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House Price Bubble Detection in Ukraine

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BCC Bilateral Assistance & Capacity Building for Central Banks

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Abstract

In this article, we developed a reliable method to detect house price bubbles using data for the largest Ukrainian cities. Further, we identified the thresholds, the breach of which is signaling that house price growth may be problematic as a bubble may be forming. In this paper, house price bubbles are detected with the help of two general approaches: ratio calculation and regression analysis. These general approaches are subdivided into two each. We calculated the Price-to-Rent and Price-to-Income ratios that can identify a possible over- or undervaluation of house prices for Ukrainian cities under the scope of this investigation. Then, we performed the regression analysis by building individual multifactor models for different cities and by running a pooled OLS regression for the panel data. According to the results, the only pronounced and prolonged period of house price bubbles is the one that coincides in time with the Global Financial Crisis – from late 2005 to early 2009. The bubble signals, produced by these methods are, on average, simultaneous and are in accordance with economic sense. A tool for measuring fundamental house prices and an indicator of bubble on housing markets will be used to monitor the systemic risks stemming from the real estate market. Thus, it will help the National Bank of Ukraine maintain financial stability.

Keywords: house price bubbles, fundamental house prices, mortgage lending, systemic risk, regression analysis.

JEL: C31, C33, E30, G21.

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I. Introduction

The real estate market, as it was proven by the previous crisis episodes all over the world, can be a major source of systemic risk and thus any imbalances on it can be a threat to the financial stability. The most widely known evidence of real estate markets being a source of systemic risk is the Global Financial Crisis (GFC) of mid-2007 – early 2009, a distinctive feature of which were price bubbles that appeared on numerous real estate markets all over the world. An excessive and uncontrolled house price growth was left without proper attention because of widespread misperception that housing was an asset class the price of which could grow forever. That perception made housing the most attractive investment, which in turn fueled demand even further and led to an amplification of the bubble. Another driver of a bubble build-up was affordable and easily accessible lending that fueled up the bubble, creating for financial institutions exposures to future crisis consequences. The overvaluation of house prices was left unsupervised, and the bubble grew into financial stability-threatening size globally. The burst of the housing bubble had negative consequences not only to property owners (such as resulting in having a negative equity), but to the complete global financial system. Banks that were holding assets, collateralized by overpriced housing, had their balance sheets and solvency at risk because of asset price corrections. When house price bubbles burst, it erased a great part of the banking equity. That was detrimental to solvency of financial institutions and led to widespread financial instability. Worsening positions of banks and even failures, in turn, resulted in impaired credit supply that had profound implications for the real economy and households all across the globe **(Aoki and Nikolov, 2012)**.

The housing bubbles that were observed on property markets all over the world during the first decade of the 2000s were definitely the most widespread and well known. However, the world history has many other examples **(Glaeser, 2013)** of massive overvaluation of house prices that was followed by a large downfall and in some cases even by a prolonged financial and (or) economic crises. One of them is the case of Japan's real estate market, which experienced a massive surge in asset prices from the latter half of 1980s to the early 1990s. Aggressive bank behavior, protracted monetary easing, taxation and regulations on land that led to higher land prices, a weak mechanism to impose discipline on economic agents and self-confidence in Japan are among the factors behind the bubble **(Okina, Shirakawa and Shiratsuka, 2001).**

In turn, a precise investigation of causes of the Global Financial Crisis **(Nier and Merrouche, 2011)** proved that widespread moral hazard and prudential requirements that were not sufficient to deal with systemic externalities also induced the imbalances on the financial markets. In the European area, one of the largest house price acceleration in the early-to-mid 2000s was experienced in the Baltic States. The bubble was determined by both supply and demand factors. The demand factors were primarily related with the lending: favorable standards, absence of caps on macroprudential ratios, such as loan-to-value ratios, and low interest rates on mortgages. The demand for housing was also fueled by low taxation, partial deductibility of mortgage interest payments, nominal convergence and rather underdeveloped rental markets **(Bukeviciute and Kosicki, 2013)**.

Taking into account the lessons learnt from the housing bubbles during the GFC and preceding asset price bubbles on the property markets in different countries, the real estate market is now constantly under close surveillance by central banks and other financial regulators globally. For instance, it is now a common practice

for central banks of numerous countries to publish annually or semiannually a financial stability report/review with a separate chapter dedicated to the analysis of systemic risks stemming from real estate market. In addition, it became obvious that to interpret the house price movements, one needs to think of the house price fundamentals, as factors that form and thus explain the behavior of asset prices. The monitoring of housing market and risks, stemming from it has become a routine for most regulators worldwide. The constant surveillance of the housing markets are now a part of the systemic risk analysis and a basis for development of the macroprudential toolkit that can limit threats to financial stability.

The most important indicator of stability of the real estate market is the level of house prices and the extent to which they are fairly valued. The misevaluation of house prices implies undervalued or overvalued house prices, as related to their intrinsic value. The overvaluation of housing, not supported by the growth of disposable income of households, can lead to lower affordability of housing and higher debt burden of the population and thus is a threat to the financial stability. In turn, high household indebtedness makes the economy at risk of big asset price movements and can cause more disruptive consequences in case of any crisis events via the collateral channel **(Hviid and Kuchler, 2017).**

The question that is widely discussed in the related economic literature is when the house price growth becomes large and risky enough to be considered a bubble. In this paper, we will try to build a framework for assessment of the intrinsic value of house prices, explained by the fundamental factors (hereinafter the fundamental level of house prices[1]) for Ukraine, as well as to identify the thresholds, the breach of which is signaling that house price growth can be considered a bubble.

Overvaluation of house prices can result in a bubble. To be classified as a bubble, asset price growth must have a certain set of features. According to **Glaeser et al. (2014)**, the signs of the bubble become obvious when the price movement is greater than the level, which can be explained by dynamics of rents or other fundamental factors. The prices then show "substantial-momentum at high frequencies", while they revert to mean at lower frequencies. According to **Fama (1965)**, asset price bubbles, overall, can be interpreted as the periods, during which the prices of assets "run well above or below the intrinsic value". Thus, in order to detect a real estate bubble, it is essential to identify an intrinsic value of housing.

I (a). Literature Review

An intrinsic level of house prices can be measured with the help of a wide variety of methods. Among the most popular are simple ratios that typically compare house prices to fundamental factors of house price growth: usually either rents or income. Among the most widely used ratios are Price-to-Income, Price-to-Rent, as well as Imputed-to-actual-rent ratio and Imputed rent-to-income ratio. This method of identifying misevaluations of house prices is described in detail by **Himmelberg, Mayer and Sinai (2005), and Case and Shiller (2003).**

Another approach to finding the fundamental level of house prices is the regression analysis, which includes univariate and multivariate models of different sorts, which are based on supply and demand variables. These methods were suggested in the literature by **Annett (2005), Skaarup and Bodker (2010), Hlaváēek and**

[1] Throughout this paper, the terms "intrinsic value" and "fundamental value" will be used interchangeably.

Komárek (2011), Anundsen et al. (2014), Belke et al. (2017) and Bourassa, Hoesli, and Oikarinen (2019), Maynou et al. (2021) and **Emenogu et al. (2021)**.

Specifically, **Annett (2005)** introduced a framework for assessing the fundamental level of house prices using a model, estimated to analyze the short- to medium-run dynamics in real house prices in a panel regression for the eight countries, and estimated using fixed effects. This paper included real disposable income per capita, real long-term interest rate, and real credit as determinants of a fundamental level of house prices.

Skaarup and Bodker (2010) formulated and estimated a traditional demand-supply housing model to investigate the housing prices trend for Denmark before, during and after the GFC. Their analysis suggested that house price growth was in general supported by the fundamental factors, such as real disposable income and financial wealth, as well as real mortgage rates. Still only a small share of price appreciation largely deviated from the fundamental during the increase in prices, which preceded the crisis.

Another research, which covered the development of the framework of fundamental house prices, was a work by **Hlaváēek and Komárek (2011)**. The authors used OLS and FE panel regressions with data on building plot prices, apartment construction prices, completed apartments, and number of apartments per 1,000 inhabitants as supply factors of the fundamental level of house prices. In addition, data on marriages, divorces, natural population growth, net migration, unemployment rate, economic activity, rate of population growth, vacancies/labor force, average monthly wage, rent per month, and loans served as demand factors of the fundamental level of housing prices. The authors discovered that house prices in the Czech Republic are determined mainly by demand factors. They also identified the periods of historical house price mispricing.

Anundsen et al. (2014) investigated the roles of house price dynamics and credit activity on the probability of crises. They found out that econometric measures of bubble-like behavior in both credit and housing markets are statistically significant and have strong positive correlation with each other. Additionally, when rising housing prices coincide with high lending activity, it markedly amplifies the probability of financial crisis.

As one of the more recent researches on this topic, the paper by **Belke et al. (2017)**, explored the level of fundamental house prices using panel regressions. The authors estimated two different specifications of the model that either exclude or include the year-specific fixed effects. They discovered that among the set of used variables, many proved to be robust determinants of fundamental house prices, which was in line with previous theoretical assumptions. Among such were construction activity and the stock of existing housing, the number of households, the age structure of the population, and the regional infrastructure.

In their research, **Bourassa, Hoesli and Oikarinen (2019)** managed to identify a large set of methods for measuring house price bubbles, based on housing data for six cities, which experienced episodes of housing overvaluation of different nature and timing. The authors found out that the best method for identifying house price bubbles both ex-ante and ex-post is the Price-to-rent ratio. This approach, according to the outcomes of research also had the best early warning signal, as it signaled of a bubble from 1 to 2 quarters before the house price growth reached the threshold of housing price bubble.

Maynou et al. (2021) analyzed the data for twelve European countries over the period from the beginning of 2004 to the end of 2016 and found out that the main determinants of real house price dynamics were mainly fiscal factors and unemployment. One of the latest works on the fundamental level of house price assessment

by **Emenogu et al. (2021)** focused on detecting periods of extrapolative expectations in house prices across Canadian cities. The research featured a non-linear heterogeneous agent model **(Bolt et al., 2019)** for the housing market in which agents switch between different types of house price expectations. As the first step in their work, the authors estimated the levels of house prices consistent with typical demand-side fundamentals, such as disposable income per capita, population, and the real effective mortgage rate. The authors concluded that the model of the fundamental level of house price valuation lacked the supply-side variables, better modeling of which remained an important avenue for future research.

A different method for detecting house price bubbles is a type of regression approach that employs unit root tests to detect bubbles, applied by **Taipalus (2006), Phillips, Wu and Yu (2011) and Yiu, Yu and Jin (2013)**. The unit root method is built on the time series particularities of the time series of house prices. Thus, under this method it is not possible to get an indication of the magnitude of a property price bubble. According to the evidence found by **Engsted, Hviid and Pedersen (2015)**, the main drawback of the unit root approach is that it can detect a bubble while it emerges, but it is not able to find any disequilibria beyond the highest point of the bubble. In other cases, as **Taipalus (2006)** and **Yiu, Yu and Jin (2013)** showed it, this approach is excessively sensitive to any deviations from equilibrium level. Thus, the unit root approach is considered not suitable for this research.

Another method that is based on the exponential growth rate (EGR), which implies that a faster than exponential rate of growth in house prices is unsustainable and thus becomes evidence of a bubble. **Zhou and Sornette (2006)** used it in their research. According to the conclusions of **Bourassa, Hoesli and Oikarinen (2019)**, this method is regarded as unappealing from a theoretical perspective since it does not relate house prices to fundamental factors and might produce incorrect bubble signals.

A present value approach suggests that the value of housing is a present value of all future earnings that it will generate, which is essentially the rental income stream. **Campbell and Shiller (1988a, 1988b)** and **Black, Fraser and Hoesli (2006)** used this method in their research. This approach is considered suitable for detecting any deviations from the fundamental house prices but is out of the scope of this research due to its complexity relative to the other aforementioned approaches.

After analyzing the literature that is available on this topic and all methods that are introduced in it, we decided to perform this research with the help of two methods: simple ratios of house prices to its fundamentals and regression analysis, which includes univariate and multivariate models, which are based on supply and demand variables. These two methods were chosen because of their efficiency in detecting house price bubbles, as proven by the literature, and simplicity of calculations and thus, understanding, given the fact that the results will be presented to the public within the regular communications of the National Bank of Ukraine.

I (b). Research Motivation

The National Bank of Ukraine is responsible for maintaining price and financial stability in the country with the goal of contributing to Ukraine's sustainable economic development. One of the biggest crises that the Ukrainian economy has gone through was the GFC of mid-2007 - early 2009, which started from the worldwide imbalances in the housing market, connected to the excessive risk-taking in a favorable

macroeconomic environment. Thus, in order to maintain financial stability, it is necessary to monitor the risks stemming from the real estate market.

One of the ways to measure the risks to financial stability is to determine and analyze the fundamental level of house prices and, thus, the level of their over- and undervaluation to the extent that can threaten the financial stability. Therefore, the main objective of this research is to develop a framework for assessing the fundamental level of house prices and monitoring any deviations of the current level of market prices from it (identifying the over- and undervaluation of house prices) that can pose risks to the stability of the national financial system.

I (c). Research Process

First, we select a range of determinants of house price dynamics specific to the Ukrainian housing market and break them down into two broad categories: supply and demand factors. Then we perform different tests, including correlation matrixes and simple univariate regressions, to determine the short list of variables that are best suited to be the fundamentals of house prices. The evidence from the literature is also of great use at this stage of the research.

The second step of this research is to calculate a set of simple indicators for six of the biggest Ukrainian cities: Kyiv, Kharkiv, Lviv, Donetsk, Dnipro and Odesa. The ratios such as Price-to-Income and Price-to-Rent provide quick and intuitively understandable evidence on the housing price mispricing. This set serves, among other things, as an additional check of the reliability of the models.

The third stage in the research is to estimate a set of econometric models of different specifications for the biggest six Ukrainian cities, based on the toolkit of fundamentals, formed in the first step of this research. The next step is to pick up the basic model that is the best suited for the Ukrainian real estate market.

After deriving the baseline model for estimation of the fundamental level of housing prices in Ukraine, we compute the fitted value and use it to compare with the actual house price level on a given regional market. This value provides us with a tool for defining the level of over- or undervaluation of housing in Ukrainian biggest six cities in a graphical form and in the form of indices.

II. Background of the Ukrainian real estate market

Since 2000, Ukraine has gone through four major crises: one was during the GFC; the social-economic crisis of 2014-15th that was deepened by the aggression in the Eastern part of Ukraine and the annexation of Crimea by the Russian Federation; the coronavirus crisis of 2020, which was prompted by the Coronavirus disease and the current crisis that was triggered by the Russia's full-scale war on Ukraine. The first three crises[2] appear clearly in Figure 1, which highlights real GDP growth during the period.

[2] The fourth crisis is not covered by the observation period of this research.

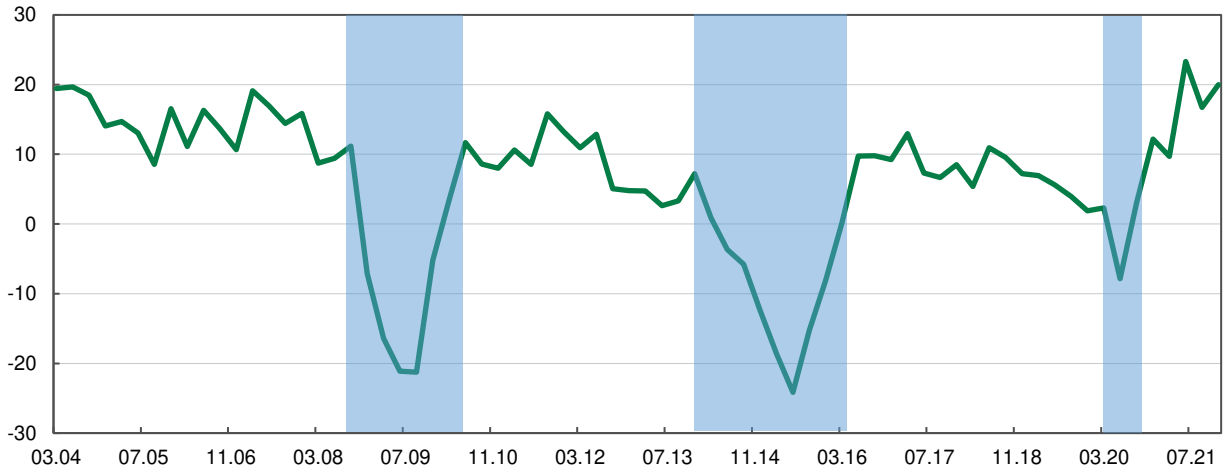


Figure 1. Real GDP growth, % y-o-y

During the last decade, the level of inflation in Ukraine was high, reaching 31.1% in mid-2008 and 60.9%[3] in April of 2015 (Figure 2). Considering the previous periods of high inflation and the fact that they undoubtedly affected house prices, this research was conducted with quantitative data entirely in real terms, as we wanted to isolate and identify the imbalances, specific to the real estate market. Another macroeconomic indicator that is of extreme importance for analysis of the housing market is the exchange rate of Ukrainian hryvnia (UAH) to US dollar (USD) (also see Figure 2). Almost all house prices, quoted in the advertisements by real estate agencies, are denominated in USD, with an exchange rate of hryvnia to the US dollar being a key reference point for both sellers and buyers. Thus, large shifts in exchange rates have a substantial effect on the house price dynamics.

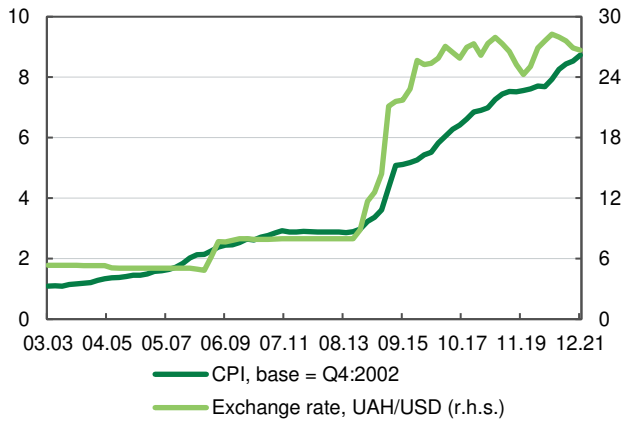


Figure 2. Consumer Price Index and Exchange Rate

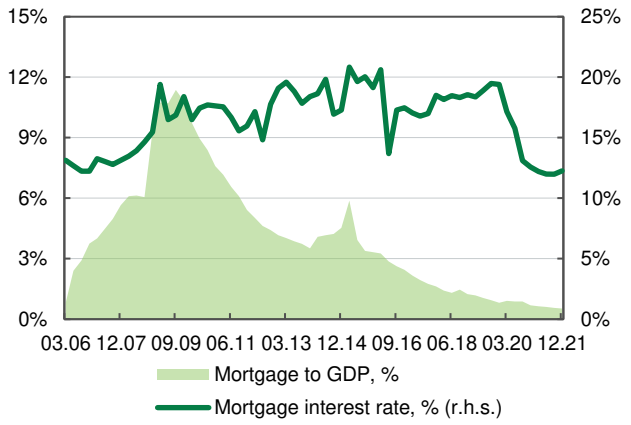


Figure 3. Mortgage to GDP and UAH interest rates

Currently mortgage lending has no significant effect on the real estate market, since the volume of loans for house purchases is unnaturally small. The mortgage-to-GDP ratio amounted to 0.55% as of the end of Q3 2021 (**National Bank of Ukraine, 2021**). This ratio reached its maximum level in 2009, when the mortgage lending was more vigorous in months preceding the economic crisis (Figure 3). During the 2009-2020 period, the mortgage market was almost inactive. The mortgage lending started to recover slowly in mid-2020, primarily

[3] The numbers are from the corresponding month of the previous year (i.e., year-to-year).

due to lower interest rates and the launch of a state-financed Affordable Mortgage program, which was offering substantially lower interest rates for borrowers, with subsequent compensation for lenders.

Most of housing purchases are financed from households' savings; buyers do not rely heavily on banks' financing. As of the end of 2020, only up to 5% of transactions were paid with the help of mortgages **(National Bank of Ukraine, 2020)**. Buyers also actively use free installments offered by developers to purchase newly built properties on the primary real estate market.

The rate of homeownership in Ukraine is extremely high. Individuals own most of the housing that is commissioned. Once the necessary refurbishment is done, they can then rent the units out to other individuals. The rental market is mostly unregulated: rental agreements are rarely registered officially or notarized. Therefore, the rental market is very elastic because the transactions on it are usually very frequent.

The housing (mostly apartments) that is owned by developers and was not yet sold to individuals (the transactions in which real estate developers sell housing to individuals) is the primary real estate market. Buyers can purchase apartments from the developers at different stages of the construction process; often that means buying a property that is not yet built. The risk of delays in construction and even the risk of purchasing an apartment that will never be finished due to, among other things, bankruptcy of the developer – are borne by the buyer. That makes investing in real estate on the primary market a risky business, which led to almost inexistent mortgage lending on the primary real estate market. Only around 10% of new mortgages in 2021 were issued for the purchase of newly built housing **(National Bank of Ukraine, 2021).**

The housing that is owned by individuals and is offered to another individual (individual-to-individual transactions) is considered the secondary real estate market. Prices on the secondary market are usually higher because housing on this segment of the market is usually fully equipped and has all the necessary refurbishments. Buyers can start living there immediately, without additional investments and any risks that the purchased housing will be unfinished.

III. Methodology

As mentioned in the Introduction section, for the purpose of this research, we rely upon two methods: simple ratios of house prices to their fundamental values and regression analysis, which includes univariate and multivariate models, which are based on supply and demand variables.

III (a). First Approach: Calculation of Ratios

As demonstrated in the literature, the most widely used ratios due to their simplicity of calculation and ease of understanding, are the Price-to-Income and Price-to-Rent ratios. Those ratios provide a measure of relative over- or undervaluation of housing by relating the house price growth to its fundamentals – income and rents. In their research, **Bourassa, Hoesli and Oikarinen (2019)** proved that the approach that relies on Price-to-Income and Price-to-Rent ratio analysis is the most efficient for correct identification of bubble and non-bubble periods. In this research, the Price-to-Income ratio is the square meter price of an apartment, multiplied by the standardized area of an apartment (70 sq. m) and divided by the average annual after-tax wage earned by the

household[4]. The Price-to-Rent ratio is the purchase price per square meter of an apartment, divided by the annual rental per square meter.

$$Price\ to\ Income\ Ratio_{t,i} = \frac{\text{Price per sq. m}_{t,i} * \text{standardized area of an apartment}}{\text{Average annual wage earned by the household after tax}_{t,i}} \quad (1)$$

$$Price\ to\ Rent\ Ratio_{t,i} = \frac{\text{Purchase price of an apartment per sq. m}_{t,i}}{\text{Annual rental per square meter}_{t,i}} \quad (2)$$

Where indices *"t,i"* stand for the given point of time and a particular city that is within the scope of our investigation: Kyiv, Lviv, Odesa, Kharkiv, Dnipro or Donetsk.

Based on the research by **Dreger and Kholodilin (2011)**, if the Price-to-Income or Price-to-Rent ratio exceeds one standard deviation of the long-term average of the time series, the probability of a house price bubble exceeds 50%. **Bourassa, Hoesli and Oikarinen (2019)** refer to a bubble when the ratio is more than 20% above its long-term average. In addition, according to **Czerniak and Kawalec (2020)**, the relationship between house prices and rental rates over a long-term period is almost constant, apart from periods during which there is a structural break on the market. Thus, we will estimate the long-term average of the Price-to-Income and Price-to-Rent ratios and compare the current values to the long-term average plus one standard deviation of the ratio values over the observation period.

III (b). Second Approach: Regression Analysis

The regression analysis will be performed with the help of one of the most common and straightforward models for defining the fundamental price level, which is a simple ordinary least squares (OLS) model for each single city, such as the following one:

$$y_{t,i} = \beta_0 + \beta_1 X_{t,i,1} + \beta_2 X_{t,i,2} + \beta_3 X_{t,i,3} + \cdots + \beta_p X_{t,i,p} + \varepsilon_{t,i}, \text{ where} \quad (3)$$

$y_{t,i}$ is a dependent variable in time "*t"* and city "*i"* and $X_{t,i,p}$ are the determinants of house price dynamics of *p* parameters in time "*t"* and city "*i"*.

After establishing the baseline model, we estimate the fitted values, which are then interpreted as fundamental house prices. Then, we compare these fitted values of fundamental house prices with the actual values of house prices for the same periods. We then identify the presence of a house price bubble on the market with the help of a threshold that amounts to two standard deviations outside the fitted time series. We will then compare the results of the two approaches to assess which one did best in identifying periods of house price bubbles for each of the six cities.

[4] The after-tax wage earned by the household is calculated based on the number of working individuals in the household, according to the State Statistics Service of Ukraine (SSSU).

IV. Data Description and Selection

IV (a). Data for Regression Analysis

At the initial stage of this research, we gathered a long list of variables that were used for estimation of the fundamental level of house prices in the literature.

Table 1.

Comprehensive list of variables that can be used for estimation of the fundamental level of house prices

Dependent variable	**Independent variables**		
House prices (for each city)	**Supply-side fundamentals (at the aggregate level)**	**Demand-side fundamentals (for each city)**	**Lending factors (at the aggregate level)**
Nominal house prices on primary and secondary real estate market (REM), UAH per sq.m.	Commissioned dwellings in Ukraine, sq.m.	Rental rate of housing, UAH per sq.m.	Mortgage portfolio (credit stock) in local currency, as of the end of period, UAH
Real house prices on primary and secondary REM, UAH per sq.m.	Construction costs index for Ukraine, points	Exchange rate corrected rental rate of housing, UAH per sq.m.	Mortgage portfolio in foreign currency, UAH
Exchange rate corrected nominal house prices on primary and secondary REM, UAH per sq.m.		Average monthly income of a person/per household, UAH	Exchange rate adjusted mortgage portfolio, all currencies, UAH
Exchange rate corrected real house prices on primary and secondary REM, UAH per sq.m.		Capital investment of households for buying or building housing, UAH	Interest rate on UAH mortgage, weighted average on the flow of credit, %
		Unemployment rate, %	New mortgage lending (flow of credit) in all currencies, over a period, UAH
		Population number, persons	NBU policy rate, %
		Share of disposable income in aggregate income of the population, %	Google trend rate of “credit” search

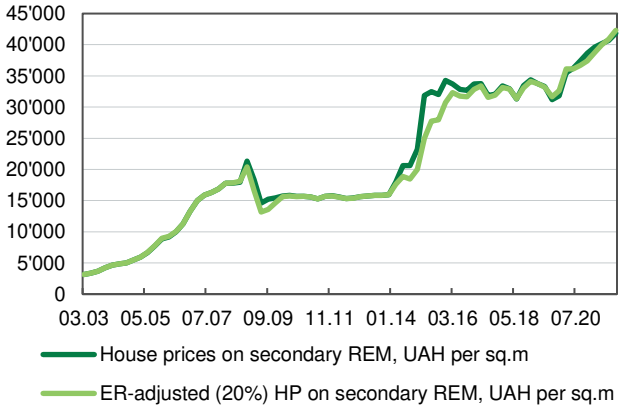
Within the scope of our research is data for six Ukrainian cities: Kyiv, Lviv, Odesa, Kharkiv, Dnipro and Donetsk. On the level of each region, we have the data on house prices (dependent variable) and data on the demand-side fundamentals (independent variables). The data on the supply-side fundamentals and lending factors are collected only at the aggregate level (i.e., for the whole country).

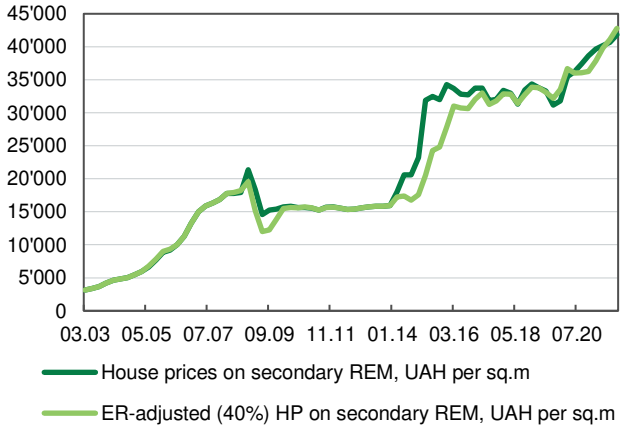
The dependent variable in this research is essentially house prices, which are measured for each city on a monthly basis since the beginning of 2003. We perform separate calculations for the primary and secondary real estate markets only for Kyiv city, since for other cities of Ukraine only the data on prices on the secondary market are available over sufficiently long time horizon. According to the type of urban development of the largest Ukrainian cities, there prevail high-rise multi-dwelling residences. Considering this, in this research we use the data on prices of dwellings from the multi-storey residential buildings. The data on the average price of dwellings for each city in a given month are from real estate agencies, which aggregate the advertisements from housing developers and individuals. Thus, the data on house prices that are used in this research are the quoted prices of apartments that are offered on the market in the end of a given month.

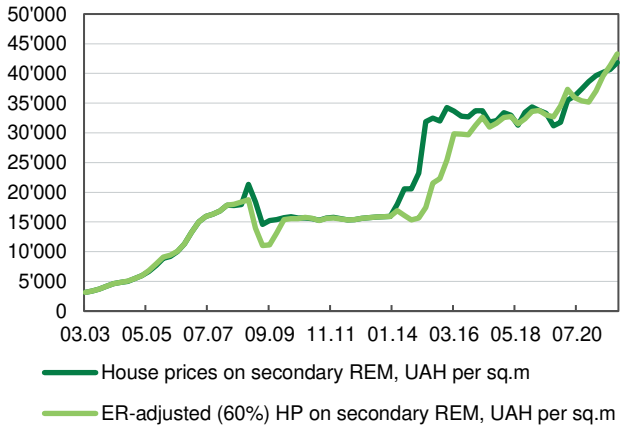
IV (b). Exchange Rate adjustment

Given the peculiarities of the Ukrainian economy, when preparing the dependent variable, we need to account for inflation and changes in the FX rate of UAH/USD. While it is relatively easy to deal with inflation by returning the real values of house prices, it is more difficult to account for the effect of foreign exchange rate dynamics. For this research, we decided to adjust house prices and rental rates for the change of the FX rate, by subtracting from the y-o-y change of house prices and rental rates, a portion of the change in the foreign exchange rate. Although house prices are believed to be closely linked to the exchange rate dynamics, in the episodes, when the movements of the latter become too substantial, there will naturally emerge other factors, such as housing demand that will partially offset these movements (within the house price growth). Therefore, to account for the exchange rate, we must choose the proper percentage of adjustment between 0% and 100%.

An appropriate level of exchange rate adjustment for house prices, firstly, should smooth out any price jumps due to hryvnia depreciation in 2008 and 2014-2016, during and after large crisis episodes in Ukraine. Secondly, it should not affect the growth pattern of house prices to such an extent when the dynamics become the reverse.







Figures 4-6. Actual house prices and alternative ER-adjustments

According to Figure 4, 20% of exchange rate adjustment is too small to smooth the spikes from hryvnia depreciation in 2008 and 2014-2016. The house price surges are still present and this appreciation is clearly not coming from any fundamentals or events on the real estate market, so we must correct for it. As we can see from Figure 6, 60% of exchange rate adjustment is too large, since it makes the house price dynamics inverse and cancels out some of the growth that was actually driven by the fundamental factors or events on the real estate market. Thus, the optimal exchange rate adjustment for the purpose of our research is 40%.

Thus, we remove from the price dynamics 40% of the growth that was contributed only by the change in the FX rate.

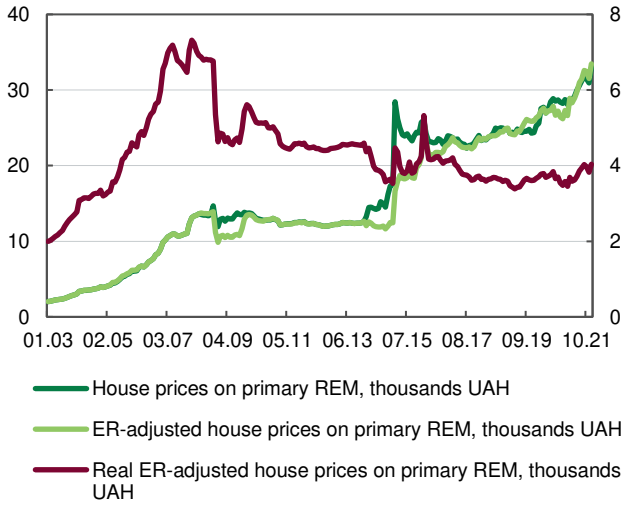


Figure 7. House price metrics for the primary real estate market of Kyiv city (monthly data)

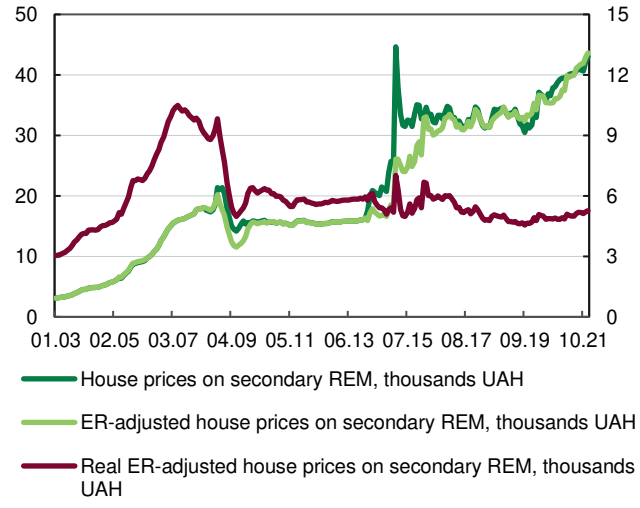


Figure 8. House price metrics for the secondary real estate market of Kyiv city (monthly data)

According to Figures 7 and 8, 40% of the FX adjustment to house prices on both markets is enough to remove spikes that were due to episodes of large UAH depreciations in 2009 and 2015. Meanwhile, the house price trend becomes completely different after accounting for inflation. The real exchange rate adjusted house prices unveil the true bubble episodes that were taking place due to imbalances on the real estate market or economy in general, not due to inflation or hryvnia depreciation. As can be seen in Figures 7-9, the real house prices were rapidly growing starting from late 2003 until mid-2007. The growth phase was followed by a subsequent correction: the decrease in house prices was almost threefold in the regional cities, while for Kyiv the price halved. That resulted in real house prices being close to the level of early 2003 for all cities in the scope of this

research, except Kyiv. In subsequent periods, the house prices slightly recovered by one-third of the lowest price. Further, except for the turbulent period from mid-2014 to mid-2015, due to the series of massive hryvnia depreciation and the social-economic crisis of 2014-15, real house prices were relatively stable and never showed any signs of a possible bubble formation. The data on house prices in Donetsk after the start of the war in the eastern part of Ukraine in 2014 is of limited reliability, since the city area has been occupied until the end of the observation period, but the data are still published by real estate agencies.

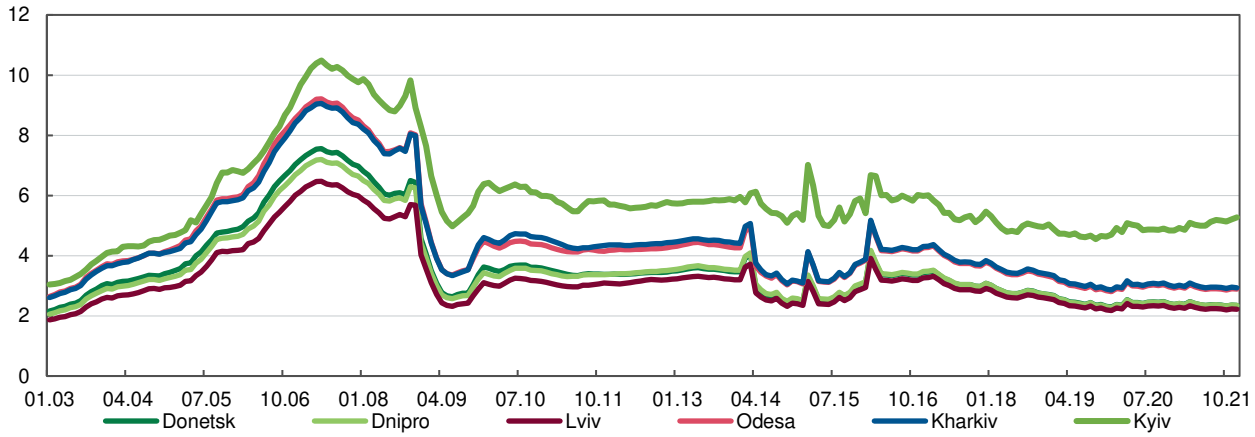


Figure 9. Real exchange rate adjusted house prices on the secondary real estate market of Ukrainian cities (monthly data), th UAH per sq. m

The independent variables are further divided into three sub-groups: supply-side fundamentals, demand-side fundamentals and lending factors. The supply-side fundamentals are usually associated with the housing stock and construction process. For this research, we selected the data on the area of commissioned dwellings in Ukraine and Kyiv and the construction cost index for Ukraine as fundamentals that explain supply factors that affect house prices. Traditionally, the list of demand-side explanatory variables is longer, since it can include every variable that explains households' current living conditions, including the access to banks' funding, that constitute the demand for housing. For our research, we chose the rental rate of housing, the average monthly income of a person, the share of disposable income in the aggregate income of the population, the capital investment of households for buying or building housing, the unemployment rate, and the population number as possible demand-side independent variables.

The lending conditions essentially contribute to the house price dynamics as a demand factor, since they describe the easiness of access to funding for house purchases by households. In this research, we isolate the variables that describe lending conditions and activity in a separate sub-group among independent variables. The reason for this is that lending conditions, according to **Bourassa, Hoesli and Oikarinen (2019)** should not be referred to as fundamental variables, since they explain not the intrinsic value of housing, but the bubble build-up itself. This assumption is backed up by the statement that an environment of low interest rates and overall favorable mortgage lending conditions were the factors that contributed to the formation of a bubble before the GFC. In addition to that, interest rates proved to be mean reverting and thus an irrelevant variable for explaining long-run house price dynamics. In the results section below, we will briefly discuss the model that includes lending conditions variables among the independent factors.

The available literature and economic intuition suggest that to generate the intrinsic level of house prices, one needs to build a model that is underspecified, thus one must select a very short list of variables that seem to be

truly fundamental. We have determined that lending conditions should not be within this short list; otherwise, we risk explaining the bubble rather than the fundamental value of housing.

The process of determining a short list of variables was essentially one of model specification selection. Thus, we performed a number of iterations to construct a model, checking its summary metrics and building a fitted value. The intention was to check whether the model coefficients and fitted values conform to economic sense of fundamental house prices. Our basic principles for model selection were:

- statistical significance of coefficients for the independent variables;
- higher R^2 and adjusted R^2, logically correct (or interpretable) signs of the coefficients for the independent variables;
- no significant correlation (over 0.8) between variables to avoid multicollinearity.

Table 2.

Short list of variables that can be used for estimation of the fundamental level of house prices

Dependent variable	**Independent variables**
House prices (for each city)	**Demand-side fundamentals (for each city)**
Exchange rate corrected real house prices on primary and secondary real estate markets, UAH per sq.m. *Monthly, from Jan 2003* *Source: real estate agencies, NBU.*	Exchange rate corrected real rental rate of housing, UAH per sq.m. (For Price-to-Rent Ratio only) *Monthly, from Dec 2009* *Source: real estate agencies, NBU.*
	Disposable real aggregate income (synthetic variable), UAH *Monthly, from Jan 2003* *Source: State Statistics Service of Ukraine, NBU.*
	Unemployment rate (according to the methodology of the International Labor Organization), *%* *Monthly, from Jan 2013* *Quarterly, from Q1 2003* *Source: State Statistics Service of Ukraine.*

Due to high seasonality, disposable real aggregate income (only the average monthly income of a person as a component of it) and the unemployment rate were seasonally adjusted with the help of the R-interface of X-13-ARIMA-SEATS, the seasonal adjustment software by the US Census Bureau.

Each of the independent variables, presented in the short list, is explained in detail below.

According to the related literature, such as **Geng (2018)**, the aggregate household income is a key factor that affects house prices, since higher income allows for buying more real estate, as well as borrowing more money for this purchase. Therefore, the next step is to construct an income variable in such a way, so it would most fully explain the possibility of households buying an apartment, or taking out a loan for it. Thus, the income variable must completely depict the affordability of housing. For this purpose, we merged the monthly real average salary, the number of population and the share of disposable income in the aggregate income of the population into one indicator. We are aware of the fact that when multiplying the average monthly salary per worker by the number of the population, we overestimate the measure of aggregate income, since there is a

share of the population that is outside the working age range or is simply unemployed. This however should not lead to a systematic bias. Despite its potential limitations, this indicator still is more valuable for our model, as it is the overall number of population that influences the housing demand the most, when compared to simply the size of the labor force.

$$\text{Disposable real aggregated income}_{t,i} = \text{Average salary per month}_{t,i} * \text{Number of population}_{t,i} * \text{share of disposable income in aggregate income}_{t,i}, \quad (4)$$

Where indices "*t,i*" stand for the given point of time and a particular city that is within the scope of our investigation: Kyiv, Lviv, Odesa, Kharkiv, Dnipro, or Donetsk (all are oblast[5] central cities). The State Statistics Service of Ukraine publishes the data on the average salary per month only at the oblast level, except for Kyiv city. However, to prove that oblast-level data are a good proxy for city-level data, we compared salaries (quarterly averages from 2017 to 2020) for the oblasts and cities that are within the scope of interest of this research. According to the results of this analysis, the prices in the cities are on average 2% higher than at the level of oblast. For Dnipropetrovsk oblast (the central city is Dnipro), the average salary is even 3% higher in the oblast than in the city. Thus, we can conclude that the oblast-level salary is a good proxy for city-level data.

In line with the data, captured on Figure 10, we can conclude that apart from two episodes of crises (2008-2009 and 2014-2015), the aggregate disposable income of households was growing even in real terms. The most rapid growth took place during the last half of the decade. The only short episode of income reduction occurred in early 2020, due to the Coronavirus pandemic. Still, the growth recovered fast and continued up to the end of 2021.

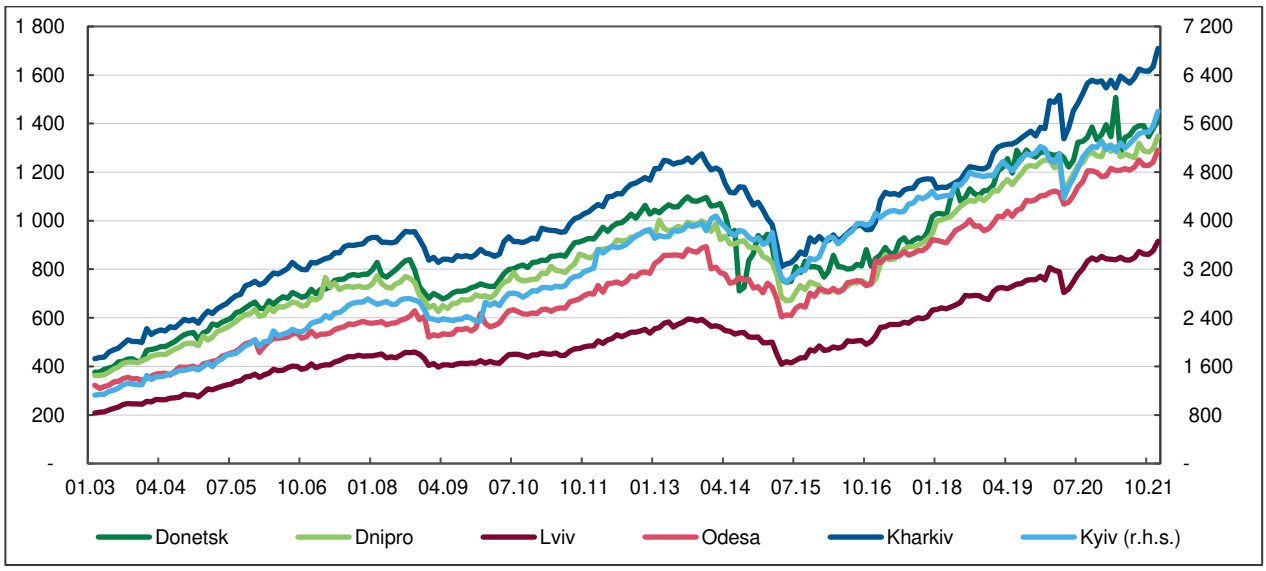


Figure 10. Real aggregate disposable income in Ukrainian cities, mln UAH

Another demand-side variable of great importance for this research is the rate of unemployment. This data is available at the city-level only for Kyiv city, while for other regions it is published only at the level of the oblast as a whole. For this research, we will use information on the level of unemployment in the oblast as a proxy for the city-level. These data are important, because they show both the current ability of households to

[5] In Ukraine, oblast is the first-level administrative division of the country. The territory of Ukraine is divided into 24 oblasts, each of which has administrative centers that are usually the largest and most developed cities of the oblast.

buy housing and the level of economic activity. In addition, given the fact that our measure of real aggregate disposable income refers to data on the average salary and a count of the whole population, it does not have a high correlation with the rate of unemployment, thus we do not face the problem of multicollinearity in the process of model specification and assessment. According to Figure 11, during the follow-up period, there were two massive "jumps" in the level of unemployment – both coincide in time with the biggest crises. It is worth mentioning that the most massive increase in the level of unemployment occurred in the Donetsk oblast after 2014. This dynamic is explained by the military aggression of the Russian Federation and the start of the war on the East of Ukraine, with the part of Donetsk oblast being occupied from mid-2014 to the end of the observation period.

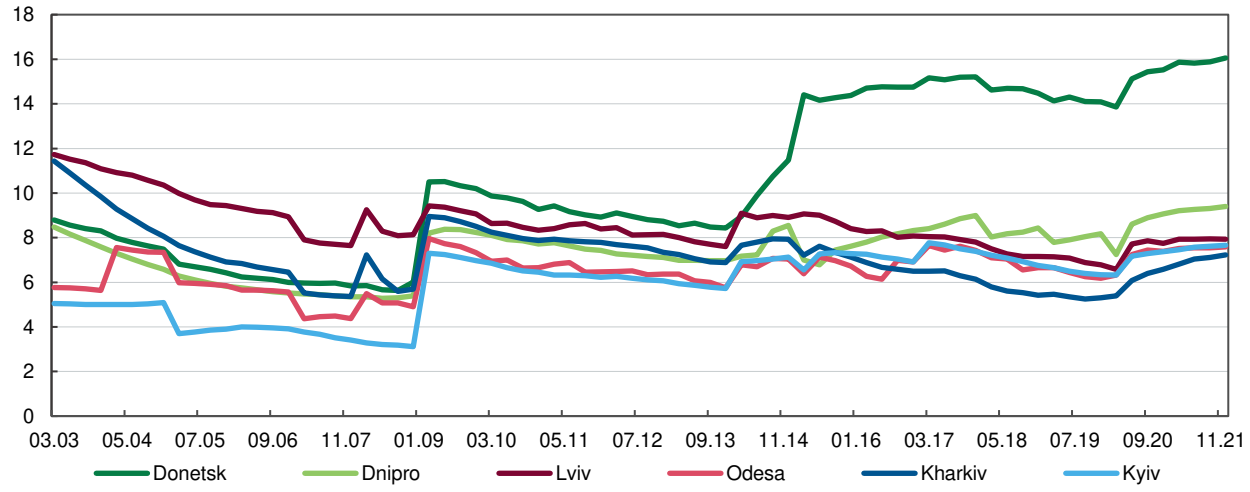


Figure 11. Deseasoned quarterly rate of unemployment (to working age population) in Ukrainian cities, %

IV (c). Data for Calculation of Ratios

For the calculation of the Price-to-Income and Price-to-Rent ratios, we need the data on house prices, household income and rental rates of housing. The sources of data on house prices and household income and the process of its preparation are explained in detail in the previous subsection, as it is also used for the regression analysis.

However, within the frame of this research, the data on rents is used only for the calculation of the Price-to-Rent Ratios, since according to the literature income is a better fundamental to explain price dynamics, due to the results of the model specification process and because of the limited number of observations. The data on average rental rates is also collected from real estate agencies that aggregate advertisements. According to Figure 12, the rental rates for apartments in Kyiv city were relatively stable during the period of observation with a short spike in 2015, due to a hryvnia depreciation. This spike was corrected with the help of the exchange rate adjustment (similar to the house prices' ER-adjustment), some peculiarities of which are explained as follows.

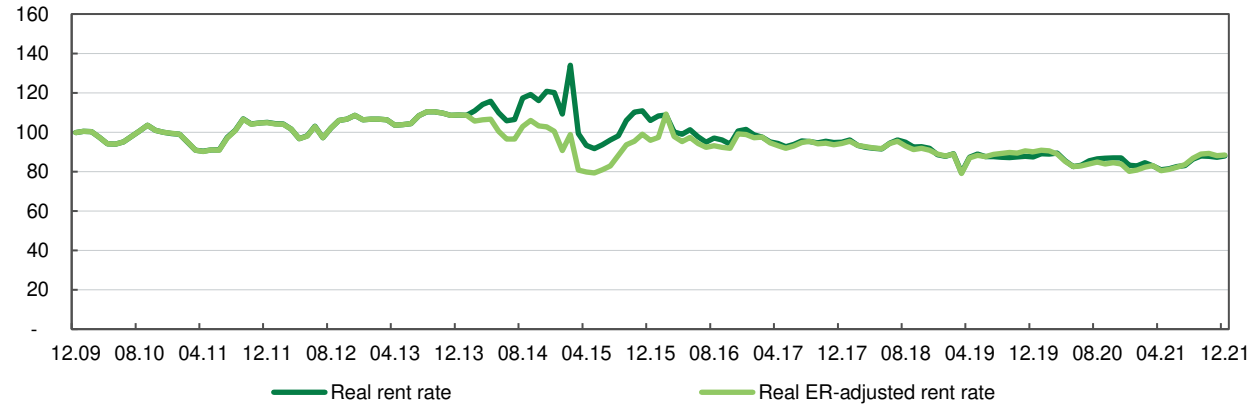


Figure 12. Rental rates in Kyiv, UAH per sq.m

The adjustment factor to house prices is 40%, while for the rental rates it is 20%. The twofold difference in the FX-contribution and thus of the ER-adjustment to the purchase and rental markets is supported by the fact that the rates on the rental market of Kyiv are usually expressed in hryvnia, with only a small share of high-class residences denominated in USD. Furthermore, for an individual, the proceeds from selling an apartment are usually perceived as savings or capital investment, while from renting more often as an operational day-to-day use or short-goal savings. Thus, the proceeds from selling, compared to the rental income, should be more often denominated in the currency that has a higher ability to store value.

V. Results

V (a). First Approach: Calculation of the Price-to-Rent Ratios

We begin with the calculation of the Price-to-Rent Ratios for Kyiv city. This ratio will be assessed for the capital only, since the data on rental rates for apartments is unavailable for other cities of Ukraine. In addition, this time series is relatively short, when compared to other fundamentals, which limits its possible use in this research.

We then proceed with the calculation of Price-to-Income Ratios for each of the six cities that are within the scope of this research. To determine the periods of possible over- or undervaluation of house prices, we calculate the long-term average for the ratio and long-term average for the ratio plus one standard deviation, which are then plotted on the graph.

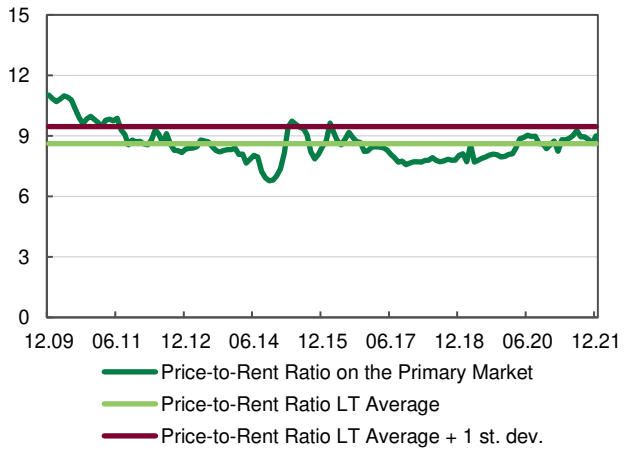


Figure 13. Price-to-Rent Ratio on the primary housing market of Kyiv city

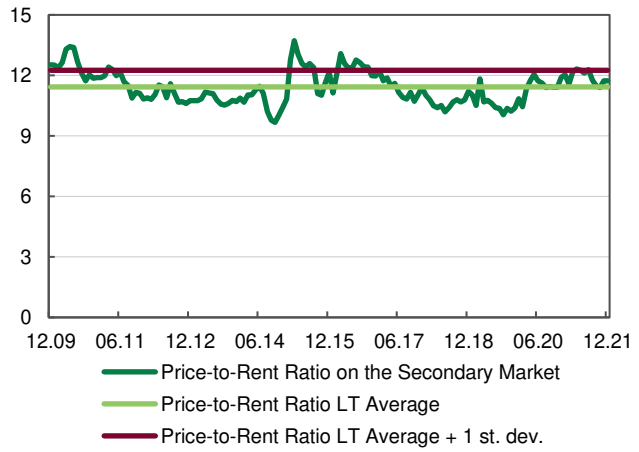


Figure 14. Price-to-Rent Ratio on the secondary housing market of Kyiv city

To account for the high degree of influence that the UAH/USD exchange rate has on both the real estate purchase and rental sectors in Ukraine, both the numerator and denominator of the Price-to-Rent ratio are exchange-rate adjusted.

According to the results of the Price-to-Rent ratio calculations that are visualized on Figures 13-14, we can draw a conclusion that there was supposedly a period of a house price bubble towards the end of the GFC, namely late 2009 – early 2010. In addition, there were residual signs of housing mispricing throughout 2011. There were also some imbalances on the real estate market during the crisis of 2014-2015, which were mainly explained by a sharp depreciation of the hryvnia.

According to **Czerniak and Kawalec (2020)**, over a long-term horizon, the relationship between house prices and rental rates is relatively constant, unless there is a structural break on the market. Thus, assuming no structural change, any large deviations in this ratio are a signal of house prices digressing from fundamental value. This is also the case on the real estate market of Kyiv city, since the ratio was relatively stable within the investigated period with a coefficient of variation that is equal to 9.85%, which stands for a weak variation. That also means that during the last decade the house prices were relatively fairly priced.

V (b). First Approach: Calculation of the Price-to-Income Ratio

As opposed to the house price or rental rates data series, there is no need to do the exchange rate adjustment on the income, since the salaries in Ukraine are predominantly denominated in hryvnias, with an IT-industry (and some rare occasions in other sectors) being an exception. However, unlike other inputs for ratio analysis, income demonstrates a high seasonality. To obtain the average annual wage earned by the household after tax, we multiply the average after-tax monthly deseasoned income of a person in a given city by the number of working people per household (at the national level) and by 12 (number of months in a year). The house price per square meter, which is multiplied by a standardized area of an apartment, is exchange-rate adjusted as in the Price-to-Rent ratio.

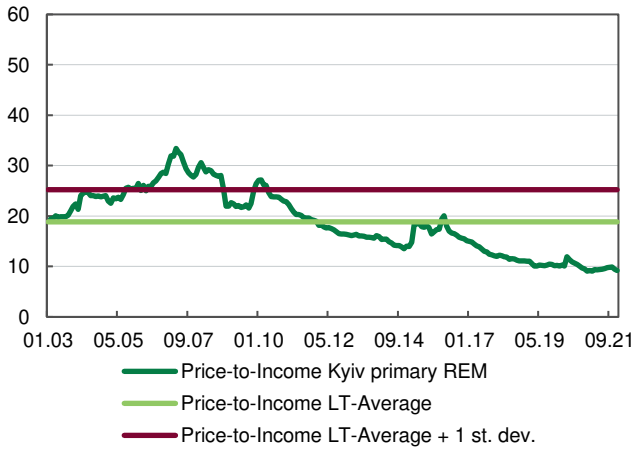


Figure 15. Price-to-Income Ratio on the primary housing market of Kyiv city

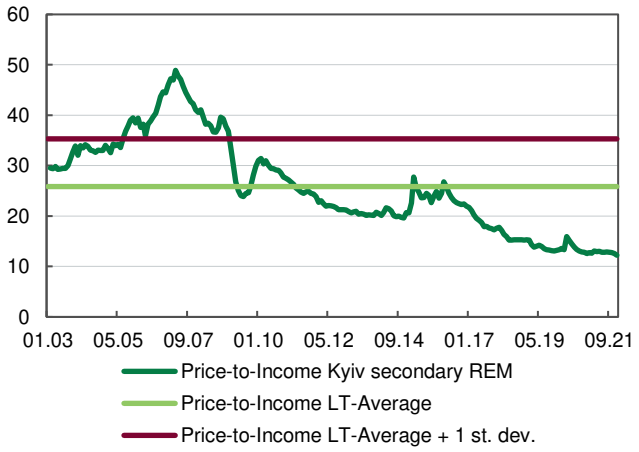


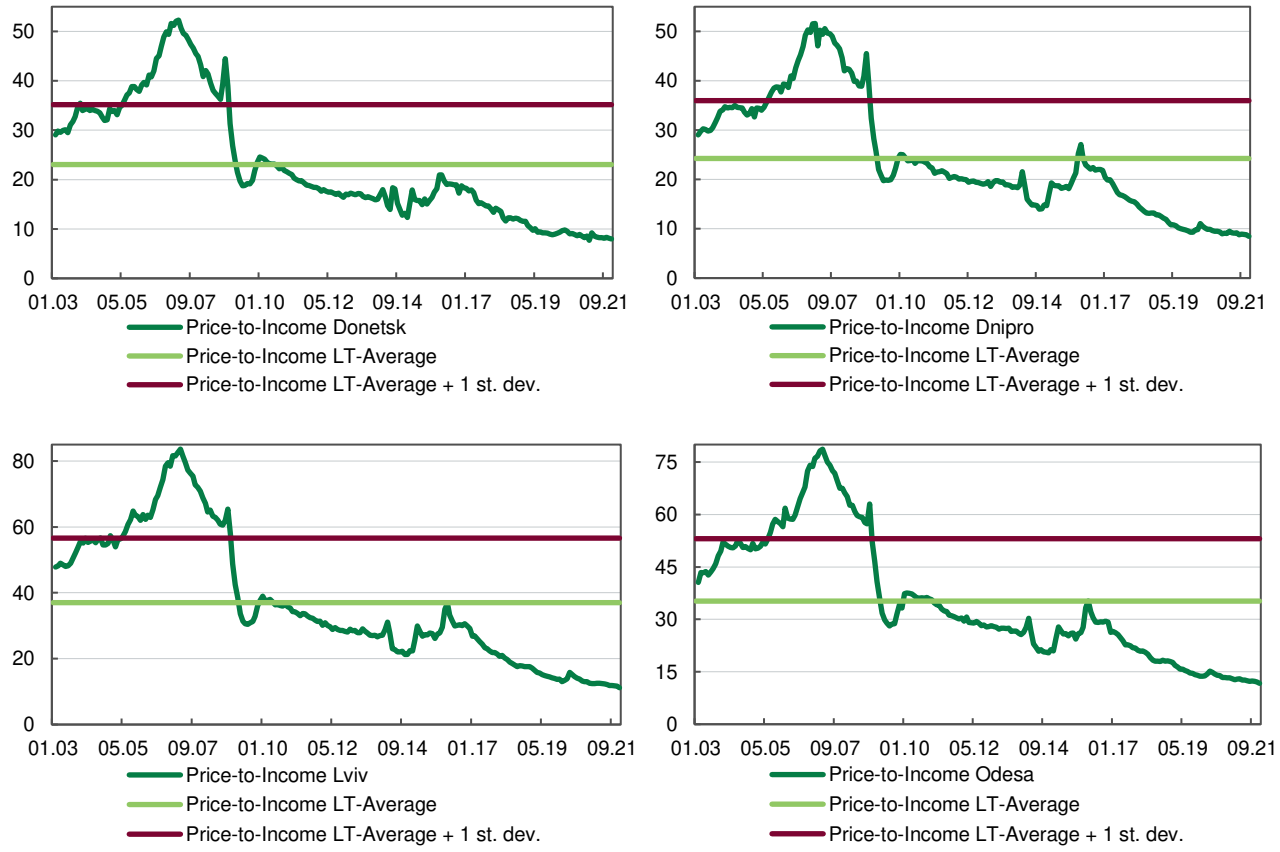
Figure 16. Price-to-Income Ratio on the secondary housing market of Kyiv city

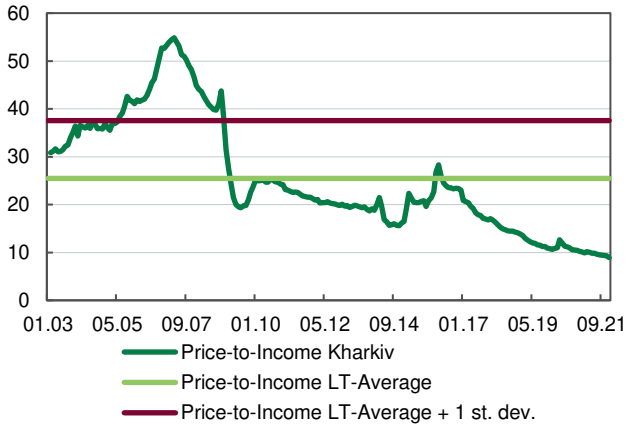
According to Figures 15-16, the house price bubble on the real estate market of Kyiv is again detected on the eve of and during the period of the GFC, from early 2006 to late 2008. In addition, some signs of disequilibrium on the housing market were also present during a short period in early 2010, as it was indicated by the Price-to-Rent ratio before. A spike of the Price-to-Income ratio in early 2015 and 2016 is primarily explained by the

sharp hryvnia depreciation. The real estate market, being closely linked to the exchange rate dynamics, needed some time to adapt to this large change in the macroeconomic conditions. Since 2016, the Price-to-Income ratio was declining, exhibiting a higher affordability of housing for households in Kyiv. Due to the fact that, unlike the Price-to-Rent ratio, numerator and denominator are the indicators of different markets (income being an indicator of the macroeconomic environment and house prices – of the real estate market), the Price-to-Income ratio is much less stable. Moreover, it can change its dynamics or even have a new trend without any structural changes. For example, in Ukraine the downward trend of the Price-to-Income ratio was explained by rising household income, with house prices being relatively constant.

It is worth pointing out that income, despite being one of the key drivers, is still not the single explanatory variable for the house price dynamics. Therefore, it can change its contribution to the house price growth depending on the other macro conditions, such as mortgage lending, unemployment, etc. An absence of or an unnaturally low level of mortgage lending weakens the "income-house prices" transmission mechanism, as it will be proved later.

For instance, before mid-2021, real estate developers could not pass their increased construction costs to consumers, since the demand was weak (this being primarily explained by almost absent mortgage lending). Thus, developers were forced to operate with low margins **(National Bank of Ukraine, 2021).** Therefore, despite the fact that household income, as the primary fundamental that is shaping the house price dynamics, was rising, the prices on the real estate market remained stable. That adds some complications to the regression analysis, which is discussed below.





Figures 17-21. Price-to-Income Ratios on the secondary real estate markets of Ukrainian cities

For the regional cities of Ukraine that fall under the scope of this investigation, the bubble episodes are more prominent. According to Figures 17-21, the Price-to-Income ratios for Donetsk, Dnipro, Lviv, Odesa and Kharkiv were extremely high during the period of early 2005 to late 2008. The level of the ratio was much higher than the average over the observation period, increased by one standard deviation, thus this period can be identified as a bubble.

However, after this period of a pronounced house price bubble, the ratio was further falling below the long-term average level. In contrast, the Price-to-Income ratio for Kyiv was much closer to the long-term average line until 2016. That is explained by the fact that the income level differs significantly for the capital and other cities, and this gap remained stable during the whole period of observation, while the house price levels for Kyiv and other cities were much closer during the bubble build-up than after the correction. For that reason, according to the figures below, the mean level and variation in Price-to-Income ratios are much greater for regional cities than for the capital. Thus, the bubble threshold level for this indicator is much higher. The analysis of the Price-to-Rent and Price-to-Income ratios for the cities within the scope of this research allows us to conclude that in Ukraine there was only one period of house price bubble, which coincided in time with the GFC. During the last half of the decade, the level of housing affordability was decreasing and remained at its historical lows. Based on the comparison with the long-term average and a bubble threshold for the Price-to-income ratio, there were no signs of house price bubble as of the end of 2021.

V (c). Second Approach: Regression Analysis

The regression approach is the second method of deriving the fundamental level of house prices within the scope of this research paper. Following Equation (3), presented in the Methodology section, and variables, described in the Data Description and Selection section we performed the regression analysis, obtained the summary statistics and calculated the fitted values that are considered the fundamental house prices.

While all calculations for the ratio approach were performed on a monthly basis, for regression analysis we use only quarterly data, because the unemployment rate, which is considered essential data for this research, is only available since January 2013 on a monthly basis. That is, this data series is too short to account for any bubble periods that have occurred in Ukraine, according to the results of the ratio analysis. The core models will be calculated using quarterly data only. First, we performed the regression analysis for each city separately

(for Kyiv – for the primary and secondary markets individually), to account for the specific dynamics that are inherent to each of them.

Table 3.

Regression summary statistics, for models, calculated separately for each city under the scope of this research on quarterly data from Q1 2003.

	Dependent variable (House prices):						
	Kyiv primary	Kyiv secondary	Donetsk	Dnipro	Lviv	Odesa	Kharkiv
adrinc	0.286**	0.439***	0.940*	0.499	-10.701***	-1.008*	-2.635***
	p = 0.022	p = 0.009	p = 0.095	p = 0.188	p = 0.000	p = 0.066	p = 0.000
dunemp	-496.484***	-855.953***	-311.880***	-962.999***	-1,307.822***	-1,242.284***	-643.042***
	p = 0.00001	p = 0.00000	p = 0.000	p = 0.000	p = 0.00000	p = 0.000	p = 0.000
Constant	6,341.732***	9,563.773***	6,099.995***	10,281.400***	21,075.610**	13,270.610***	10,505.690***
	p = 0.000	p = 0.000	p = 0.000	p = 0.000	p = 0.000	p = 0.000	p = 0.000
Observations	76	76	76	76	76	76	76
R2	0.249	0.366	0.509	0.701	0.413	0.563	0.477
Adjusted R2	0.228	0.349	0.495	0.693	0.397	0.552	0.462
Residual Std. Error (df = 73)	953.816	1,267.457	959.683	697.028	1,279.698	1,063.156	804.506
F Statistic (df = 2; 73)	12.083***	21.061***	37.795***	85.557***	25.691***	47.119***	33.228***
Note:	*p<0.1; **p<0.05; ***p<0.01						

Where the "adrinc" is the aggregate disposable income for each city and "dunemp" the deseasoned unemployment rate for each city.

According to Table 3, the most import conclusion that we must draw is that we managed to build models with sufficiently high explanatory power for all cities. For most of them – we obtained intuitively clear and significant coefficients. Therefore, this analysis enables us to fit the fundamental house prices, in order to proceed with a bubble detection framework. The results of individual regressions for primary and secondary markets of Kyiv city give us a chance to make another major conclusion. The aggregate disposable income and unemployment variables have more statistically significant coefficients in the model, when the explained variable is data on house prices on the secondary market. That corresponds with basic economic sense, as the transactions on the secondary market occur between individuals and, thus, the prices are more affected by the changes in household welfare, comparing to the transactions on the primary market.

The regression results indicate that the signs of coefficients for the aggregate disposable income variable are intuitively wrong for some cities. That is, for Lviv, Odesa and Kharkiv the income variable appears with a negative sign of the coefficient.[6] Though it is wrong intuitively and according to economic sense, it is explained by the fact that even though income was growing for almost the entire last decade, house prices remained

[6] For the purpose of this research, as it was mentioned previously, the regression analyses rely on models that are in levels and that are adjusted for inflation. The negative, contrintuitive signs of the coefficients for some cities are eliminated when the regression analysis is built on growth rates instead of levels; and when the data on both (or either) left-hand side and (or) right-hand side is in nominal instead of real terms. The model that incorporates the variables that are presented in nominal terms has proven not suitable for bubbles detection. First, when both left-hand side and right-hand side data is in nominal terms, the model works well (high R^2 and correct signs of coefficients) only due to the inflation that is inherent to both dependent and independent variables. Thus, we fail to explain the real house price movements, but explain the dynamics due to inflation primarily. Secondly, when we have nominal variables on either side (we checked the model results while using nominal house prices, as it is best supported by economic sense), the independent variables fail to account for the impact of inflation and, therefore, the fitted values cannot be used to detect the house price bubbles. Taking into account that the counterintuitive signs are further justified, we did not deviate from the method (level-based) that is considered to be best suited for the purpose of this research, according to the literature.

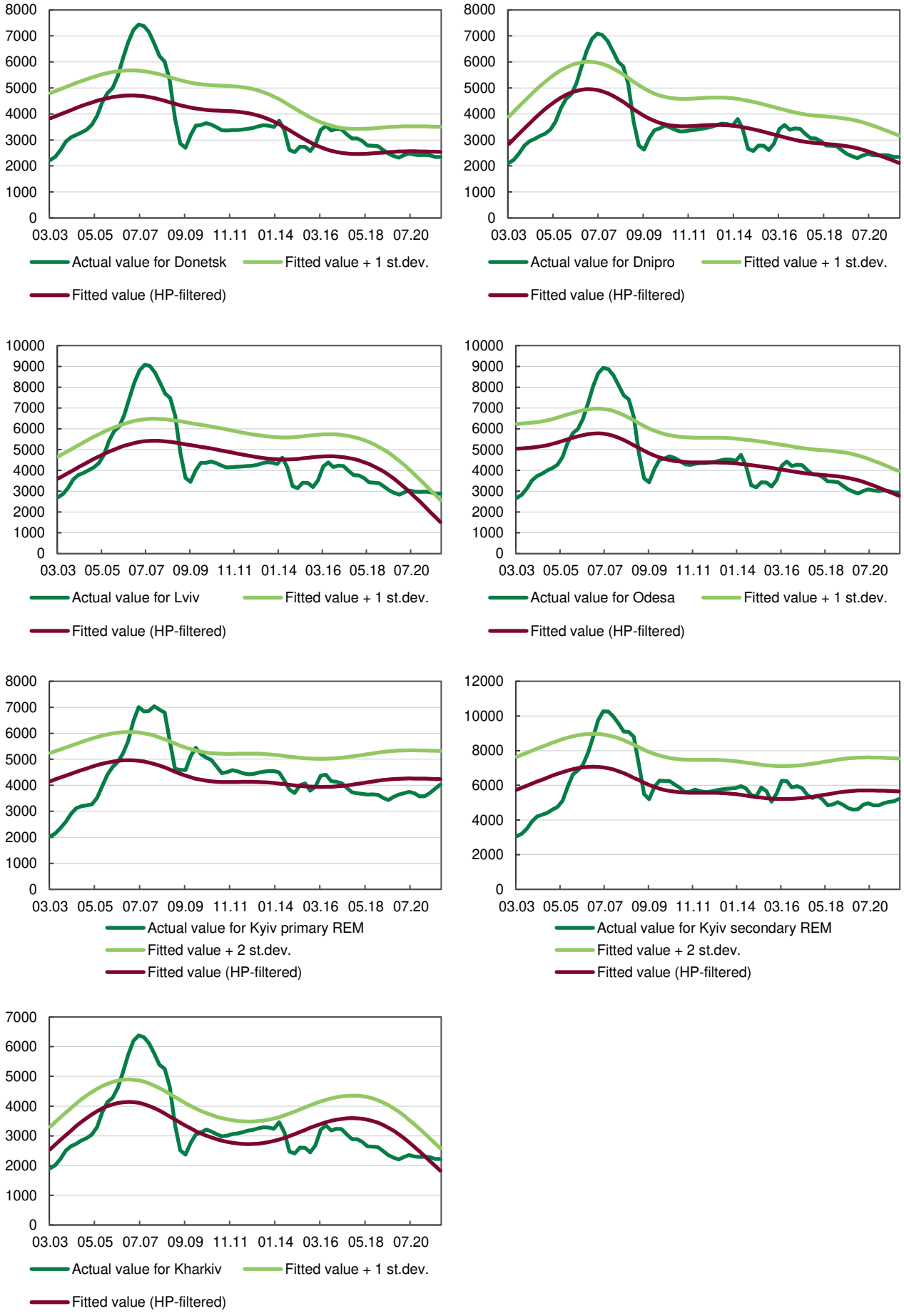
stable. Such situation was primarily explained by the almost absent mortgage lending due to both unaffordable high mortgage interest rates and low mortgage supply from banks because of low level of creditors rights protection (as well as low mortgage demand from households in previous periods). Since normally even though the income is growing, this growth has limited impact on housing affordability if households are unable to purchase it in installments (use mortgage lending). Therefore, this income coefficient signs phenomenon is not due to erroneous model specification or any computational mistakes. This is largely explained by the fact of the almost full absence of a mortgage market in Ukraine that is unnatural for housing markets and has led to low demand even during periods of improving household welfare. This is supported by the statement that the sensitivity of house prices to its drivers largely depends on the structural characteristics of each economy **(BIS, 2020)**, with the mortgage market and its peculiarities being one of the most important elements of the structure.

At the same time, the coefficients for the unemployment rate variables are correct and highly statistically significant for all cities. It is also worth noting that the R^2 strongly differs across cities. Although the data and model specification are the same for all regions, the strongest explanatory power of models is recorded for Dnipro, Odesa and Donetsk cities, while for Kyiv, the R^2 is quite low. Again, for the purpose of this research we can allow underspecified models[7], since we do not want the fundamental level to follow the price pattern too closely. In such a way, it can incorporate the bubble build-up.

The fitted values based on regression results form the fundamental house prices, which are then increased by one standard deviation to determine the bubble threshold, except for Kyiv, where the fitted value is increased by two standard deviations. However, in the Methodology section it was mentioned that an appropriate level of bubble threshold is two standard deviations, for the purpose of this research we decided to choose one for most of the cities, since we have a high variation of house prices there. This high value of the volatility estimate for prices is stemming not from the frequent or large-scale price changes, but from a significant price correction after the house price bubble. Nevertheless, it is not the case for Kyiv city. The reasons for this are described in the ratio analysis section.

According to Figures 22-28, for almost all cities that are investigated, the bubble on housing market was detected only during the period of GFC that is from mid-2006 to early 2009. Afterwards, there are no signs of massive price overvaluation. However, we are not fully satisfied with the fact that for some cities, our individual model provides counterintuitive results. In this way, the fundamental values for Lviv, Odesa and Kharkiv are falling when the income is increasing, which contradicts the economic sense.

[7] In order to fit the fundamental house prices, which are then used to detect house price bubbles, the model must be underspecified. Otherwise, we risk to fit and explain the bubble as well. However, to check if the addition of mortgage lending variables makes our model fully specified, we tested the models with the *New mortgage issued during the quarter to GDP* variable. This variable has a very high correlation with the dependent variable, has positive and significant coefficients and provides high R^2 for the models. The R^2 for the models with *New mortgage issued during the quarter to GDP* variable being added to our baseline specification for all six cities under investigation was in the range from 82.1% to 91.7%. Due to the high correlation of the unemployment rate and mortgage variables for Kyiv and Dnipro cities, the "fully specified" models for these cities were estimated with the unemployment rate incorporated into the aggregate income variable. Nevertheless, for the purpose of our research, we use the model in its baseline specification and low-to-medium R^2 statistics.



Figures 22-28. Comparison of fundamental values, bubble thresholds and actual values of house prices in Ukrainian cities

Fundamental values – fitted values of individual regressions for each city separately. Bubble thresholds – fundamental values, increased by 1-2 standard deviations for fitted values (as stated on graph). Actual values – real exchange rate adjusted house prices (dependent variables) for each city. Fitted values are filtered with HP-filter with lambda 1600.

To reinforce the results of the individual regressions, we decided to perform our analysis further based on panel data. We applied the pooled OLS regression model and the regression model based on the between estimator for the panel data, which has data for all cities across all the period of observation.

Table 4.

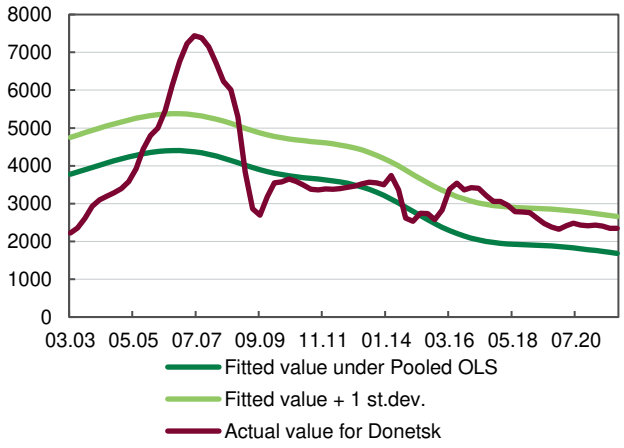
Results of the pooled OLS model on the panel data

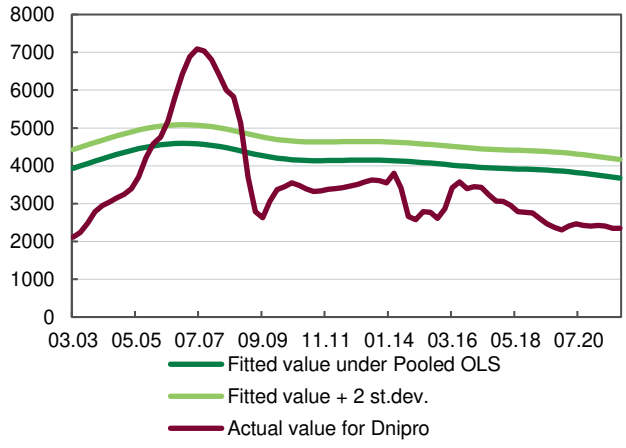
Pooling Model				
Call:				
plm(formula = rer ~ adrinc + dunemp, data = panel, model = "pooling", index = c("city", "Date"))				
Balanced Panel: n = 7, T = 76, N = 532				
Residuals:				
Min.	1st Qu.	Median	3rd Qu.	Max.
-2874.93	-1003.75	-250.42	733.70	5092.66
Coefficients:				
	Estimate	**Std. Error**	**t-value**	**Pr(>|t|)**
(Intercept)	6301.525403	237.094168	26.5782	<2.2e-16***
adrinc	0.128446	0.047566	2.7004	0.007148**
dunemp	-305.127774	27.097043	-11.2606	<2.2e-16***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Total Sum of Squares: 1369200000				
Residual Sum of Squares: 1.058e+09				
R-Squared: 0.22725				
Adj. R-Squared: 0.22432				
F-statistic: 77.7821 on 2 and 529 DF, p-value: < 2.22e-16				

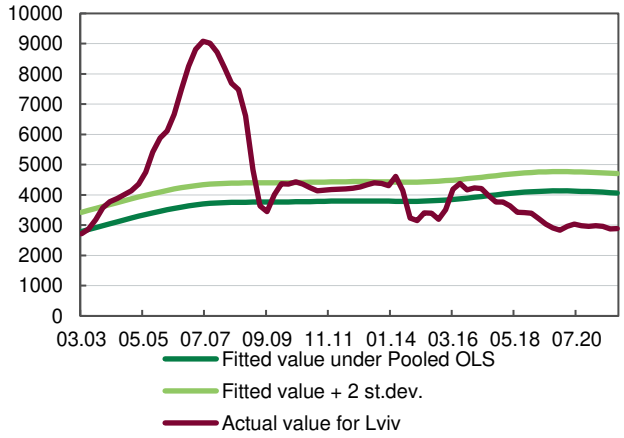
Where "adrinc" is the aggregate disposable income for each city and "dunemp" the deseasoned unemployment rate for each city.

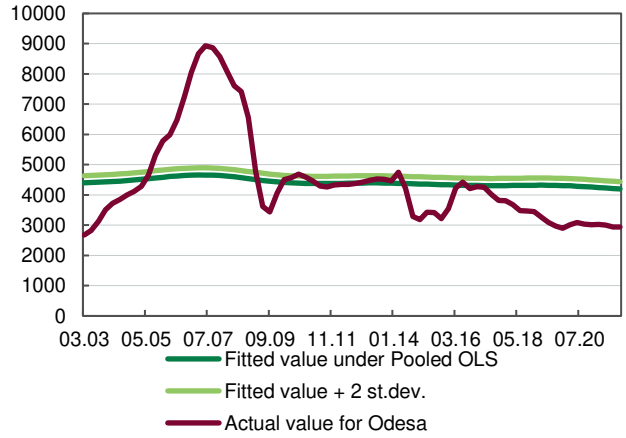
According to the results of the pooled OLS model, presented in Table 4, both the aggregate disposable income and unemployment rate variables appear with the right sign. The unemployment rate and aggregate income are also significant here. The R^2 appears to be sufficient for the purpose of our research also. Although in the literature there are some doubts about the appropriateness of pooled OLS estimators for panel data regressions, since it does not account for different individual effects, there is also some evidence of this method being more useful in some cases. According to **Baltagi et al. (2000)**, pooled OLS models may outperform their heterogeneous counterparts due to the relative variability of the data between individual time series and panels. Following an RMSE criterion, the efficiency gains from pooling can offset the biases due to interstate heterogeneities. In this research, the pooled OLS model for panel data seems to correctly catch the interdependencies between variables and provide some meaningful results.

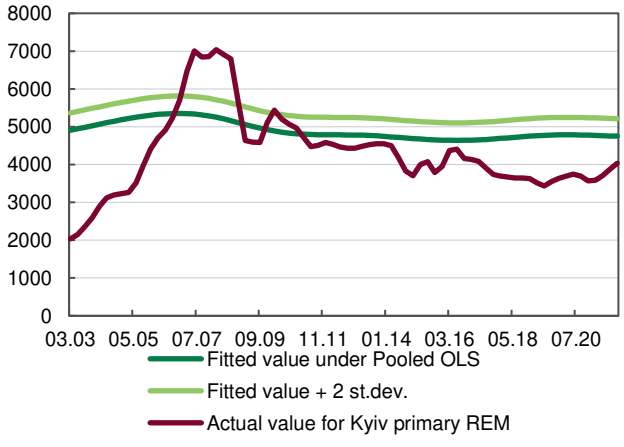
According to the fitted values, produced by the pooled OLS model that are presented in Figures 29-35 the results of this regression analysis produce similar bubble periods to those that we have identified previously in this section. That is, the bubble is identified in general only during the GFC period – from early 2006 to mid-2009. Still, this model provides us with interesting results for Donetsk city. As opposed to the results of individual regressions, the pooled OLS model indicates that the period after 2014 is a period of declining fundamental house prices for Donetsk, since the rate of unemployment for the Donetsk oblast was constantly increasing during this period.

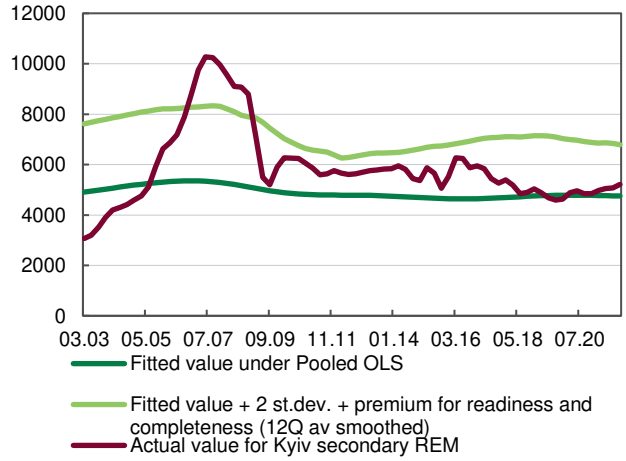


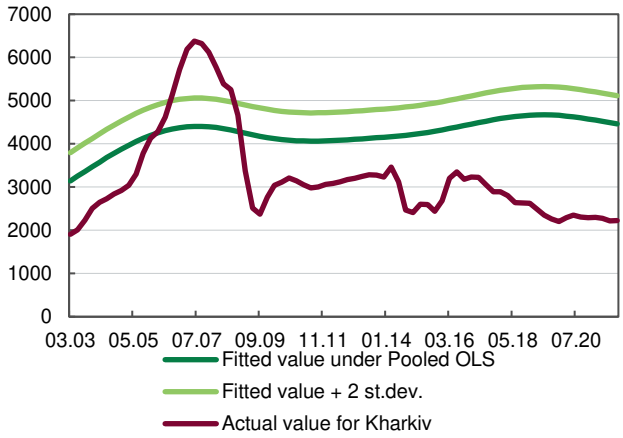












Figures 29-35. Comparison of fundamental values, bubble thresholds and actual values of house prices Ukrainian cities

Fundamental values – fitted values of pooled OLS regression for panel data. Bubble thresholds – fundamental values, increased by two standard deviations for fitted values (as stated on the figures). Actual values – real exchange rate adjusted house prices (dependent variables) for each city. Fitted values are filtered with HP-filter with lambda 1600.

Since the pooled OLS model does not account for individual variation in the explained variable when producing the fitted values, the fundamental house prices for Kyiv city are produced jointly for the primary and secondary markets, since the explanatory variables were the same for both. Thus, we decided to make the bubble threshold for the secondary REM higher. We additionally increased the fundamental value for Kyiv secondary housing market, fitted by pooled OLS model, not only by two standard deviations, but also by the value of a premium for readiness and completeness of the housing (why housing on the secondary is more expensive than on the primary market is described in detail in the Background section). The premium for readiness and completeness of the housing is a ratio of house prices on the secondary market to house prices on the primary market that is then smoothed by taking the 12Q average.

Thus, according to regression analyses, we identified the periods of house price overvaluation that occurred on the real estate markets of Ukrainian cities under the scope of our research from the beginning of 2003 to the end of 2021. This has allowed us to reaffirm the results of the ratio analysis that indicated that the house price bubble has taken place on Ukrainian real estate markets only once – during the GFC. Since then, house prices remained well below the level of fundamental house prices for most of the time. For most cities, the gap between the fundamental house prices and actual values has been recently increasing due to increasing welfare of households and relatively stable real house prices.

VI. Conclusions

In the process of this research, we managed to build a framework for assessing the fundamental values of house prices and identification of bubbles on the residential real estate market for six Ukrainian cities: Kyiv, Donetsk, Dnipro, Kharkiv, Lviv and Odesa. The Ukrainian economy and real estate market have a number of peculiarities, such as episodes of high inflation, high dollarization of the housing market and an inactive mortgage market. Thus, although this research draws upon many comparable studies, we had to make a number of corrections, such as using a dependent variable that is adjusted for the UAH/USD exchange rate. Since in Ukraine we have a pronounced division into primary and secondary real estate markets, we constructed the

fundamental house price value and a framework for the detection of bubbles for both housing markets of the city of Kyiv. First, we formed a long list of all possible variables that are deemed fundamental for house prices in the literature. Then, through trial and error and multiple iterations of model specification, we developed a short list of variables that work the best as fundamental variables.

To achieve the stated goal of this research, we used two general approaches: ratio calculation and regression analysis. These general approaches were then subdivided into two each. We calculated the Price-to-Rent and Price-to-Income ratios that can identify a possible over- or undervaluation of house prices for Ukrainian cities under the scope of this investigation. Then, we performed the regression analysis by building individual multifactor models for different cities and by running a pooled OLS regression for the panel data. In the process of running individual regressions, we faced a problem of inverse coefficient signs for aggregate disposable income. This is an unnatural relationship between income and the value of housing, which is entirely explained by an almost non-existent market of mortgage lending. However, we do not consider this a permanent distinction of the Ukrainian economy; on the contrary, before the start of the war in February 2022, we had been expecting the market to reach normality in the course of time. Our expectations had been driven by the weak but steady recovery of mortgage lending from mid-2020 to January 2022 and the results of banking surveys **(National Bank of Ukraine, 2021)** that were asserting that the market would be several times more active in the years to come. Thus, we had been expecting that with the gradual recovery of the mortgage market, households' income that is a true fundamental of house prices, would start driving the intrinsic value of housing that would be reflected by the calculations of fundamental house prices under this framework. We expect this framework to become increasingly more valuable with the recovery of the mortgage market, since most overvaluations on the residential real estate market were driven by massive mortgage lending.

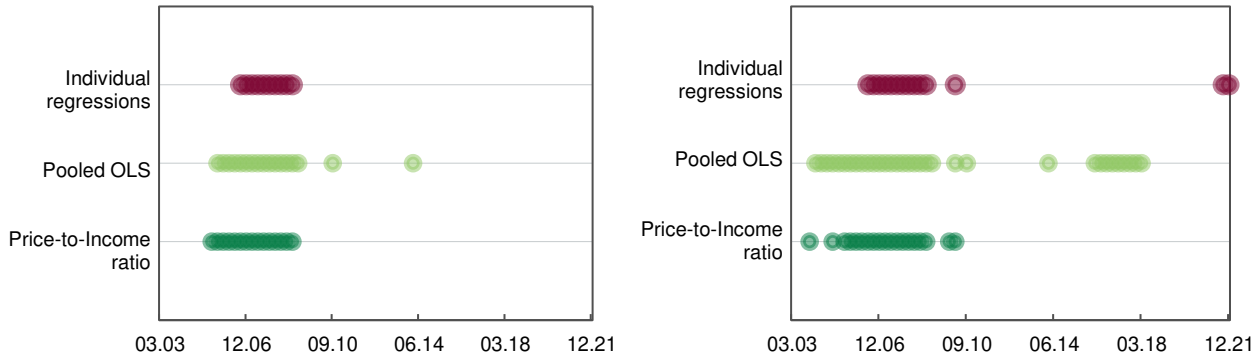


Figure 36-37. Bubble signals with different approaches

On fig.36 only signals of a bubble that appear for at least 2 cities simultaneously are presented.
On fig.37 signals of a bubble that appear for at least 1 city are presented.

The results of the analysis, performed under this research indicate that since 2003 the largest Ukrainian cities experienced only one true house price bubble – during the GFC. According to Figure 36, we can see that the bubble signals from three methods: Price-to-Income ratio, individual regressions and a pooled OLS panel regression indicate that there was a bubble from late in 2005 to early 2009. We consider the Price-to-Income ratio to be the universal method, since it was the first to capture the signs of bubble at its beginning and caught

the signals straight to its end. Slightly less sensitive was the pooled OLS panel data regressions, which detected a bubble with a lag of one quarter. In addition, the last to capture the overvaluation was the individual regressions approach. It is also worth noting that some signs of a bubble were detected by the pooled OLS approach in the late 2010, when house prices bounced back after the bubble burst, while the fundamentals were still low after the crisis. Since it lasted only for one quarter and only prevailed for two cities, Lviv and Odesa, there are no grounds to call this episode a bubble. Based on Figure 37, we can notice a bubble episode that occurred on the residential real estate market of Donetsk in early 2016 to the end of 2017. This is explained by the fact that despite relatively constant quoted prices (at least nominally), the welfare of households was deteriorating, due to rising unemployment in Donetsk oblast after it was partly occupied by Russian and Russia-sponsored troops. During the last half of the decade, there were no pronounced and prolonged signs of house price bubbles on the real estate markets of Ukraine.

Table 5.

Comparison of bubble signals across different approaches

	Type of regression analysis compared to ratio analysis	Donetsk	Dnipro	Lviv	Odesa	Kharkiv	Kyiv primary REM	Kyiv sec-ry REM
Number of quarters in which bubble signals were different	Individual regressions	7	6	7	5	5	8	6
	Pooled OLS panel data regression	14	3	7	4	6	8	5
% of quarters in which bubble signals were different	Individual regressions	9%	8%	9%	7%	7%	11%	8%
	Pooled OLS panel data regression	18%	4%	9%	5%	8%	11%	7%

According to Table 5, the bubble signals, produced by the different methods, in total, coincide in time. We compared the signals, produced by both the regression methods with the results of the Price-to-Income ratio analysis, since the latter produced the best results in view of the timing and with regard to economic sense. Thus, the percentage of quarters in which bubble signals were simultaneous with the ones that were produced by ratio analysis was generally higher for the individual regressions, since they did not capture the deterioration of welfare conditions (according to the unemployment rate solely) in Donetsk oblast in 2016-2017. In total, all three methods provide reasonable and concurrent results that collectively form a reliable framework for detecting price bubbles on the residential real estate markets of Ukraine.

Although the methods provide the same results when detecting the past house price bubbles, they work differently when it comes to identifying the periods of house price overvaluation in the future. While methods, based on regression analysis are well suited for detection of house price bubbles in the periods to come, since the threshold is dynamic and depends on the current well-being of the households, the ratio analysis relies on the threshold that is a long-term average and thus is constant. Therefore, although the ratio analysis is good for detecting bubbles in the past, it requires some improvement to make it more suitable for future identification of price overvaluation. The aforementioned fine-tuning is among the next steps, planned within this research.

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