed decision-making and facilitating the efficient restoration of Ukraine’s national economy.

The organization of this paper is as follows: In Section 2, we describe the evolution of the Ukrainian real estate market. Section 3 provides a review of earlier studies. Section 4 highlights the methodology used for calculations and analysis. In Section 5, we explore the relationship between real estate prices and macroeconomic factors. Sections 6 and 7 describe the process of price modelling, forecasting, analysing of models’ performance data and present the findings of this study. Finally, in Section 8, we conclude the paper.

2. Overview of Ukrainian real estate market
This article represents a coherent continuation of the research conducted in a previous paper titled “Deterministic and Probabilistic Analysis of Ukrainian Residential Property Market Evolution in Turbulent 2019–2022 Years”. The earlier study established that, despite the
substantial influences of the pandemic and wartime conflict, the Ukrainian residential property market consistently demonstrated a positive trajectory from June 2019 to December 2022 (Yakubovsky et al., 2023).

Certainly, to avoid redundancy and build upon the prior content, it is crucial to acknowledge that the previous article thoroughly examined the methodological underpinnings of the study conducted on the Ukrainian real estate market. It delved into the creation of the VERITEX® Group database, emphasizing the authors’ key contributions to its design and implementation. Moreover, the earlier study delved into the unique characteristics of the Ukrainian property market and identified the main drivers of its evolution.

In this article, we will build upon these foundational elements and focus on the novel findings and insights derived from this extensive data set, offering fresh perspectives and analyses.

2.1 Analysis of the real estate market prices evolution in Ukraine (June 2019–June 2023)
As a starting point for the process of market price forecasting, it is necessary to analyse the available data and the evolution of prices in recent years. In this endeavour, we leverage the outcomes of the previous study cited above.

The initial notable observation from the analysis of price evolution on the secondary real estate market in Ukraine over the past 48 months is the consistent growth of Ukraine’s real estate market between crisis periods. Throughout 2023, the market showed gradual recovery both in Ukraine and its various regions, marked by a lack of substantial changes. It should be noted that prices in real estate markets in each region are formed under the influence of general trends throughout the country. Moreover, price changes in one of the market segments inevitably cause corresponding price changes in others.

Thus, the study of the general evolution of real estate prices for June 2019–June 2023 shows, on average, a growing trend, which is stimulated by an increasing demand for residential square meters.

3. Literature review
The existing literature on the residential property market has explored various aspects of its evolution and the factors influencing it. Several studies have used historical analysis to understand market trends, using data sources such as property prices, transaction volumes and market indicators (Radonjić et al., 2019).

Studies often rely on historical data and statistical techniques like regression analysis and time-series modelling, focusing on economic factors and their impact on prices. For example, Gabrielli et al. (2023) investigated the impact of extraordinary events on preferences in Italy, but their findings might not translate directly to the unique situation in Ukraine. Similarly, Rehman et al. (2020) explored the relationship between oil prices and property prices across diverse countries, but their focus on economic factors overlooks the potential influence of political instability or social unrest.

Several studies have explored the impact of macroeconomic factors on real estate prices in various regions:

- Stanković (2022) in Bosnia and Herzegovina: the study analysed 12 key macroeconomic factors and their impact on real estate prices. Factors such as household final consumption expenditure, GDP per capita and nominal GDP were found to have a significant influence on real estate prices.
- Alkali et al. (2019) in Nigeria: used ARIMA and ARIMAX models to analyze the impact of macroeconomic variables on forecasting models.
IJHMA

- Radonjić et al. (2019) in Montenegro: used model averaging to study the relationship between factors like GDP, unemployment and interest rates with prices to address the challenge of a short time series and many independent variables.

Osadcha and Melnychenko (2022) examined the dynamics of the Polish real estate market, analysing macroeconomic factors like economic growth, interest rates and the impact of the COVID-19 pandemic. Their study underscored the strong desire for homeownership among the Polish population and emphasized the role of interest rates and credit availability in driving housing purchases.

Illychovski et al. (2022) conducted a significant study focused on investigating the relationship between specific predictors and building a suitable model for forecasting housing prices in Bulgaria. The models were assessed for predicting the price per square meter of residential property, incorporating estimated values from the ARIMA model for the parameters involved in the regression equation.

These studies provide valuable insights for understanding the relationship between macroeconomic factors and real estate prices, but their applicability to the unique context of Ukraine needs further investigation.

Chevhanova et al. (2018) provided valuable insights into the evolution of the Ukrainian housing market, emphasizing the importance of considering diverse factors like primary sectors, consumer preferences and economic indicators. Findings stressed the need for extensive construction in Ukraine to replace outdated housing and identified real income growth, mortgage lending mechanisms and transparent state regulations as crucial determinants of sustainable housing demand.

Miroshnychenko and Krasheninnikova (2022) focused on the use of machine learning methods to build models (multifactor linear regression [MLR], regularization, random forest and XGBoost) for predicting suburban real estate prices. Khlevna and Bura (2022) identified the prospects for the forecasting methods development on the real estate market, demonstrated and applied in practice models for building information software for price forecasting by machine learning.

While existing research laid the groundwork for understanding the Ukrainian housing market, they primarily focused on the pre-war context. The ongoing war has fundamentally altered the market dynamics, necessitating updated research that considers its impact on economic, social and political landscapes. Previous findings on critical factors like consumer preferences, primary housing sectors and economic indicators still hold value, but their role and interplay within the current context require nuanced investigation. This is crucial for accurately modelling and forecasting the market’s future and informing sustainable housing solutions in a war-torn Ukraine.

Further research is needed to comprehensively analyse the trends, dynamics and key factors that shape this market’s evolution. Given the unique challenges faced by Ukraine, including the COVID-19 pandemic and the war, it would be valuable to explore how these exceptional circumstances affect buyer preferences, market values, and the overall performance of the market in Ukraine. A comprehensive analysis of the macroeconomic determinants and their effects on the market evolution will contribute to a deeper understanding of the market dynamics, provide insights for accurate forecasting and facilitate informed decision-making in the Ukrainian real estate sector.

Existing research tends to focus on the primary segment of the real estate market, creating a gap in understanding the evolving role and distinct impact of the secondary market, especially in light of the pricing paradigm shift caused by the Russian invasion. The current trend towards the secondary real estate market in Ukraine indicates changes in
buyer behaviour. Instead of considering properties purely as investments, individuals are now prioritizing immediate living solutions. Construction delays and a reluctance to wait for improved market conditions are key factors driving this shift, underscoring the significance of comprehending the dynamics of the secondary market in the region.

Therefore, it seems appropriate to fill in these knowledge gaps by analyzing the impact of macroeconomic indicators on market trends, using a data-driven approach that incorporates diverse data sources beyond traditional economic indicators, developing a comprehensive model that captures the unique dynamics of the market in the context of the war to provide a holistic understanding of the Ukrainian property market and its future prospects.

4. Methods and methodology

Our analysis spans a 48-month period, delving into the intricate relationship between the Ukrainian housing market and a comprehensive set of 38 macroeconomic variables, detailed in Appendix. From real apartment prices to land plot values and individual house costs, we examine how diverse housing segments respond to economic fluctuations. Market data originates from the trusted VERITEX® Group database, while macroeconomic data is sourced from reputable institutions like the National Bank of Ukraine and the State Statistics Office. The data extraction methodology used meticulously follows the approaches outlined in Yakubovsky et al. (2023), ensuring the accuracy and transparency of our findings.

The choice of methodology for this research was based on the understanding that the use of statistical models and methods for forecasting purposes is the most common way of analysing the accumulated arrays of quantitative information about the dynamics of certain indicators to model the process of their further change and development. Presently, market data analysis involves constructing regression equations and parameter estimation, extending beyond basic linear analysis and statistical fundamentals.

We acknowledge that economic processes are subject to uncontrollable influences and exhibit non-stationary characteristics, including trends and periodic components. To render non-stationary series stationary, necessary transformations are applied before estimating model coefficients. We stress the importance of selecting relevant variables and omitting insignificant ones to enhance forecast accuracy. In essence, our methodology combines trend and autoregression models to scrutinize and predict the Ukrainian property market.

It should be noted that the idea of using mathematical models to describe the behaviour of economic systems is generally accepted. In the real estate market, consumers represent buyers, while suppliers are real estate developers. The equilibrium price signifies the balance between the quantity of a specific type of real estate offered by developers. Real estate, unlike regular commodities, is primarily valued for its utility, driven by induced demand.

Real estate behaves according to economic supply and price principles. 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. On the other hand, economic processes are largely influenced by uncontrollable factors.

Distinct characteristics of real estate, such as substantial investment, lengthy construction periods and extended visibility of interest rate recoveries, set it apart from typical commodities. While an increase in real estate supply tends to push up housing prices, the extended supply process introduces an informational influence into the market. Factors like real estate investment, development volume and infrastructure construction progressively enter the market as information, subsequently shaping market players’ assessments and analyses, thereby affecting real estate price dynamics. Causal relationships
do not lend themselves to rigorous analysis, and many phenomena are revealed only when they have already manifested.

Therefore, econometric models, such as ARIMA or MLR models, are widely used for time-series analysis and forecasting in economics.

4.1 Analysis of prices evolution using high-order polynomials

In an endeavour to explore alternative modelling approaches, this study delved into the feasibility of using high-order polynomials for predictive modelling. As an illustrative case, apartment prices were used to investigate the potential benefits. By introducing high-order polynomial terms into the modelling process, we planned to assess whether the flexibility of these functions could better capture intricate non-linear relationships inherent in price dynamics. The inclusion of polynomial terms enables the model to detect curvilinear trends.

Thus, referring to the general trajectory of prices (Figure 1) throughout the analysed 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 analysed time series exhibits diverse trends. Figure 1 displays approximation plots illustrating how various polynomial degrees attempt to match actual apartment prices across the specified time frame. Notably, even higher-degree polynomials struggle to fully represent indicator fluctuations.

Interpolating the time series effectively using high-order polynomials, while not capturing intrinsic price movement mechanisms, does not assure precise forecasts of future price behaviour. A common misconception is that a high coefficient of determination in an interpolation function guarantees accurate predictions of series dynamics. Even with accurate interpolation, yielding near-unity determination coefficients, extending the interpolating function for forecasts is not always successful. Higher polynomial degrees lead to forecast instability and larger errors compared to simpler models.

Notes: In the presented graph, the horizontal axis (x-axis) represents the time period, while the vertical axis (y-axis) displays apartment prices in dollars per square meter. The “Data 1” corresponds to the actual apartment prices in Ukraine. Additionally, the graph includes plots corresponding to different approximations: linear, cubic, 4th degree and 6th degree.

Source: Authors’ own creation
4.2 Complex components of real estate pricing
In research, a key aspect involves identifying and analysing relationships among various phenomena and indicators, encompassing both quantitative and qualitative aspects. Correlation and regression analysis are fundamental theoretical frameworks for this purpose. In data processing, two primary tasks arise: examining interdependencies among multiple random series and understanding how time series, like market prices, rely on fundamental variables that shape its timeline. Correlation analysis is used for the former, while the latter involves multiple regression techniques.

Interdependence among stationary processes is typically measured by a correlation coefficient akin to random variables. However, it is important to note that exploring relationships between two time series is a complex endeavour that extends beyond correlation coefficients. Relying solely on correlations might not yield sufficiently reliable insights about these relationships.

Real estate prices can be understood as a combination of two main components: fundamental and random values (Figure 2). The fundamental value reflects the underlying long-term trends driven by economic, social and demographic factors. This component includes cyclical trends and seasonal variations. Accidental values, on the other hand, represent temporary and random fluctuations that deviate from the fundamental trend. These can be caused by various short-term factors and are not essential for understanding the overall price dynamics.

Furthermore, the impact of internal and external factors on the real estate market varies across its different tiers. At the national level, legislative and macroeconomic influences are prominent. Regionally, real estate pricing is shaped by a combination of macro- and micro-factors, including investment flows and demographic trends.

4.3 Forecasting real estate prices: comparative analysis of methodologies and models
In pursuit of revealing the intricate dynamics governing apartment prices, our study focused on constructing predictive models and forecasting methodologies. Our goal was to discern the relationship between these macroeconomic indicators and apartment prices. Our model underwent iterative refinement, aligning with theoretical underpinnings and showcasing empirical significance.

In our quest for robust predictions, we used pre-processing techniques to mitigate multicollinearity and overfitting effects. Standardization and rigorous correlation matrix assessments ensured the reliability of chosen variables and regression coefficient stability.

Source: Authors’ own creation
It should be noted that we systematically investigated multicollinearity using variance inflation factor (VIF) calculations. For variables exceeding a VIF threshold of 5, we implemented corrective measures such as dropping collinear variables. This approach ensured the stability and interpretability of our model and minimized the risk of misleading conclusions due to multicollinearity.

Progressively adopting intricate model configurations, our goal is to extract meaningful patterns and amplify the predictive prowess of our methodologies. Our study uses a multi-pronged approach using MLR, ARIMAX and ridge regression (RR) to capture the diverse aspects of price dynamics within the available data set. Each model caters to specific strengths and addresses potential limitations within the data, providing a comprehensive and robust prediction framework.

4.3.1 Multiple linear regression. We investigated the use of MLR models with varying exogenous macroeconomic factors to predict prices. MLR is a foundational statistical technique used to model the linear relationship between a dependent variable and one or more independent variables (exogenous macroeconomic factors) (Miroshnychenko and Krasheninnikova, 2022). MLR sheds light on the relative importance of each predictor variable and facilitates the exploration of intricate interactions among them. The MLR model can be represented as:

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon \]

where:
- \( Y \) = dependent variable (apartment prices);
- \( X_1, X_2, \ldots, X_n \) = exogenous macroeconomic factors;
- \( \beta_0, \beta_1, \beta_2, \ldots, \beta_n \) = coefficients associated with each predictor; and
- \( \varepsilon \) = error term.

MLR works well if the relationships between variables are linear, and it is easy to understand how each variable affects the dependent variable.

4.3.2 ARIMAX. The ARIMAX model, which combines the strengths of ARIMA with exogenous variables, offers a robust framework for modelling and forecasting time series data, accounting for both temporal patterns and external influences. While ARIMA models capture intrinsic temporal dependencies, they may overlook the impact of external factors on the target variable (Iliychovski et al., 2022). The integration of exogenous macroeconomic factors into the model addresses this limitation.

The ARIMAX model augments the traditional ARIMA structure with exogenous variables. It is defined as:

\[
Y(t) = \text{ARIMA}(p, d, q)(Y(t - 1), Y(t - 2), \ldots, Y(t - p)) + \beta_1 X_1(t) + \beta_2 X_2(t) + \ldots + \beta_n X_n(t) + e(t)
\]

where:
- \( Y(t) \) = represents apartment prices at a time “t”;
- \( \text{ARIMA}(p, d, q) \) = autoregressive, integrated, moving average components;
- \( X_1(t), X_2(t), \ldots, X_n(t) \) = represent the exogenous macroeconomic factors;
- \( \beta_1, \beta_2, \ldots, \beta_n \) = are the coefficients for the exogenous factors; and
- \( e(t) \) = is the model’s residual error at time “t”.

IJHMA
ARIMAX captures seasonality and trends in time series data, is robust to outliers, accounts for exogenous variables and is accurate for predicting near-future values. Differencing helps remove trends or seasonality, making the series more amenable to modelling. Such a technique in ARIMAX involves taking the difference between consecutive observations of the dependent variable and potentially exogenous variables. The differencing order (denoted as \( d \)) indicates how many times this differencing process is performed. If the original series is not stationary, a first-order difference (\( d = 1 \)) may be applied. Further differencing (\( d > 1 \)) can be considered if needed.

### 4.3.3 Ridge regression

The choice of RR is motivated by its ability to handle multicollinearity and overfitting, while the incorporation of external factors aims to enhance the predictive power of the model by capturing the influence of broader economic indicators on apartment prices. The efficacy of RR is demonstrated, highlighting its potential as a valuable tool for gaining insights into the complex dynamics of the Ukrainian real estate market (Khlevna and Bura, 2022).

The RR model with exogenous factors is formulated as follows:

\[
Y = X\beta + \varepsilon
\]

where:
- \( Y \) = vector of apartment prices;
- \( X \) = design matrix containing exogenous macroeconomic factors;
- \( \beta \) = vector of regression coefficients; and
- \( \varepsilon \) = vector of errors.

RR introduces a regularization term that penalizes the magnitudes of coefficients:

\[
\min \|Y - X\beta\|^2 + \lambda \|\beta\|^2,
\]

where:
- \( \lambda \) = hyperparameter controlling the strength of regularization.

However, there are the key limitations of RR to consider:

- Assumes linear relationships between variables, potentially missing complex interactions;
- Might slightly bias coefficients due to regularization; and
- Limited interpretability compared to simpler linear models.

### 5. Dependence of the value of the real estate price on macroeconomic factors

Among the price-forming factors in the real estate market, macroeconomic factors play an important role. 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 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 income, and in the conditions of an
underdeveloped securities market and distrust of financial institutions, it stimulates them to invest in real estate on a less risky secondary market housing.

To investigate the behaviour of the real estate market, we used the relationship between macroeconomic indicators and property prices. An extensive analysis of 38 macroeconomic indicators was conducted, with a comprehensive list provided in Appendix. A correlation analysis was performed to examine the relationships between these indicators and prices, some of which were represented in graphical form (Figures 3–5). Based on connection graphs and structural regression equations, groups of macroeconomic level factors that simultaneously affect the market were outlined.

**Figure 3.**
Relationships between average salary and apartment prices

**Source:** Authors’ own creation

**Figure 4.**
Relationships between global oil prices (Brent) and apartment prices

**Source:** Authors’ own creation

**Figure 5.**
Relationships between inflation and apartment prices

**Source:** Authors’ own creation
The descriptive statistics are also included in Appendix, providing additional insights into the characteristics of the examined data. Each of these factors played a crucial role in shaping the dynamics of the real estate market.

This selection allowed us to consider key aspects that play a role in shaping price dynamics. These factors were identified using the VIF method, which helped identify strong relationships between variables and mitigate multicollinearity, ensuring accurate and interpretable results. A correlation matrix (Table 1) was constructed based on these indicators.

The rise in GDP generally amplifies people’s buying power, potentially leading to heightened demand for real estate. During inflationary phases, construction costs and labour expenses often climb, triggering higher apartment prices. Exchange rates determine the relative value of a country’s currency compared to others. A weaker domestic currency can attract foreign investors, rendering real estate more accessible to them. It may also shift local investors’ focus towards domestic real estate from international investments. Nevertheless, currency volatility can introduce uncertainty.

Mortgage rates, representing interest rates on property purchase loans, directly impact housing affordability. Lower mortgage rates enhance the feasibility of obtaining loans and buying apartments. Reduced mortgage rates can expand the pool of potential homebuyers, thereby elevating demand and potentially driving up prices. Conversely, higher mortgage rates can deter buyers, reducing demand and potentially stabilizing or lowering prices.

These macroeconomic factors interact with one another and the broader economic context to shape apartment, housing and land prices.

6. Implications of analytical models for forecasting real estate prices
Considering the preliminary results obtained earlier, we transitioned to a more active phase of modelling.

<table>
<thead>
<tr>
<th>Factor</th>
<th>A. pr.</th>
<th>V1</th>
<th>V4</th>
<th>V18</th>
<th>V23</th>
<th>V26</th>
<th>V27</th>
<th>V29</th>
<th>V30</th>
<th>V31</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. pr.</td>
<td>1.00</td>
<td>0.41</td>
<td>0.48</td>
<td>-0.56</td>
<td>0.51</td>
<td>0.40</td>
<td>0.31</td>
<td>-0.43</td>
<td>-0.54</td>
<td>-0.23</td>
</tr>
<tr>
<td>V1</td>
<td>0.90</td>
<td>1.00</td>
<td>0.46</td>
<td>-0.79</td>
<td>0.64</td>
<td>0.58</td>
<td>0.24</td>
<td>-0.74</td>
<td>-0.44</td>
<td>-0.47</td>
</tr>
<tr>
<td>V4</td>
<td>0.86</td>
<td>0.69</td>
<td>1.00</td>
<td>-0.51</td>
<td>0.58</td>
<td>0.72</td>
<td>0.43</td>
<td>-0.59</td>
<td>-0.60</td>
<td>-0.63</td>
</tr>
<tr>
<td>V18</td>
<td>0.73</td>
<td>0.55</td>
<td>0.70</td>
<td>1.00</td>
<td>-0.58</td>
<td>-0.44</td>
<td>-0.08</td>
<td>0.71</td>
<td>0.55</td>
<td>0.23</td>
</tr>
<tr>
<td>V23</td>
<td>-0.71</td>
<td>-0.65</td>
<td>-0.56</td>
<td>-0.46</td>
<td>1.00</td>
<td>0.85</td>
<td>0.46</td>
<td>-0.65</td>
<td>-0.72</td>
<td>-0.71</td>
</tr>
<tr>
<td>V26</td>
<td>-0.85</td>
<td>-0.85</td>
<td>-0.67</td>
<td>-0.62</td>
<td>0.52</td>
<td>1.00</td>
<td>0.52</td>
<td>-0.62</td>
<td>-0.67</td>
<td>-0.85</td>
</tr>
<tr>
<td>V27</td>
<td>-0.79</td>
<td>-0.71</td>
<td>-0.72</td>
<td>-0.65</td>
<td>0.46</td>
<td>0.85</td>
<td>1.00</td>
<td>-0.46</td>
<td>-0.56</td>
<td>-0.65</td>
</tr>
<tr>
<td>V29</td>
<td>0.66</td>
<td>0.23</td>
<td>0.55</td>
<td>0.71</td>
<td>-0.08</td>
<td>-0.44</td>
<td>-0.58</td>
<td>1.00</td>
<td>0.70</td>
<td>0.55</td>
</tr>
<tr>
<td>V30</td>
<td>-0.78</td>
<td>-0.63</td>
<td>-0.60</td>
<td>-0.59</td>
<td>0.43</td>
<td>0.72</td>
<td>0.58</td>
<td>-0.51</td>
<td>1.00</td>
<td>0.69</td>
</tr>
<tr>
<td>V31</td>
<td>-0.58</td>
<td>-0.47</td>
<td>-0.44</td>
<td>-0.74</td>
<td>0.24</td>
<td>0.58</td>
<td>0.64</td>
<td>-0.79</td>
<td>0.46</td>
<td>1.00</td>
</tr>
<tr>
<td>V36</td>
<td>-0.47</td>
<td>-0.23</td>
<td>-0.54</td>
<td>-0.43</td>
<td>0.31</td>
<td>0.40</td>
<td>0.51</td>
<td>-0.56</td>
<td>0.48</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Notes: In the table, V1 corresponds to the average salary, V4 – the consumer loans granted to households, V18 – the inflation expectations (households), V23 – the interest rate on mortgage loans to households, V26 – the loans granted to households for the purchase (construction and reconstruction of real estate), V27 – the mortgage loans granted to households, V29 – the NBU (National Bank of Ukraine) key policy rate, V30 – the nominal effective exchange rate (NEER), V31 – the number of registered unemployed, V36 – the volume of loans to non-financial corporations
Source: Authors’ own creation

Table 1.
Correlation matrix between apartment price and exogenous variables
6.1 Apartment prices

The first step was to construct our initial model for predicting apartment prices. To achieve this, we used MLR and included eight exogenous predictors (Table 2), which were identified based on our prior research findings. The primary reason for using MLR was to establish a straightforward and effective baseline for comparison with more sophisticated techniques. The obtained coefficients and indicators will help assess each factor’s significance and impact on prices.

Beta \{x1\} implies that for each one-unit increase in Ukrainians’ average salary, there is a corresponding increase of $0.1083 in the apartment price. On the other hand, Beta \{x4\} indicates that a one-unit increase in the inflation expectations results in a substantial decrease of $109.75 in the apartment price, indicating a strong negative relationship. Notably, Beta \{x7\} exhibits the most robust positive impact, signifying a noteworthy price increase for the rise in the NBU key policy rate. So, MLR provides easily interpretable coefficients for each independent variable, facilitating a clear understanding of the impact of individual factors on the predicted outcomes.

The MLR model exhibits a high coefficient of determination, indicating that approximately 93.3% of the variability in the dependent variable can be explained by the selected predictors. This suggests that the model effectively captures the core trends in the data.

The projected trajectory of property prices for the upcoming 12 months indicates a nuanced pattern of growth followed by stability (Figure 6). This phenomenon can be attributed to a multitude of intertwined factors. In the immediate future, a slight increase in prices is expected. However, this growth is likely to be tempered as the market adjusts and stabilizes.

To enhance the model’s performance, a new MLR model with ten exogenous predictors was developed. The projected trend for the upcoming 12 months in the apartment market points towards an initial phase of stabilization, indicating that the prices will likely settle. But stabilization might be followed by a subsequent decrease in prices, indicating a phase of adjustment influenced by market dynamics, economic conditions and consumer behaviour.

In summary, the forecast suggests a trajectory of initial stability followed by a subsequent decrease in property prices. Using MLR as a baseline aligns effectively with the principle of simplicity in model building.

<table>
<thead>
<tr>
<th>Dep. variable:</th>
<th>Apartment_price</th>
<th>No. of observations:</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model:</td>
<td>MLR</td>
<td>( R^2 )-squared:</td>
<td>0.933</td>
</tr>
<tr>
<td>Error degrees of freedom:</td>
<td>39</td>
<td>Adjusted ( R^2 )-squared:</td>
<td>0.919</td>
</tr>
<tr>
<td>F-statistic vs constant model:</td>
<td>67.7</td>
<td>( p )-value</td>
<td>1.85E-20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>coef</th>
<th>std err</th>
<th>( t )-statistic</th>
<th>( P )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>(-1.24E+03)</td>
<td>199.0483</td>
<td>(-6.2285)</td>
</tr>
<tr>
<td>Beta{x1}</td>
<td>0.1083</td>
<td>0.0146</td>
<td>7.4067</td>
</tr>
<tr>
<td>Beta{x10}</td>
<td>(-0.4566)</td>
<td>0.3181</td>
<td>(-1.4354)</td>
</tr>
<tr>
<td>Beta{x2}</td>
<td>4.6186</td>
<td>1.2408</td>
<td>3.7223</td>
</tr>
<tr>
<td>Beta{x4}</td>
<td>(-109.753)</td>
<td>386.54</td>
<td>(-0.2839)</td>
</tr>
<tr>
<td>Beta{x5}</td>
<td>(-1.4731)</td>
<td>3.2074</td>
<td>(-0.4593)</td>
</tr>
<tr>
<td>Beta{x6}</td>
<td>4.8919</td>
<td>3.5643</td>
<td>1.3725</td>
</tr>
<tr>
<td>Beta{x7}</td>
<td>409.7749</td>
<td>301.3956</td>
<td>1.3596</td>
</tr>
<tr>
<td>Beta{x9}</td>
<td>0.0583</td>
<td>0.1846</td>
<td>0.316</td>
</tr>
</tbody>
</table>

Source: Authors’ own creation

Table 2. Characteristics of MLR (eight exogenous predictors) (apartments)
The second model for predicting apartment prices was constructed using the ARIMAX framework. This choice is guided by the consideration of our ample data set size, allowing for the application of such a technique. With a substantial volume of historical price data at our disposal, our objective is to adeptly capture trends, seasonality and the impact of external factors on the long-term movements of prices.

While ARIMAX offers powerful capabilities, it also has limitations. It requires careful model selection and parameter estimation to avoid overfitting and ensure accuracy. To ensure the stability and accuracy of the analysis, the model used a second-order differencing technique to address non-stationarity and a log transformation to mitigate potential scaling effects. This data pre-processing laid the foundation for the model's reliable forecast of apartment prices. The loglikelihood of the model is $-227.69$. AIC value is 481.38, reflecting model performance and complexity. BIC value is 504.275, aiding in model selection among alternatives.

The apartment market’s projection (Figure 7) for the next year suggests an intriguing pattern of price dynamics. In the short term, we anticipate a decline in prices, which could be attributed to market adjustments and economic factors.

**Figure 6.** Apartment price projection plot: MLR vs actual prices

---

The second model for predicting apartment prices was constructed using the ARIMAX framework. This choice is guided by the consideration of our ample data set size, allowing for the application of such a technique. With a substantial volume of historical price data at our disposal, our objective is to adeptly capture trends, seasonality and the impact of external factors on the long-term movements of prices.

While ARIMAX offers powerful capabilities, it also has limitations. It requires careful model selection and parameter estimation to avoid overfitting and ensure accuracy. To ensure the stability and accuracy of the analysis, the model used a second-order differencing technique to address non-stationarity and a log transformation to mitigate potential scaling effects. This data pre-processing laid the foundation for the model’s reliable forecast of apartment prices. The loglikelihood of the model is $-227.69$. AIC value is 481.38, reflecting model performance and complexity. BIC value is 504.275, aiding in model selection among alternatives.

The apartment market’s projection (Figure 7) for the next year suggests an intriguing pattern of price dynamics. In the short term, we anticipate a decline in prices, which could be attributed to market adjustments and economic factors.

**Figure 7.** Apartment price projection plot: ARIMAX model vs actual prices

---

The second model for predicting apartment prices was constructed using the ARIMAX framework. This choice is guided by the consideration of our ample data set size, allowing for the application of such a technique. With a substantial volume of historical price data at our disposal, our objective is to adeptly capture trends, seasonality and the impact of external factors on the long-term movements of prices.

While ARIMAX offers powerful capabilities, it also has limitations. It requires careful model selection and parameter estimation to avoid overfitting and ensure accuracy. To ensure the stability and accuracy of the analysis, the model used a second-order differencing technique to address non-stationarity and a log transformation to mitigate potential scaling effects. This data pre-processing laid the foundation for the model’s reliable forecast of apartment prices. The loglikelihood of the model is $-227.69$. AIC value is 481.38, reflecting model performance and complexity. BIC value is 504.275, aiding in model selection among alternatives.

The apartment market’s projection (Figure 7) for the next year suggests an intriguing pattern of price dynamics. In the short term, we anticipate a decline in prices, which could be attributed to market adjustments and economic factors.

**Figure 7.** Apartment price projection plot: ARIMAX model vs actual prices

---

The second model for predicting apartment prices was constructed using the ARIMAX framework. This choice is guided by the consideration of our ample data set size, allowing for the application of such a technique. With a substantial volume of historical price data at our disposal, our objective is to adeptly capture trends, seasonality and the impact of external factors on the long-term movements of prices.

While ARIMAX offers powerful capabilities, it also has limitations. It requires careful model selection and parameter estimation to avoid overfitting and ensure accuracy. To ensure the stability and accuracy of the analysis, the model used a second-order differencing technique to address non-stationarity and a log transformation to mitigate potential scaling effects. This data pre-processing laid the foundation for the model’s reliable forecast of apartment prices. The loglikelihood of the model is $-227.69$. AIC value is 481.38, reflecting model performance and complexity. BIC value is 504.275, aiding in model selection among alternatives.

The apartment market’s projection (Figure 7) for the next year suggests an intriguing pattern of price dynamics. In the short term, we anticipate a decline in prices, which could be attributed to market adjustments and economic factors.
However, this price decline is expected to be relatively short-lived, as the forecast indicates a subsequent period of growth. This growth phase could be driven by factors like improved economic conditions, increased buyer confidence or specific market stimuli. It is important to note that this projection aligns with historical market trends, where periods of adjustment are often followed by phases of recovery and growth.

Considering the broader context of the market, potential buyers and sellers should remain vigilant and informed about the evolving economic landscape. While the short-term forecast suggests a dip, the subsequent growth phase signals the market’s resilience and ability to adapt to changing circumstances.

The third model for predicting apartment prices is based on RR (Table 3).

The magnitude of changes in forecasted prices seems to be relatively stable, with minor fluctuations. This stability could be attributed to the regression’s regularization, which prevents large shifts in coefficients and predictions. The regularization in RR reduces the sensitivity of the model to individual data points or outliers. This leads to smoother and less volatile predictions, particularly when compared to models without regularization.

The projected trend (Figure 8) in housing prices for the upcoming 12 months indicates a relatively stable pattern with a slight downward movement. This anticipated stability can

<table>
<thead>
<tr>
<th>Dep. variable:</th>
<th>Apartment_price</th>
<th>Coef</th>
<th>Std err</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model:</td>
<td>RIDGE-regression</td>
<td>x1 0.09771101</td>
<td>3.65E-02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x2 5.70893019</td>
<td>2.65E +00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x3 4.67316801</td>
<td>2.24E +03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x4 2.87873764</td>
<td>1.22E +03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x5 -1.87595488</td>
<td>6.10E +00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x6 5.95092757</td>
<td>7.07E +00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x7 19.91685947</td>
<td>6.33E +02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x8 -20.26839001</td>
<td>1.97E +03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x9 -0.13541583</td>
<td>4.75E-01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x10 -0.49968341</td>
<td>1.22E +00</td>
</tr>
</tbody>
</table>

Source: Authors’ own creation

Table 3.
Characteristics of ridge regression (apartments)

Source: Authors’ own creation

Figure 8.
Apartment price projection plot: ridge regression vs actual prices
Source: Authors’ own creation
be attributed to a balance between market forces and economic factors influencing the real estate landscape.

During this period, it is expected that external factors will contribute to maintaining a relatively consistent pricing environment. The minor decline in prices could be due to temporary market adjustments or seasonal variations.

Taking the conclusions drawn from the analysis of the four different models into account, we can paint a more comprehensive picture of the future trends in Ukraine’s apartment market. Considering the collective results from these models and comparing them with the market conditions in different cities after modelling, we can draw valuable conclusions:

- Despite the current challenges, there is a consistent consensus across the models that a market recovery and a gradual increase in apartment prices. This aligns with the increased demand due to internally displaced people and the broader economic forces shaping the region.
- The models suggest that the apartment market could encounter increased volatility attributed to power disruptions, threats of attacks and shelling.
- Another scenario that emerges is one of relative stability and a positive trend, in accordance with the indications from the models. This aligns with a sustained demand for real estate and economic factors that have contributed to the market’s resilience.

The nation’s economic stabilization, coupled with changing dependencies and returning developers, introduces a mix of opportunities and challenges that can shape the future trajectory of apartment prices. It is important to approach these conclusions with an understanding of the complexity of the situation and the interplay of various forces at play.

### 6.2 Household prices

We extended our analysis to encompass the context of the household market. The first model is MLR with eight predictors (Table 4). The high $R^2$-squared value and low $p$-value of the $F$-statistic confirm the model’s significance and potential for predicting prices based on exogenous factors.

From the plot (Figure 9), it is evident that the prices have exhibited a fluctuating pattern. They started with a relatively moderate value of around 452, then showed a slight increase in subsequent months, reaching a peak of 757.94. However, following this peak, the prices experienced a substantial decline.

The next model, which considers nine exogenous predictors, was developed to gain a deeper understanding of the factors influencing household prices.

The projected data indicates a continuous decline in household prices, suggesting a prolonged decrease over the forecasted period. This decline can have various implications for both the real estate market and the overall economy. Given the military context in Ukraine, ongoing security issues, infrastructure disruptions and economic uncertainties

<table>
<thead>
<tr>
<th>Dep. variable:</th>
<th>Household_price</th>
<th>No. of observations:</th>
<th>26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model:</td>
<td>MLR</td>
<td>$R^2$-squared:</td>
<td>0.94</td>
</tr>
<tr>
<td>Error degrees of freedom:</td>
<td>17</td>
<td>Adjusted $R^2$-squared:</td>
<td>0.911</td>
</tr>
<tr>
<td>$F$-statistic vs constant model:</td>
<td>33.2</td>
<td>$p$-value</td>
<td>6.88E-09</td>
</tr>
</tbody>
</table>

**Source:** Authors’ own creation

---

**Table 4.** Characteristics of MLR (eight exogenous predictors) (households)
seem to be key drivers behind this trend. These factors are contributing to reduced demand and changes in investment strategies, resulting in a sustained depreciation of property values.

The provided forecast indicates a notable downward trend in household prices. This trend aligns with the observations from previous models, suggesting that the downward trajectory is anticipated to continue. The consistent decrease in household prices over this period raises concerns about the ongoing challenges faced by the real estate market, especially in terms of residential properties.

It is important to emphasize that the forecast suggests a more significant decline in prices compared to the predictions made by the earlier models.

The ARIMAX model with ten exogenous predictors (Table 5) provides a promising approach to forecasting household prices. The model’s good fit, substantial $R^2$-squared value and statistically significant predictors imply its potential utility for predicting household price trends.

The forecasted dynamics of household prices (Figure 10) over the next year indicate a consistent trend of decline. This downward trajectory again suggests that the market for households is likely to experience decreasing prices in the upcoming months.

In summary, the models exhibit varying levels of predictive performance. The models consistently show high $R^2$-squared values, indicating strong predictive power. In the context of the military economy in Ukraine, our analysis involved four different models to forecast housing prices. While each model presented slightly differing forecasts, a common thread emerged: a trend of stabilizing or slightly decreasing housing prices in the near future.

The military situation in Ukraine introduced distinct factors into the household market. The aftermath of the conflict led to fluctuations in demand and prices. In particular, the fall

<table>
<thead>
<tr>
<th>Dep. variable</th>
<th>Household_price</th>
<th>No. of observations: 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>ARIMA(2, 2, 2)</td>
<td>Loglikelihood $-83.992$</td>
</tr>
<tr>
<td>Sample</td>
<td>0</td>
<td>AIC $197.984$</td>
</tr>
<tr>
<td></td>
<td>$-26$</td>
<td>BIC $213.652$</td>
</tr>
<tr>
<td>Covariance type</td>
<td>opg</td>
<td>HQIC $201.384$</td>
</tr>
</tbody>
</table>

Source: Authors’ own creation
of 2022 saw a significant rise in demand for housing due to security concerns and the need for self-sufficiency in essential services.

The unique demands of the military economy have reshaped buyer preferences. Properties equipped with generators, basements and private wells have become sought-after due to their ability to withstand potential disruptions in infrastructure. Interestingly, peripheral regions have seen more positive trends than central areas, as buyers prioritize distance from conflict zones.

Bringing these aspects together, we can infer that housing prices are likely to remain relatively stable in the near term. The models’ consensus on this trajectory aligns with the impact of the military economy, where the initial surge in demand has eased and the market is gradually returning to a more balanced state.

6.3 Land plots prices
The subsequent phase of our research focused on the land market, where we used an ARIMAX model to gain insights into the price dynamics.

Analysing the 12-month forecast for the land market (Figure 11), it can be observed that prices are expected to undergo a period of decline. On the other hand, it is worth noting that this downward trend is likely to be temporary, as the forecasts suggest a subsequent increase in prices in the following periods.

The analysis of the land market reveals distinct trends based on the nature of development and its relation to the ongoing conflict. Industrial development areas located in conflict-affected zones are expected to experience significant disruptions due to the hostilities. Meanwhile, agricultural and residential development zones have been following a growth trajectory, aligning with pre-war patterns, particularly in areas that are geographically distant from the conflict zones. These conclusions underline the substantial impact of conflict on different sectors of the land market and emphasize the importance of geographic location in determining market behaviour.

7. Analysing model performance
In the context of our research, an exhaustive comparison of model outputs against the real system has been meticulously conducted to elucidate predictive dynamics across diverse
real estate segments. Specifically, our focus has encompassed the realms of apartment prices, house prices and land prices.

Empirical revelations from our investigation bring to light a discernible trade-off between model complexity and predictive accuracy. Noteworthy observations emerge indicating that while a model incorporating ten exogenous factors may capture a wealth of information, a reduction to nine or eight factors facilitates simplification without incurring a significant loss of accuracy. This finding underscores the potential of simpler models to enhance interpretability and generalization to novel data sets. Our comparative analysis of models featuring varying numbers of predictors accentuates the critical importance of striking an optimal balance between model complexity and predictive power.

In the realm of interpretability, it is observed that MLR distinguishes itself by virtue of its simplicity and facile interpretation. The linear nature of the model allows for a clear understanding of the impact of each predictor variable, rendering MLR an optimal choice when prioritizing ease of comprehension.

Furthermore, the ARIMAX model emerges as a prominent contributor to improved prediction accuracy in contrast to conventional ARIMA models. This enhancement is attributed to the model’s incorporation of exogenous macroeconomic factors, thereby amplifying its capacity to capture external influences and furnish more precise and robust predictions of real estate prices.

Turning attention to ridge regression, recognized as a regularization technique adept at addressing multicollinearity and overfitting, we extend its applicability by including exogenous macroeconomic factors. The objective is to fortify predictive accuracy by accounting for external influences within the data set. Empirical findings unequivocally demonstrate that ridge regression, when coupled with exogenous factors, outperforms traditional linear regression in terms of prediction accuracy. The regularization term within ridge regression plays a pivotal role in managing multicollinearity, thereby augmenting the model’s stability and overall predictive performance.

In synthesis, our research navigates the intricate landscape of real estate predictive modelling, revealing nuanced insights into the delicate balance between model intricacy and efficacy. The juxtaposition of MLR, ARIMAX and ridge regression within this framework provides stakeholders with a comprehensive understanding of model interpretability, explainability and performance across varied real estate segments.

**Figure 11. Land price projection plot: ARIMAX vs actual prices**

*Source: Authors’ own creation*
An essential facet of our methodology is its reliance on historical real estate prices. This anchoring in past data not only ensures the realism of the model but also lays the foundation for robust predictions based on observed trends and patterns. The use of historical data is a key factor in the models’ ability to adapt to changing market conditions and generate accurate predictions even in dynamic and unpredictable environments.

The employment of multiple models within our framework is a strategic choice aimed at capturing the multifaceted dynamics of the real estate market. MLR, RR and ARIMAX each contribute unique perspectives, allowing for a more nuanced understanding of the complex interplay between various factors influencing property prices. This multi-model approach enhances the comprehensiveness and reliability of our predictions, aligning with the diverse nature of real estate markets.

Moreover, the resilience of our methodology to changes in the market stands as a testament to its practical utility. In a high-risk environment where market conditions are prone to fluctuations, the robustness of our predictive tools ensures a steadfast performance. This adaptability is crucial for stakeholders making informed decisions in the face of uncertainties, ultimately reinforcing the practical applicability of our research findings in real-world scenarios.

8. Concluding remarks
In conclusion, the comprehensive analysis of price dynamics within the real estate market, encompassing apartments, houses and land, has yielded significant insights into the intricate interplay of economic factors and their impact on property values. The meticulous examination of historical trends, coupled with advanced predictive modelling techniques, has provided a nuanced understanding of market behaviour.

In the near future, there will not be any significant price or demand shocks. In summary, the combination of all factors does not provide grounds to expect substantial changes in housing prices in the immediate future.

Turning to the household sector, the models predict a similar pattern of stabilization after a brief decrease, underscoring the market’s resilience in the face of economic challenges. In the realm of land prices, the analysis captures the seismic shift in dynamics following the opening of the agricultural land market. Despite the disruptions caused by geopolitical events, the market exhibited a capacity for recovery, emphasizing the pivotal role of external factors in dictating land price movements.

The present investigation underscores the value of MLR and RR in predicting property prices with a remarkable degree of accuracy. In parallel, the synthesis of these models with ARIMAX further fortifies such predictive tools, allowing for a comprehensive examination of property price trends.

In each sector, the models demonstrated varying degrees of accuracy, attesting to the complexity of real estate markets and their susceptibility to multifaceted influences. The methodology uses historical real estate prices what ensures that the model is based on real-world data and is likely to be accurate. Multiple models capture the different dynamics of the market. Moreover, the methodology was designed to be robust to changes in the market. This helps to ensure that the predictions are accurate even in a high-risk environment.

The Ukrainian real estate market is a high-risk market due to the ongoing war. The war has caused significant disruption to the market, including a decrease in demand, an increase in supply and uncertainty about the future. The developed methodology can be used to predict prices in this high-risk environment.

The methodology used in this study has demonstrated promising outcomes in practical application, and its efficacy is anticipated to further enhance with the accumulation of
additional data and the incorporation of updated tools in subsequent periods. Importantly, the generalizability of this methodology extends to other markets that have access to requisite data, encompassing those characterized by elevated risk levels, such as those currently affected by the ongoing impact of war. Considering these findings, we assert that the utilization of multifactor models is entirely justified for the identification of trends and the accurate forecasting of real estate prices within the short- and medium-term perspectives. This conclusion not only underscores the validity of our methodology but also highlights its potential applicability in diverse market contexts, providing valuable insights for informed decision-making in real estate forecasting.

References

Further reading
### Table A1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment price</td>
<td>Real apartment price, $ per square meter</td>
</tr>
<tr>
<td>Land plot price</td>
<td>Land plot price, $ per 100 square meter</td>
</tr>
<tr>
<td>House price</td>
<td>Real house price, $ per square meter</td>
</tr>
<tr>
<td>V1</td>
<td>Average salary</td>
</tr>
<tr>
<td>V2</td>
<td>BAEI</td>
</tr>
<tr>
<td>V3</td>
<td>Compensation of employees</td>
</tr>
<tr>
<td>V4</td>
<td>Consumer loans granted to households</td>
</tr>
<tr>
<td>V5</td>
<td>Consumer loans volume to households</td>
</tr>
<tr>
<td>V6</td>
<td>CPI</td>
</tr>
<tr>
<td>V7</td>
<td>Index of construction companies' business activity expectations</td>
</tr>
<tr>
<td>V8</td>
<td>Economic sentiment indicator</td>
</tr>
<tr>
<td>V9</td>
<td>Exchange rate expectations (banks)</td>
</tr>
<tr>
<td>V10</td>
<td>Exchange rate expectations (businesses)</td>
</tr>
<tr>
<td>V11</td>
<td>Exchange rate expectations (financial analysts)</td>
</tr>
<tr>
<td>V12</td>
<td>Exchange rate expectations (households)</td>
</tr>
<tr>
<td>V13</td>
<td>GDP</td>
</tr>
<tr>
<td>V14</td>
<td>Global oil prices (Brent)</td>
</tr>
<tr>
<td>V15</td>
<td>Inflation expectations (banks)</td>
</tr>
<tr>
<td>V16</td>
<td>Inflation expectations (businesses)</td>
</tr>
<tr>
<td>V17</td>
<td>Inflation expectations (financial analysts)</td>
</tr>
<tr>
<td>V18</td>
<td>Inflation expectations (households)</td>
</tr>
<tr>
<td>V19</td>
<td>Inflation</td>
</tr>
<tr>
<td>V20</td>
<td>Volume of cash foreign currency</td>
</tr>
<tr>
<td>V21</td>
<td>Interest rate on consumer loans to households</td>
</tr>
<tr>
<td>V22</td>
<td>Interest rate on loans to households (total)</td>
</tr>
<tr>
<td>V23</td>
<td>Interest rate on mortgage loans to households</td>
</tr>
<tr>
<td>V24</td>
<td>Interest rates on mortgage loans to non-financial corporations</td>
</tr>
<tr>
<td>V25</td>
<td>Interest rates on new loans to non-financial corporations</td>
</tr>
<tr>
<td>V26</td>
<td>Loans granted to households for the purchase (construction and reconstruction of real estate)</td>
</tr>
<tr>
<td>V27</td>
<td>Mortgage loans granted to households</td>
</tr>
<tr>
<td>V28</td>
<td>Mortgage loans volume to households</td>
</tr>
<tr>
<td>V29</td>
<td>NBU key policy rate</td>
</tr>
<tr>
<td>V30</td>
<td>NEER</td>
</tr>
<tr>
<td>V31</td>
<td>Number of registered unemployed</td>
</tr>
<tr>
<td>V32</td>
<td>Official hryvnia exchange rates</td>
</tr>
<tr>
<td>V33</td>
<td>Personal remittances</td>
</tr>
<tr>
<td>V34</td>
<td>REER</td>
</tr>
<tr>
<td>V35</td>
<td>Total household loans volume</td>
</tr>
<tr>
<td>V36</td>
<td>Volume of loans to non-financial corporations</td>
</tr>
<tr>
<td>V37</td>
<td>Volume of mortgage loans to non-fin. corporations</td>
</tr>
<tr>
<td>V38</td>
<td>Volume of PCW</td>
</tr>
</tbody>
</table>

**Source:** Authors' own creation

---

**Corresponding author**

Valery Yakubovsky can be contacted at: vyakubovsky@ukr.net

---

For instructions on how to order reprints of this article, please visit our website: [www.emeraldgrouppublishing.com/licensing/reprints.htm](http://www.emeraldgrouppublishing.com/licensing/reprints.htm)

Or contact us for further details: permissions@emeraldinsight.com