

Simeonovski, Kiril; Ramadani, Gani; Unevskaja Andonova, Danica

Working Paper

Assessment of the fundamental value of residential properties in the Macedonian real estate market with a macroprudential approach

Working Paper, No. 2/2025

Provided in Cooperation with:

National Bank of the Republic of North Macedonia, Skopje

Suggested Citation: Simeonovski, Kiril; Ramadani, Gani; Unevskaja Andonova, Danica (2025) : Assessment of the fundamental value of residential properties in the Macedonian real estate market with a macroprudential approach, Working Paper, No. 2/2025, National Bank of the Republic of North Macedonia, Skopje

This Version is available at:

<https://hdl.handle.net/10419/336492>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

National Bank of the Republic of North Macedonia



Working paper No. 2

2025

Assessment of the fundamental value of residential properties in the Macedonian real estate market with a macroprudential approach

Kiril Simeonovski, Gani Ramadani and Danica Unevska Andonova¹

Abstract

In this analysis, an indicator to assess residential property prices in the Macedonian real estate market was developed by applying a macroprudential approach to analysing borrowing capacity. The indicator of household borrowing capacity is calculated as the ratio of the market value to the fundamental value of real estate, whereby a higher actual market price indicates that real estate prices are overvalued and therefore less affordable, while a higher fundamental price indicates that prices are undervalued and therefore more affordable. The analysis of the Macedonian real estate market for the period from Q1 2012 to Q4 2023 concludes that residential property prices, according to both forms of the borrowing capacity (static and dynamic), were overvalued during almost the entire analysed period. The analysis reveals that lowering the regulatory threshold of the DSTI indicator, which central banks use as an instrument to prevent excessive household indebtedness, would reduce the fundamental value of residential properties and thus make them less affordable. Nevertheless, given that this represents only one possible analytical approach, the results should be interpreted with caution and within the context of a broader analysis of the Macedonian real estate market.

JEL-classification: G12, R31, E37.

Keywords: market value of residential properties, fundamental value of residential properties, static borrowing capacity, dynamic borrowing capacity.

¹ Email addresses: SimeonovskiK@nbrm.mk, RamadaniG@nbrm.mk and UnevskaD@nbrm.mk. The views expressed herein are those of the authors and do not necessarily represent the views of the National Bank of the Republic of North Macedonia.

1. Introduction

The issue of housing affordability is of particular interest both to households faced with the decision of whether to buy or rent a housing unit as well as to policymakers concerned with household creditworthiness and the maintenance of financial stability. Since the financial crisis of the late 2000s underscored the importance of the real estate market for financial stability, the economists and policymakers have begun paying closer attention to movements in real estate prices as a potential source of systemic risk. Moreover, the shift towards macroprudential regulation has led to limitations on households' borrowing capacity and on the maximum amount of housing loan they can obtain through the introduction of thresholds for the DSTI (debt service-to-income) and LTV (loan-to-value) indicators. Consequently, the following questions emerge as logical: "Are residential properties affordable at current prices and under the current credit and regulatory conditions and level of disposable income?" and "What impact changes in housing prices and in regulatory conditions might have on housing affordability?"

The main purpose of this analysis is to provide answers to the stated questions regarding the Macedonian real estate market, taking into account movements in residential property prices in Skopje, the level of disposable income, and the credit and regulatory conditions in the Macedonian economy. To that end, we follow the macroprudential approach for borrowing-capacity analysis developed by Andrlje & Plašil (2019) and Plašil & Andrlje (2019), who analysed housing affordability in the Czech Republic and Canada. In this analysis, a macroprudential approach is applied, using the DSTI and LTV indicators as macroprudential instruments for assessing the quality of household credit demand². Furthermore, the assessment of households' borrowing capacity is based on actual data on disposable household income, interest rates on housing loans, and the average maturity of housing loans, while the average market value of traded real estate is determined by using actual data for the Macedonian real estate market in line with National Bank's methodology. The time frame of the analysis covers the period from Q1 2012 to Q4 2023.

It should be highlighted that the objective of this analysis is not to forecast the future movements of the variables used in the model, but to apply a modern macroprudential approach to assess whether residential property prices on the Macedonian market are undervalued or overvalued. In this analysis, the measure of undervaluation or overvaluation of residential properties is defined as the deviation of the market value from their estimated fundamental value. Although various approaches exist for estimating the equilibrium value of housing prices (e.g., structural vector autoregression models, cointegration approaches etc.), the fundamental value of residential properties in this analysis is measured through their affordability for the average household—that is, through the maximum acceptable price a household can pay based on its disposable income as well as credit and regulatory conditions, without including other supply and demand factors of the housing market. Therefore, the results and conclusions should be interpreted with a degree of caution given that this represents only one possible analytical approach.

The contribution of this analysis to the research literature regarding the relationship between the Macedonian real estate market and the stability of the Macedonian financial system

² According to the Decision on macroprudential instruments for the quality of household credit demand ("Official Gazette of the Republic of North Macedonia" Nos 2/23 and 96/23), the DSTI (debt service-to-income), LTV (loan-to-value), and DTI (debt-to-income) indicators are determined as macroprudential instruments, and upper limits of DSTI and LTV are also defined.

is threefold. Firstly, it analytically complements the contribution of Davidovska-Stojanova et al. (2008) by applying a new approach for assessing the equilibrium value of real estate prices and deviations from it. Secondly, it applies a simple methodology for determining housing affordability, following the examples of Andrle & Plašil (2019) and Plašil & Andrle (2019), by introducing an indicator that signals whether housing prices in the real estate market are overvalued or undervalued. Thirdly, the analytical approach is useful for policymakers because it enables monitoring how changes in the DSTI indicator would affect changes in the overvaluation or undervaluation of residential property prices.

Beyond the introduction, the rest of the analysis is structured as follows. Section 2 reviews the related literature on housing affordability, real estate price movements and the relationship between borrowing capacity and financial stability. Section 3 elaborates the methodology of the approach for assessing housing affordability through a borrowing-capacity analysis. Section 4 presents and comments on the results of the empirical analysis using data from the Macedonian real estate market, while Section 5 analyses the impact of potential regulatory changes in the DSTI indicator. Section 6 contains concluding remarks.

2. Literature review

The economic literature analysing real estate price dynamics and the relationship between the real estate market and financial stability is extensive, particularly for highly developed countries, with significant contributions from researchers in central banks and international financial institutions³. Notably, early studies in this field have primarily analysed the connection between the real estate market and economic activity, while later studies focused more on its relationship with financial stability and the use of macroprudential instruments. This section provides an overview of the main approaches for real estate market analysis, such as: (1) incorporating real estate market variables into dynamic stochastic general equilibrium (DSGE) models; (2) analysing factors that influence real estate prices with application of structural vector autoregressive (SVAR) models; (3) cointegration approaches for assessing real estate overvaluation; and (4) alternative non-regression approaches for analysing real estate overvaluation.

Incorporating real estate market dynamics into DSGE models helps to assess aggregate effects on other sectors of the economy (e.g. Iacoviello & Neri, 2010; and Guerrieri & Iacoviello, 2017), while other researchers use these models to examine the effectiveness of macroprudential measures in mitigating shocks originating in the real estate market (e.g. Funke & Paetz, 2016; and Rabanal, 2018). From the first group, Iacoviello & Neri (2010), in an analysis of the US real estate market, found that spillover effects from the housing market onto the broader economy should not be ignored; moreover, they tend to grow over time and primarily affect consumption rather than investment. From the second group, Rabanal (2018), in a study on Hong Kong, found that the introduction of macroprudential instruments prevented double-digit growth in real estate prices and in household indebtedness (measured by the household credit-to-GDP ratio).

³ Examples include McCarthy & Peach (2004), OECD (2005), ECB (2011, 2015), Igan & Loungani (2012), Ott (2014); Turk (2015), Philipponnet & Turrini (2017), Warisse (201), Geng (2018), Andrle & Plašil (2019), Plašil & Andrle (2019), Deb et al. (2022), BoE (2023), Beraldi & Zhao (2023), Biljanovska et al. (2023) and Valderrama et al. (2023).

Structural vector autoregressive models allow identification of structural factors, i.e., shocks that cause changes in real estate prices (e.g. Iacoviello, 2000; Rubio-Ramirez et al., 2010; Nocera & Roma, 2017; Ben-David, 2019; and Deb et al., 2022). In one of the earliest studies on this topic, Iacoviello (2000), through an analysis of housing price fluctuations in six European countries, found that monetary policy shocks have a significant effect on real estate prices, and the time needed for this effect to materialise largely coincides with the timing of the impact on economic activity. In a more recent study, Deb et al. (2022), analysing real estate markets in Asia and Oceania, concluded that misalignment between real estate prices and borrowing costs is a key factor for exposing housing prices to risk, and that the high household indebtedness can spill over into the real economy and financial stability.

Some authors, in order to assess the degree of overvaluation, use models based on cointegration techniques in which real estate prices are expressed as a function of the long-term equilibrium real price, determined by market conditions and demand side factors (e.g. Ott, 2014; Turk, 2015; Geng, 2018; and Valderrama et al. 2023). In an analysis of European real estate markets, Valderrama et al. (2023) concluded that real estate prices were significantly overvalued in most countries by the end of 2022. The trend of overvaluation in highly developed countries began at the onset of the pandemic, while in emerging economies it became more pronounced towards the end of 2021.

A group of authors analysing real estate price movements avoid using regression models and instead develop a structural models and indices (e.g. Andrlje & Plašil, 2019; Plašil & Andrlje, 2019; and Biljanovska et al. 2023). Andrlje & Plašil (2019) and Plašil & Andrlje (2019) apply two structural approaches for analysing housing affordability with clearly defined parameters and inputs: (1) the borrowing-capacity approach and (2) the intrinsic-value approach. The authors estimate the fundamental value of residential properties and, by comparing it with the market value, determine whether real estate values are overvalued or undervalued. As reasons for avoiding regression, Plašil & Andrlje (2019) cite the weak connection of regression models with economic theory in terms of structural characteristics and variable selection, as well as the backward-looking nature of regression models, which rely on historical data and require sufficiently long time series. Biljanovska et al. (2023) develop a housing-affordability index based on data for several variables from the real estate market and the financial sector, including the price of a housing unit, interest rates on housing loans, the LTV ratio, average maturity of housing loans, average residential property size, average household size, and median household income. The index is calculated as the ratio of median household income to the monthly loan payment (annuity) required for purchasing a housing unit.

3. Theoretical model

In this section, a theoretical model is developed based on the approach for assessing housing affordability through borrowing capacity according to Andrlje & Plašil (2019) and Plašil & Andrlje (2019)⁴, and additional adjustments reflecting the conditions in the Macedonian financial system and the Macedonian real estate market were incorporated. This approach is suitable for our country because it uses the DSTI and LTV indicators as macroprudential instruments applied

⁴ The authors also develop an approach for assessing housing affordability by discounting the expected future rental income from the traded housing unit as a basis for calculating the fundamental value of housing units. However, this approach cannot be applied to the Macedonian real estate market due to the lack of reliable data on rental prices.

in the Macedonian financial system, as well as because the results obtained from the model are sensitive to changes in macroprudential regulation.

Borrowing capacity indicates the maximum amount of a housing loan that households can obtain based on disposable income, interest rates, and the size of debt repayments. By its nature, the concept is macroprudential because it depends on legal regulations, i.e. the application of the DSTI and LTV indicators as macroprudential instruments. Essentially, the concept is based on the premise that households cannot allocate their entire disposable income for debt repayment of the approved loans due to the necessity of meeting consumption needs.

Two forms of borrowing capacity are explained: (1) static and (2) dynamic. The first refers to housing affordability at the time the housing loan is approved, while the second analyses the household's capacity to service the loan throughout the entire repayment period.

Before explaining static and dynamic borrowing capacities in more detail, it is useful to introduce three assumptions regarding the loan maturity and the macroprudential instruments arising from the existing regulation in our country.

Assumption 1: In the housing loan market, there is a maximum maturity of housing loans and therefore a maximum repayment period of $s_{max} \leq 120$,⁵ such that the household's loan repayment period does not exceed this upper limit, i.e., $s_{i,t} \leq s_{max} \leq 120$.

Assumption 2: In the economy, there is an upper threshold for the DSTI indicator of $\alpha_{max} = 0.50$ ⁶ such that each household allocates a share of its disposable income at a rate within this threshold, i.e., $\alpha_{i,t} \leq \alpha_{max} = 0.50$.

Assumption 3: In the economy, there is an upper threshold for the LTV indicator of $\lambda_{max} = 0.85$ ⁷ such that each bank approves a housing loan whose share in the value of the housing unit is within this threshold, i.e., $\lambda_{i,t} \leq \lambda_{max} = 0.85$.

For simplicity, permitted exceptions to these thresholds according to the domestic regulation as well as the possibility for a bank to issue a more prudent loan relative to these thresholds are not taken into consideration.

3.1. Static borrowing capacity

The static borrowing capacity aims to set a condition for housing affordability at the time when the housing loan is approved, and therefore it takes into account market developments only during that specific period.

⁵ According to the Decision on macroprudential instruments for the quality of household credit demand ("Official Gazette of the Republic of North Macedonia" Nos 2/23 and 96/23), the total maturity of a housing loan may not exceed 30 years (120 quarters).

⁶ According to the Decision on macroprudential instruments for the quality of household credit demand ("Official Gazette of the Republic of North Macedonia" Nos 2/23 and 96/23), the value of the DSTI indicator may not exceed 55% if the bank approves housing loans in denars, or 50% if the bank approves housing loans in foreign currency or in denars with a foreign exchange clause. Given that, on average, 93.2% of newly approved housing loans in the Macedonian economy during the analysed period, from Q1 2012 to Q4 2023, were approved in denars with a foreign exchange clause or in foreign currency, it is considered that this threshold is more appropriate for the purposes of this analysis.

⁷ According to the Decision on macroprudential instruments for the quality of household credit demand ("Official Gazette of the Republic of North Macedonia" Nos 2/23 and 96/23), the value of the LTV indicator may not exceed 85%.

Each household in the economy i in period t decides to allocate a certain amount α_i of its disposable income $Y_{i,t}$ to repay the housing loan such that the monthly repayment (annuity) A_i can be expressed as:

$$A_{i,t} = \alpha_{i,t} Y_{i,t} \quad (1)$$

where $0 \leq \alpha_{i,t} \leq \bar{\alpha}_{i,t}$ and $\bar{\alpha}$ represents the upper limit of the share of disposable income that the household may allocate for housing loan repayment, i.e. the DSTI indicator for housing loans. The upper limit $\bar{\alpha}_{i,t}$ depends on regulatory requirements and can be expressed as

$$\bar{\alpha}_{i,t} = \alpha_{max} - \alpha_{i,t}^* \quad (2)$$

where α_{max} is the regulatory DSTI indicator, while $\alpha_{i,t}^* = \sum_{j=1} A_{i,j} / \sum_{j=1} Y_{i,j}$ is the weighted share of monthly repayment obligations on other loans relative to income at the time those loans were granted, i.e. the DSTI indicator for all other loans. In cases where the household does not hold other loans, $\alpha_{i,t}^* = 0$ and $\bar{\alpha}_{i,t} = \alpha_{max}$.

Given the monthly repayment of housing loan $A_{i,t}$, the monthly nominal interest rate p_t and the selected loan repayment period s_i , the amount of the newly approved housing loan for each household $L_{i,t}$ can be calculated using the standard formula for a loan with equal annuities and decursive compounding:

$$L_{i,t} = A_{i,t} \frac{1 - r_t^{12s_i}}{r_t^{12s_i}(1 - r_t)} \quad (3)$$

where $r_t = 1 + p_t/100$ is the decursive factor, and it is assumed that interest is calculated on a monthly basis.

Assuming that the LTV indicator is regulated, this implies that the amount of credit exposure for the housing loan approved by the bank is lower than the market value of the housing unit, that is

$$L_{i,t} = \lambda_{i,t} V_{i,t} \quad (4)$$

where $\lambda_{i,t}$ is the share of the housing loan in the market value of the housing unit (i.e. the LTV ratio), for which $0 \leq \lambda_{i,t} \leq \lambda_{max}$ and $V_{i,t}$ is the market value of the housing unit. The difference between the market value of the housing unit and the amount of the housing loan represents the one-time downpayment that the household has to pay to the bank D_i so that

$$V_{i,t} = L_{i,t} + D_{i,t} = \lambda_{i,t} V_{i,t} + D_{i,t} \Leftrightarrow D_{i,t} = V_{i,t}(1 - \lambda_{i,t}) \quad (5)$$

where equation (4) is substituted.

On the other hand, the market value of the housing unit is determined by supply and demand conditions in the real estate market and can be decomposed as:

$$V_{i,t} = H_{i,t} P_{i,t} \quad (6)$$

where $H_{i,t}$ is the total area of the housing unit in square metres and $P_{i,t}$ is the market price per square metre. By combining equations (1), (3), (5) and (6), we obtain the key formula

$$H_{i,t}P_{i,t} = Y_{i,t} \frac{1 - r_t^{12s_{i,t}}}{r_t^{12s_{i,t}}(1 - r_t)} \frac{\alpha_{i,t}}{\lambda_{i,t}}, \quad (7)$$

from which it follows that the market value of the housing unit depends on the household's current disposable income, nominal market interest rates, and the DSTI and LTV indicators, which represent the link between macroprudential policy and the real estate market within this framework.

When Assumptions 1-3 are satisfied, and given the market-determined nominal interest rate p_t and the housing unit value $V_{i,t}$, housing is affordable if the disposable income of the household satisfies

$$Y_{i,t} \geq H_{i,t}P_{i,t} \frac{\lambda_{i,t} r_t^{12s_{i,t}}(1 - r_t)}{\alpha_{i,t} (1 - r_t^{12s_{i,t}})}, \quad (8)$$

which is obtained by expressing $Y_{i,t}$ from equation (7). Equation (8) provides a necessary and sufficient condition for a household to acquire a home, i.e. it represents the affordability threshold, meaning that there is no lower level of disposable income at which a housing unit could be purchased according to the given market conditions and regulatory constraints.

3.2. Dynamic borrowing capacity

The dynamic borrowing capacity aims to determine the maximum amount of a housing loan that a household can obtain while still being able to service the loan throughout the entire repayment period, thereby significantly reducing the risks of excessive future debt burden.

Given that most housing loans are approved with an initial rate fixation period, followed by a period with variable interest rate, equation (3) can be rewritten as

$$L_{i,t} = \left(A_{i,t} \frac{1 - r_t^m}{r_t^m(1 - r_t)} + \sum_{n=1}^N A_{i,t+m+n} r_{t+m+n}^n / r_t^m \right) / \prod_{n=1}^N r_{t+m+n} \quad (9)$$

where $m = 1, \dots, M$ denotes the number of periods during which a fixed interest rate applies and $n = 1, \dots, N$ denotes the number of periods with a variable interest rate, with $s = m + n$ representing the total repayment period of the housing loan.

By substituting equation (1) into equation (9) and rearranging it, we obtain

$$L_{i,t} = \left(\bar{\alpha}_{i,t} Y_{i,t} \frac{1 - r_t^m}{r_t^m(1 - r_t)} + \sum_{n=1}^N \bar{\alpha}_{i,t+m+n} Y_{i,t+m+n} r_{t+m+n}^n / r_t^m \right) / \prod_{n=1}^N r_{t+m+n}, \quad (10)$$

from where it is evident that the annuity amount during the fixed-rate repayment period $A_{i,t}$ is determined by the income at the time the housing loan is approved, whereas the annuity amount during the variable-rate repayment period $A_{i,t+m+n}$ is determined by the income in each period. However, households expect their income in each future period to grow at a rate g_t , thus their borrowing capacity will increase continuously. Incorporating the income growth assumption into equation (10) and rearranging it, we obtain

$$L_i = \left(\bar{\alpha}_{i,t} Y_{i,t} \frac{1 - r_t^m}{r_t^m (1 - r_t)} + \frac{Y_{i,t+m}}{r_t^m} \sum_{n=1}^N \bar{\alpha}_{i,t+m+n} [\gamma_{t+m+n} r_{t+m+n}]^n \right) / \prod_{n=1}^N \gamma_{t+m+n} r_{t+m+n} \quad (11)$$

where $\gamma_{t+m+n} = 1 + g_{t+m+n}/100$ is the income-growth factor.

Hence, according to the dynamic approach represented by the general expression in equation (11), the household's capacity to service the housing loan primarily depends on changes in nominal market interest rates and the growth rate of disposable income.

Households seek to satisfy the inequality $\alpha_{i,t+s} \leq \bar{\alpha}_{i,t+s}$, that is, the share of the monthly repayment in income must remain below the upper DSTI threshold. Consequently, they expect to be able to allocate an amount equal to $\bar{\alpha}_{i,t+s}$ of disposable income towards loan repayment each month. When $\alpha_{i,t+s} < \bar{\alpha}_{i,t+s}$, the difference represents a surplus of disposable assets, which households invest to earn a return at rate ρ_{t+s} . Conversely, when $\alpha_{i,t+s} > \bar{\alpha}_{i,t+s}$, the difference represents a shortfall of assets, and the household must borrow to obtain the necessary resources to repay the remaining portion of the loan. Accordingly, depending on whether $\alpha_{i,t+s}$ is above or below $\bar{\alpha}_{i,t+s}$, disposable income can be expressed through the following recursive relations:

$$Y_{i,t+s+1} = \begin{cases} Y_{i,t+s} [\gamma_{i,t+s} + (\bar{\alpha}_{i,t+s} - \alpha_{i,t+s}) \pi_{t+s}], & \alpha_{i,t+s} < \bar{\alpha}_{i,t+s} \\ Y_{i,t+s} \gamma_{i,t+s}, & \alpha_{i,t+s} = \bar{\alpha}_{i,t+s} \\ Y_{i,t+s} [\gamma_{i,t+s} + (\bar{\alpha}_{i,t+s} - \alpha_{i,t+s}) r_{t+s}] & \alpha_{i,t+s} > \bar{\alpha}_{i,t+s} \end{cases} \quad (12)$$

where $\pi_{t+s} = 1 + \rho_{t+s}/100$ is the return factor and $r_{t+s} = 1 + p_{t+s}/100$ is the borrowing-cost factor.

However, forecasting the periods in which households will experience surpluses or shortfalls of assets is complex and depends on uncertainty about future events. Therefore, for simplicity, it is assumed that their net effect on disposable income over the entire repayment horizon is neutralised. The model is also simplified by assuming that the share of monthly repayment obligations on other loans α_i^- is fixed throughout the repayment period, i.e., $\alpha_i^- = \alpha_{i,t}^-$, which implies that the upper limit of the housing loan repayment share remains constant, i.e. $\bar{\alpha}_i = \bar{\alpha}_{i,t+s}$. Finally, it is assumed that households expect income to grow at a constant rate over the entire repayment horizon $\bar{g} = \mathbb{E}(g_{t+1}) = \dots = \mathbb{E}(g_{t+s})$ and expect the average interest rate during the variable-rate period to be $\bar{p} = \mathbb{E}(p_{t+m+1}) = \dots = \mathbb{E}(p_{t+m+N})$.

Based on these simplifying assumptions and their application to equation (11), the maximum loan amount that a household can obtain under given market conditions and the

expectations for the repayment period can be determined by solving the following optimisation problem:

$$\max_{\alpha_{i,t+s}} \left\{ \bar{\alpha}_i Y_{i,t} \left[\frac{1 - r_t^m}{r_t^m (1 - r_t)} + \bar{\gamma}^{m+1} r_{t+m} \frac{1 - (\bar{\gamma} r_{t+m})^n}{(\bar{\gamma} r_{t+m})^n (1 - \bar{\gamma} r_{t+m})} \right] \right\} \quad (13)$$

subject to the constraint $\alpha_{i,t+s} = \bar{\alpha}_i$

where $\bar{\gamma} = 1 + \bar{g}/100$ is the expected income-growth factor over the entire repayment period and $r_{t+m} = 1 + \bar{p}/100$ is the decursive factor for future periods with a variable interest rate. Annual property tax and housing maintenance costs are excluded from equation (13) for additional simplification.

Regarding the maximum loan that a household can obtain according to the static and dynamic borrowing capacities, it holds that $L_i^d \leq L_i^s$, meaning that the maximum loan under the dynamic form cannot exceed the maximum loan under the static borrowing capacity. This implies that, despite the expected improvement in the household's creditworthiness during the loan repayment period, the maximum amount that can be obtained at the time the loan is granted cannot be changed as it depends solely on current market conditions.

3.3. Market to fundamental value ratio indicator

By aggregating the data for all households, the borrowing capacity of the entire economy can be easily estimated. If Y_t is the average disposable income per household, r_t is the decursive factor for the average nominal interest rate on housing loans p_t , s_t is the average maturity of housing loans, $\bar{\alpha}_t$ is the upper limit of the share of disposable income that a household may allocate to housing loan repayment and λ_t is the LTV indicator, then the maximum amount of a housing loan that the average household⁸ can obtain L_t^a may be calculated as

$$L_t^a = \bar{\alpha}_t Y_t \frac{1 - r_t^{12s_t}}{r_t^{12s_t} (1 - r_t)}, \quad (14)$$

and substituting the maximum available amount of loan in equation (4) yields the maximum value of a housing unit that the average household can afford—that is, the fundamental value of a housing unit F_t —which can be determined as

$$F_t = \frac{L_t^a}{\lambda_t}. \quad (15)$$

Comparing the average market value V_t of a housing unit with its fundamental value F_t allows to assess whether market prices are overvalued or undervalued. The following cases may arise:

- when the market value is higher than the fundamental value, i.e. $V_t > F_t$, housing prices are overvalued and therefore unaffordable for the average household;

⁸ The term "average household" refers to a household with the average income in the economy.

- when the market value is lower than the fundamental value, i.e. $V_t < F_t$, housing prices are undervalued and therefore affordable for the average household; and
- when the market value equals the fundamental value, i.e. $V_t = F_t$, prices are affordable for the average household and the housing market is in equilibrium.

This can be generalised by constructing an indicator of the market value relative to the fundamental value AHI_t , which represents an index and is calculated as

$$AHI_t = \frac{V_t}{F_t} \times 100, \quad (16)$$

such that $AHI_t > 100$ when housing prices are overvalued, $AHI_t < 100$ when housing prices are undervalued and $AHI_t = 100$ when the housing market is in equilibrium.

Large deviations from market equilibrium may cause drastic changes in housing prices and affect financial stability. On the one hand, when housing prices are significantly overvalued, the average household cannot afford to obtain a housing loan to purchase a residential property at the average market value. Theoretically, this would reduce housing demand, thereby putting downward pressure on prices. On the other hand, when housing prices are significantly undervalued, the average household can relatively easily obtain a housing loan to purchase a residential property at the average market value. This would increase housing demand and one could expect rising housing prices. However, this effect should be interpreted with caution because it takes time for such effects to be materialised, and other factors affecting housing demand (e.g. rental levels, location of newly built dwellings, infrastructure etc.) should not be disregarded.

4. Empirical analysis

The empirical analysis is divided into three parts. The first part examines the main movements of the variables during the analysed period, the second part provides a description and overview of the variables used to calibrate the model, and the third part presents and comments on the results from the analysis. For the purposes of this empirical analysis, quarterly data are used for the period from Q1 2012 to Q4 2023.

4.1. Key variable movements and stylised facts

Given the movements in the variables during the analysed period, the following stylised facts can be concluded.

The supply of residential properties experiences fluctuating movements, determined by the number of issued building permits for residential buildings and the number of completed buildings (see Figures 1 and 2).

According to the growth rate of completed residential buildings, the supply of residential properties recorded strong growth in the period 2012 – 2013, followed by downward movements during 2014 – 2017 and a trend of moderate growth from 2018 onwards. The decline in housing supply from 2014 to 2017 occurred amid a significant reduction in the number of issued building permits for residential buildings and a drop in the total area of the planned residential dwellings

from early 2013 to mid-2015, as well as high volatility in the credit market for the construction sector and a significant share of non-performing loans in total loans approved to this sector. This period is also characterised by low household income growth rates and stagnating interest rates on housing loans, while, from the second half of 2015, a slowdown in the growth of housing loans is observed. Starting from the first quarter of 2018, housing supply shows signs of recovery, reflecting the increased number of issued building permits for residential buildings and the growth of the total area of the planned residential dwellings during 2016 and 2017. However, it is important to note that housing supply during this period faced numerous challenges that emerged in the following years, related to the COVID-19 pandemic and the global inflation surge due to the war in Ukraine.

Figure 1. Rate of change of completed residential buildings

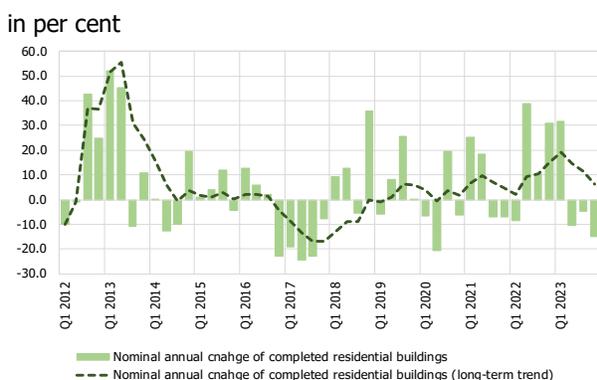
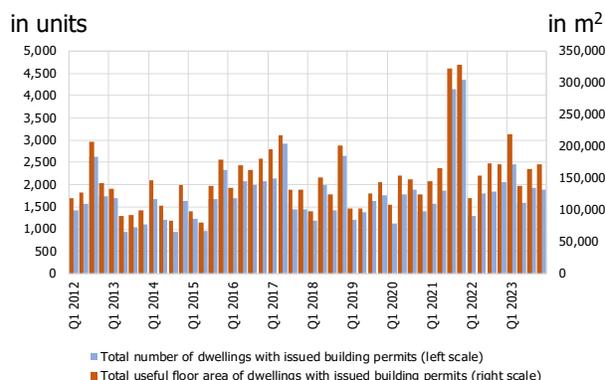


Figure 2. Issued building permits for residential buildings



Source: Authors' calculations based on data from the State Statistical Office.

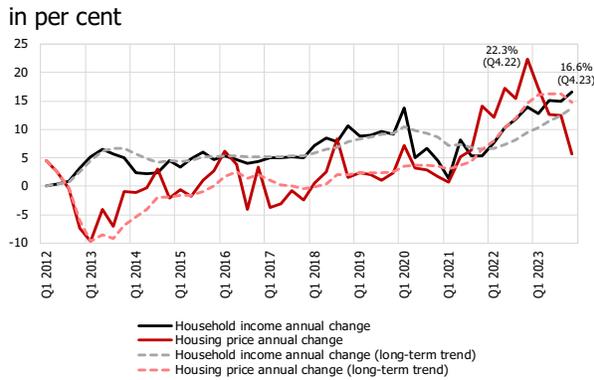
Notes: The data shown in the figures are for the whole country. Long-term trend is assessed by applying the one-sided Hodrick-Prescott filter with $\lambda = 1600$.

Household income grew at a higher rate than housing prices up to 2021, after which a period of accelerated housing price growth followed (see Figures 3 and 4).

This fact by itself may suggest that, during most of the analysed period, residential properties were more affordable for households, except during the period of rapid housing price increases. These developments occurred in a time of very low inflation and deflation in the Macedonian economy, when household income growth was low and housing prices experienced small decline. With the rise in the general price level mainly driven by global factors, including increases in construction material costs⁹, from the first quarter of 2021, a sharp increase in both housing prices and household income was observed, which were particularly pronounced during the inflation surge in 2022. From the second half of 2021 onwards, housing prices began to increase at a faster rate than household income, and, by the second half of 2022, the annual growth rates of housing prices exceeded 20%, after which a slowdown followed.

⁹ As a consequence of the increased prices of construction materials, the average annual growth of material costs in construction was 15.7% in 2021 and 24.2% in 2022 after a two-year period of declining material costs on an annual basis.

Figure 3. Nominal annual change in household income and housing prices



Source: Authors' calculations based on data from the National Bank.
 Notes: Long-term trend is assessed by applying the one-sided Hodrick-Prescott filter with $\lambda = 1600$. Housing price is according to the National Bank's methodology.

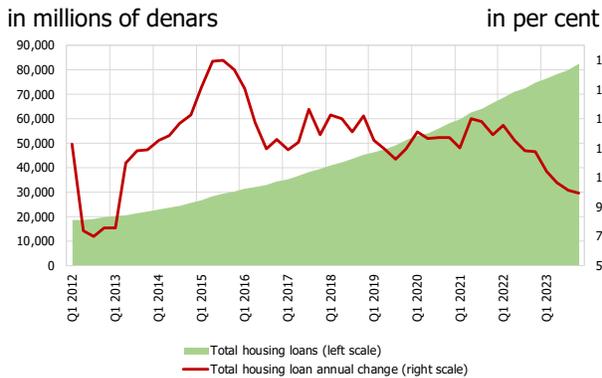
Figure 4. Movements in the housing price/household income indicator



Source: Authors' calculations based on data from the National Bank and the State Statistical Office.

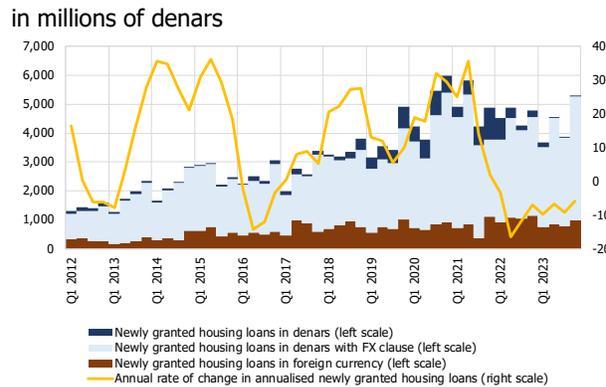
Housing lending has recorded stable double-digit growth rates throughout most of the analysed period, and newly approved housing loans have also shown an upward trend (see Figures 5 and 6).

Figure 5. Total housing loans and annual rate of change



Source: Authors' calculations based on data from the National Bank.

Figure 6. Newly approved housing loans by currency structure

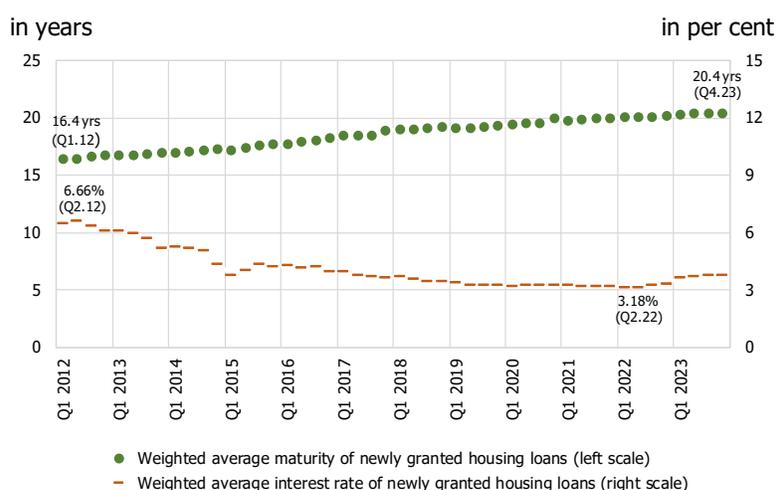


During the analysed period, total housing loans increased by an average of 13.6% annually. With an exception of the period from Q2 2012 to Q1 2013, when loan growth weakened amid the European sovereign debt crisis, in the remainder of the period, the growth rate was in double-digit territory all the time. An acceleration of growth is observed from 2013 to mid-2015 when improved housing loan conditions and declining interest rates were registered. From the second half of 2015 until early 2022, the growth of housing loans remained largely stable, while signs of deceleration emerged with rising inflation and tighter lending conditions following the onset of the war in Ukraine in 2022. Newly granted housing loans were steadily increasing until

the first half of 2021, after which they remained at a slightly lower level. Throughout the entire analysed period, most newly granted housing loans were denominated in denars with a foreign exchange clause (on average 73.1%), while the smallest share was made up by loans approved in denars (on average 6.5%).

The average repayment period of newly granted housing loans has been increasing, while the interest rate on newly granted housing loans has generally shown a declining trend (see Figure 7).

Figure 7. The average repayment period and average interest rate of newly granted housing loans during the analysed period



Source: Authors' calculations based on data from the National Bank.

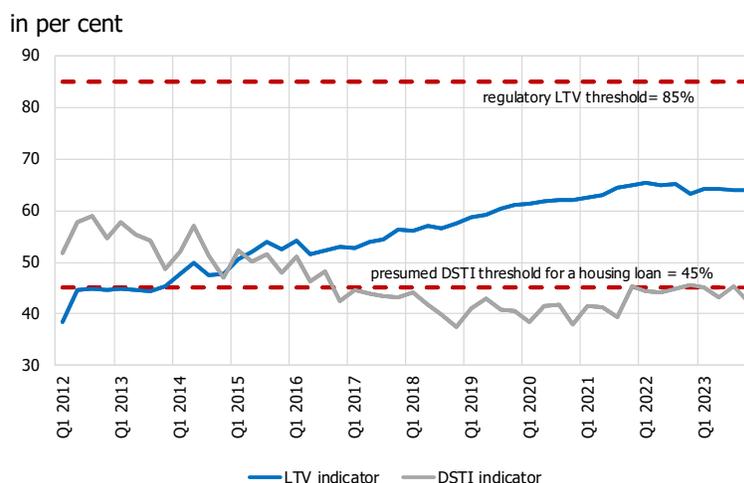
In Q4 2023, the average repayment period of newly granted housing loans was 20.4 years, which is four years longer than the average period of 16.4 years recorded in Q1 2012. These developments occurred amid a loosening of housing loan conditions by the banks, reflected in lower interest rates and longer initial rate fixation periods. The average interest rate on housing loans declined significantly from its peak of 6.66% in Q2 2012 within just two and a half years, followed by a short period of increase during 2015 and 2016, while, from 2017 onwards, it has consistently remained below 4%. However, a slight increase in housing loan interest rates emerged with the tightening of monetary policy during the inflation surge that followed the onset of the war in Ukraine and the global energy crisis.

The value of the LTV indicator shows an upward trend and is on average below the regulatory threshold, while the value of the DSTI indicator for housing loans has been declining in the period 2012–2016, during which it was above the threshold (see Figure 8).

In addition to lower interest rates and longer initial rate fixation periods, the easing of housing loan conditions is also reflected in the upward trend of the LTV indicator, whose value increased from 38.5% in Q1 2012 to 65.3% in Q1 2022. Regarding the DSTI indicator, the highest values that are ranging between approximately 50% and 60%, which is above the presumed

threshold for housing loans¹⁰, were recorded during the period 2012–2016. Subsequently, as a result of declining interest rates, longer loan maturities and higher disposable income, the presumed DSTI indicator for housing loans dropped below 45% at the end of 2016 and the beginning of 2017. During the period 2017–2021, the indicator remained in the interval of roughly 40% to 45%, before experiencing a moderate increase amid the accelerated rise in real estate prices and the required loan amount towards the end of 2021, after which it stabilised again.

Figure 8. LTV and DSTI indicators during the analysed period



Source: Authors' calculations based on data from the commercial banks.

4.2. Variable description and model calibration

The empirical analysis consists of calibrating the model with actual values for the Macedonian financial sector and real estate market, as well as assigning the expected values for the future movements of the variables. A description of the variables in the model is given in turn (more details in Appendix 1).

As a measure of household disposable income, the nominal average net wage multiplied by the average number of employed persons per household is used¹¹, calculated as the ratio between the number of employed persons and the number of households¹². It is expected that disposable income during the loan repayment period will grow at a constant rate based on the change in the nominal average net wage over the last five-year period¹³. The market average value of listed residential properties for sale represents the product of the average floor area and

¹⁰ The regulatory threshold of the DSTI indicator according to Assumption 2 is 50%, while the assumed threshold of the DSTI indicator for housing loans is 45% (more details are provided in subsection 4.2).

¹¹ Disposable income essentially includes more elements than just wages, such as pensions, private transfers to households from abroad (remittances), income from capital investments and etc., which suggests a possible underestimation of the disposable income. However, given that in the process of applying for housing loans, wage income is primarily taken into account for assessing borrowers' creditworthiness, we consider that the average wage is a representative indicator of disposable income in this analysis.

¹² Given the methodological changes in calculating the number of employed persons and the publication of the results from the 2021 census, starting from Q1 2021, a fixed ratio of 1.4 is used, corresponding to the number of employed persons in Q4 2020.

¹³ The five-year period is chosen as a measure of the medium-term wage cycle, whose duration depends on the length of the inflation cycle and productivity developments in the economy.

the average price per square metre based on the NBRNM methodology for calculating the housing price index (see more in Davidovska Stojanova et al., 2008)¹⁴.

The average maturity represents a weighted average of the maturities of newly granted housing loans in each period. For the entire analysed period, it is assumed that the initial rate fixation period is five years, while a variable interest rate is applied in the remaining period.¹⁵ The annual interest rate during the fixation period, that is, in the first five years, is equal to the rate at the time the loan is approved, and in the remaining period it is expected to average 6.5%.¹⁶

The LTV ratio in each period is calculated as a weighted average of the amount of newly granted loans relative to the value of the housing units used as collateral, while the regulatory maximum of the ratio is 85% in line with Assumption 3 explained previously. The monthly debt service obligation for all loans relative to disposable income represents the DSTI indicator, and the regulatory maximum for this indicator is 50% in accordance with Assumption 2 described above. It is further assumed that the average monthly repayment obligation for other loans accounts for 5% of disposable income in all periods, thus the maximum level of the DSTI indicator based solely on housing loans is set at 45%.

4.3. Results and discussion

The analysis based on the static borrowing capacity shows that the fundamental value of residential properties has a continuous upward trend, driven by the increase in disposable income and the decline in interest rates (see Figures 9 and 10). However, a comparison with the market value indicates that the average market value of dwellings purchased with loans was overvalued throughout the entire analysed period, except in Q4 2018, Q1 2020, Q4 2020 and Q3 2021 when housing prices were undervalued. The overvaluation is particularly pronounced in the beginning of the analysed period. With the relative stability of the market value and the increase in the fundamental value of residential properties, the ratio between them shows a downward trend in the period 2012 – 2018. As a result, the highest overvaluation of 47.3% is observed in Q3 2012, while the highest undervaluation of 6.5% is recorded in Q4 2018. In the period 2019 – 2021, the real estate market is largely in equilibrium. Higher overvaluation of housing values reappears during the period of significant housing price growth from Q4 2021 onwards, although this trend remains well below the historically highest rates of overvaluation. In this period, the highest overvaluation of housing prices by 14.2% was observed in Q4 2022.

The fundamental value calculated with the dynamic borrowing capacity is identical to that obtained with the static capacity up to Q4 2016 given the previously explained assumption that the household is not able to obtain a higher housing loan amount based on expectations of improved future creditworthiness. However, the estimated fundamental value derived from the dynamic borrowing capacity in this period, given the assumption that the household can obtain a higher housing loan amount due to expected future income flows, is higher. This difference arises

¹⁴ The data refer only to residential properties listed for sale within the territory of the City of Skopje, and the calculated market average prices differ from the prices published by the Agency for Real Estate Cadastre.

¹⁵ The results of the bank survey conducted by the National Bank during 2023 indicate that the initial rate fixation period ranges from five to ten years. However, since the analysis covers a longer historical period during which the fixation period was not as long, and also due to greater prudence and the need to cover this period in assessing the dynamic borrowing capacity for the entire period under review, a five-year period has been selected as the more appropriate option.

¹⁶ As the data for the long-term interest rate on housing loans in the Macedonian market is unavailable, the estimate is based on the long-term average interest rate on newly granted housing loans in the Macedonian market and on the 30-year mortgage rate in the US market (given the heterogeneity of European markets).

from the level of income and the higher interest rates during the period up to the end of 2026, which results in lower assessment of creditworthiness at the time of loan approval than in future repayment periods when income is higher and the long-term variable interest rate is applied. As a result, the estimated value of the indicator points to lower overvaluation of housing prices compared to the static capacity. More specifically, while housing prices in Q3 2012 were assessed as overvalued by 47.3% with the static capacity approach, the dynamic capacity indicates an overvaluation of 17.4%. Starting from Q1 2017, the fundamental value based on the dynamic borrowing capacity is lower than the one based on static capacity calculation as a result of the widened spread between the expected long-term interest rate in the variable-interest-rate period and the interest rate at the time the housing loan is approved. Hence, the indicator of the ratio between market and fundamental values in this period suggests a slightly higher overvaluation, albeit still significantly below the historically highest rates indicated by the static borrowing capacity. However, it should be noted that these results are greatly influenced by the presumed values of the model parameters, as well as the level of the regulatory thresholds of the macroprudential instruments.

Figure 9. Movements in the market and fundamental values of residential properties

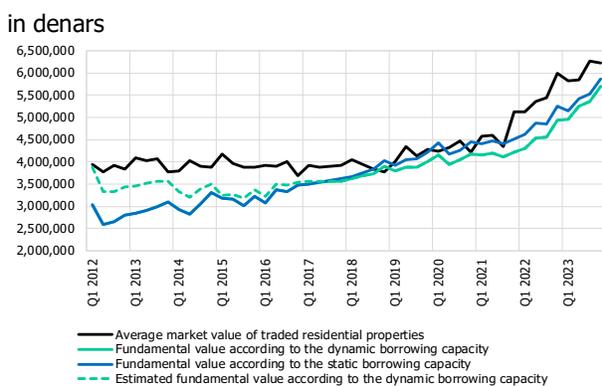
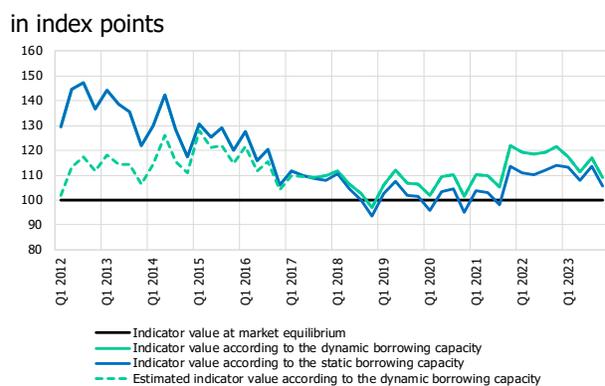


Figure 10. Movements in the market to fundamental value ratio



Source: Authors' calculations based on data from the National Bank and the State Statistical Office.

The overvalued market price of residential properties does not imply that all households in the economy face difficulties obtaining a housing loan; similarly, an undervalued market price does not mean that all households are creditworthy. On the contrary, an overvalued market price shifts the threshold to the right, meaning that housing becomes accessible only to households with above-average income. Conversely, an undervalued market price indicates that the creditworthiness threshold shifts to the left of the average household income, meaning that purchasing a home through a housing loan becomes accessible even to households with below-average income. Finally, it should be taken into account that the household income distribution curve generally exhibits positive skewness, which means that the median value is lower than the average (i.e. $\tilde{Y} < \bar{Y}$), implying that the market value must be undervalued for housing to be affordable for half of all households.

5. Sensitive analysis to macroprudential instruments

The degree of undervaluation or overvaluation of housing prices is strongly influenced by the settings of macroprudential instruments, specifically the regulatory threshold of the DSTI

indicator.¹⁷ For instance, a lower regulatory maximum for the DSTI would imply a lower maximum monthly repayment obligation and thus a lower maximum loan amount available to households (lower borrowing capacity), which would result in higher overvaluation of housing and reduced housing affordability in the market. Furthermore, lower housing availability would redirect demand towards cheaper and smaller residential properties, which will contribute to downward pressure on housing prices to some extent. To illustrate the sensitivity of housing affordability to macroprudential policy, this section presents a sensitivity analysis of the ratio between market and fundamental values of residential properties for different DSTI values. The economic literature generally suggests that the regulatory maximum of the DSTI indicator should be 40% (see Albacete & Lindner, 2013; Giordana & Ziegelmeyer, 2017; Albacete et al., 2020; Noerhidajati et al., 2021; and Enzinger et al., 2022), which is significantly lower than the values of 55% and 50% applied in the Macedonian financial system. As a consequence, a lower bound of 40% is used in the sensitivity analysis based on the literature, while an upper bound of 55% is taken according to the regulatory DSTI value for approved loans in denars. A value of 45% is also applied in the analysis. It is important to note that, while the level of the threshold affects the amount of the fundamental value, it does not affect its dynamics, so the degree of relative change in each period remains the same.

Figure 11. Market to fundamental value ratio for different values of the DSTI indicator (static borrowing capacity)

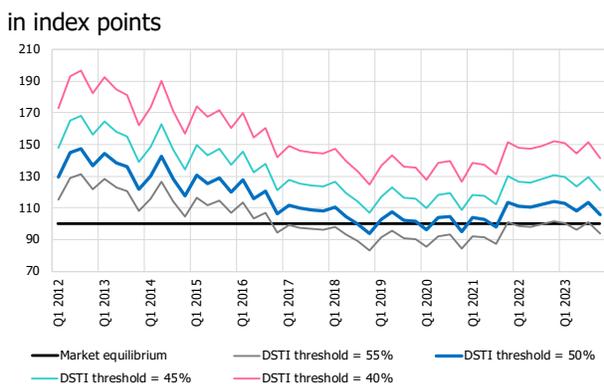
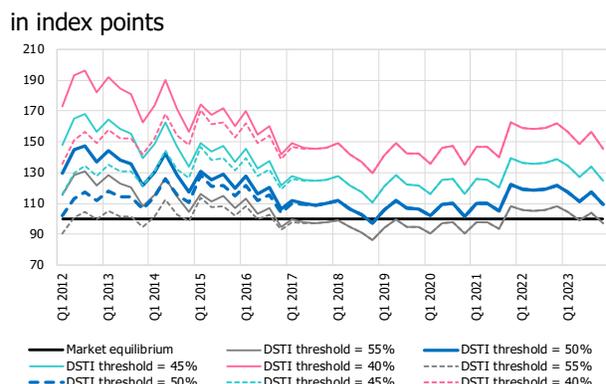


Figure 12. Market to fundamental value ratio for different values of the DSTI indicator (dynamic borrowing capacity)



Source: Authors' calculations based on data from the National Bank and the State Statistical Office.

Notes: The dashed lines in Figure 12 show the values of the indicator that are calculated with the estimated fundamental value according to the dynamic borrowing capacity.

The results for different regulatory thresholds of the DSTI indicator indicate that lowering the threshold reduces the fundamental value of residential properties as households are constrained to allocate a smaller portion of their income for mortgage repayment and, consequently, can obtain a lower loan amount and vice versa (see Figures 11 and 12). Furthermore, a lower DSTI threshold leads to higher overvaluation of housing prices according to the ratio of market to fundamental values and vice versa. For instance, calculations for $\alpha_{max} = 0.55$ show that the market value of residential properties was undervalued from Q4 2017 to Q3 2021. On the other hand, calculations for $\alpha_{max} = 0.45$ and $\alpha_{max} = 0.40$ indicate that the market value was overvalued in every period, meaning that purchasing a home under such conditions is only accessible to households with above-average income. In fact, the fundamental value of

¹⁷ Given that the market value of the LTV indicator is significantly below the regulatory threshold throughout the analysed period, the change in the regulatory threshold of this indicator is not included in the sensitivity analysis.

residential properties under both the static and dynamic borrowing capacities for $\alpha_{max} = 0.55$ is lower by one third than for $\alpha_{max} = 0.40$. However, the different housing affordability that results from adjustments in the regulatory DSTI threshold does not necessarily lead to changes in housing prices, as not all dwellings on the market are subject to mortgage financed transactions and therefore the impact would be limited.

6. Conclusions

The purpose of assessing the static borrowing capacity is to determine whether a household with an average income in the economy can obtain a housing loan in an amount that would allow it to acquire own home, while the assessment of the dynamic capacity is to determine whether the household would be able to repay the housing loan in the long run under assumed market conditions and thus retain ownership of the acquired home.

In this analysis, the concepts of static and dynamic borrowing capacities, combined with the LTV and DSTI indicators as macroprudential instruments, are used to estimate the fundamental value of residential properties. By comparing the market value with the fundamental value, an indicator of housing affordability is introduced, which shows whether the prices of residential properties are overvalued, meaning that they are not affordable for a household with an average income, or are undervalued, meaning affordable for household with an average income. The results of the analysis indicate that residential property prices, according to the static borrowing capacity, were overvalued in almost the entire analysed period, suggesting that purchasing a home was generally available mainly to households with above-average income. Notably, a decrease in overvaluation is observed in the period 2012 – 2018, driven by higher household income growth relative to housing price growth and an accelerated decline in interest rates on newly granted housing loans. Calculations based on the dynamic borrowing capacity confirm these findings for the period 2012 – 2016, after which they point to slightly higher overvaluation due to a wider spread between the expected long-term interest rate and the interest rate at the time of housing loan approval. The analysis also reveals that the curve of the indicator measuring the ratio of market to fundamental value is sensitive to potential regulatory changes in the DSTI indicator; therefore, a lower regulatory threshold would imply a lower fundamental value, a higher ratio of market to fundamental value, greater overvaluation of residential properties and thus lower housing affordability for the average household. Reducing the DSTI indicator should partly contribute to a decline in housing prices, but the impact would be limited because not all housing market transactions are financed with housing loans.

This analysis has certain limitations. Firstly, due to the non-availability of quarterly data on disposable household income, disposable income is represented by the average net wage, which excludes additional income earned by households as well as inflows from private transfers from abroad. Secondly, due to the lack of data on household income distribution, the income distribution function and the deviation of the median from the average income cannot be accurately calculated, which prevents an assessment of what share of households can afford to acquire their own home through the housing affordability indicator. Thirdly, when evaluating the dynamic borrowing capacity, the expected long-term interest rate on housing loans is taken into account, which may not necessarily correspond to real economic conditions and may be subject to shocks. Fourthly, the analysis uses a partial equilibrium that does not take into account the feedback effects between housing prices, supply, demand and macroeconomic conditions, meaning that the results should be interpreted with caution. According to this, future research on

this topic would aim to improve the methodology for calculating the housing affordability indicator, estimate the share of the population that can acquire own home, apply new methods and analysis of the feedback effects among variables and include the housing affordability indicator within more comprehensive analyses of housing price dynamics.

References

Albacete, N. & Lindner, P. (2013). "Household Vulnerability in Austria – A Microeconomic Analysis Based on the Household Finance and Consumption Survey." *Financial Stability Report*, Oesterreichische Nationalbank, 25: 57–73.

Albacete, N.; Fessler, P. & Propst, P. (2020). "Mapping financial vulnerability in CESEE: understanding risk-bearing capacities of households is key in times of crisis." *Financial Stability Report*, Oesterreichische Nationalbank, 39: 71–87.

Andrie, M. & Plašil, M. (2019). "Assessing House Prices in Canada: Borrowing Capacity and Investment Approach." *IMF Working Paper No. 2019/248*, International Monetary Fund, Washington DC.

Bank of England (2023). "How are the rising cost of living and interest rates affecting households' ability to pay their mortgage." Bank Overground, January.

Ben-David, I.; Towbin, P. & Weber, S. (2019). "Inferring Expectations from Observables: Evidence from the Housing Market." *National Bureau of Economic Research Working Paper No. 25702*, National Bureau of Economic Research, Cambridge, Massachusetts.

Beraldi, F. & Zhao, Y. (2023). "The Pricing-Out Phenomenon in the U.S. Housing Market." *IMF Working Paper No. 2023/001*, International Monetary Fund, Washington DC.

Biljanovska, N.; Fu, C. & Igan, D. (2023). "Housing affordability: a new data set." BIS Working Papers No. 1149, Bank for International Settlements, Basel.

Deb, P.; Finger, H.; Kashiwase, K.; Kido, Y.; Kothari, S.; Papageorgiou, E.; Hoyle, H. & Oeking, A. (2022). "Housing Market Stability and Affordability in Asia-Pacific." *IMF Working Paper No. 2022/020*, International Monetary Fund, Washington DC.

Davidovska Stojanova, B.; Jovanovic, B.; Kadievska Vojnovic, M.; Ramadani, G. & Petrovska, M. (2008). "Real Estate Prices in the Republic of Macedonia." *MPRA Paper 43166*, University Library of Munich, Germany.

European Central Bank (2011). "Box 3: Tools for Detecting a Possible Misalignment of Residential Property Prices From Fundamentals." *Financial Stability Review*, European Central Bank, Frankfurt.

European Central Bank (2015). "Box 3: A Model-Based Valuation Metric for Residential Property Markets." *Financial Stability Review*, European Central Bank, Frankfurt.

Enzinger, M.; Koch, M. & Riedl, A. (2022). "Financial vulnerabilities and debt at risk of CESEE borrowers: a cross-country analysis." *Financial Stability Report*, Oesterreichische Nationalbank, 44: 25–44.

Funke, M. & Paetz, M. (2016). "Dynamic Stochastic General Equilibrium – Based Assessment of Nonlinear Macroprudential Policies: Evidence from Hong Kong." *Pacific Economic Review*, PAER-15-05-0037.R1.

Geng, N. (2018). "Fundamental Drivers of House Prices in Advanced Economies." *IMF Working Paper No. 2018/164*, International Monetary Fund, Washington DC.

Giordana, G. & Ziegelmeier, M. (2017). "Household debt burden and financial vulnerability in Luxembourg." *Data needs and Statistics compilation for macroprudential analysis*, 46, Bank for International Settlements, Basel.

Guerrieri, L. & Iacovielli, M. (2017). "Collateral constraints and macroeconomic asymmetries." *Journal of Monetary Economics*, 90: 28–49.

Iacoviello, M. (2000). "House prices and the macroeconomy in Europe: Results from a structural var analysis." *Working Paper Series 18*, European Central Bank, Frankfurt.

Iacoviello, M. & Neri, S. (2010). "Housing Market Spillovers: Evidence from an Estimated DSGE Model." *American Economic Review*, 2(2): 125–164.

Igan, D. & Prakash L. (2012). "Global Housing Cycles." *IMF Working Paper No. 2012/217*, International Monetary Fund, Washington DC.

McCarthy, J., & Peach, R. W. (2004). "Are Home Prices the Next "Bubble"?" *Economic Policy Review*, 10(3), Federal Reserve Bank of New York, New York City.

Nocera, A. & Roma, M. (2017). "House prices and monetary policy in the euro area: evidence from structural VARs." *Working Paper Series 2073*, European Central Bank, Frankfurt.

Noerhidajati, S.; Purwoko, A. B.; Werdaningtyas, H.; Kamiland, A. I. & Dartanto, T. (2021). "Household financial vulnerability in Indonesia: Measurement and determinants." *Economic Modelling*, 96: 433–444.

OECD (2005). "Recent House Price Developments: The Role of Fundamentals." *OECD Economic Outlook No. 78*, Organization for Economic Cooperation and Development, Paris.

Ott, H. (2014) "Will euro area house prices sharply decrease?." *Economic Modelling*, 42(C).

Philipponnet, N. & Turrini, A. (2017). "Assessing House Price Developments in the EU." *Discussion Paper No. 048/2017*, European Commission, Brussels.

Plašil, M. & Andrlé, M. (2019). "Assessing House Price Sustainability." *CNB Thematic Article on Financial Stability*, Czech National Bank, Prague.

Rabanal, P. (2018). "An Estimated DSGE Model to Analyze House Market Policies in Hong Kong SAR." *IMF Working Paper No. 2018/090*, International Monetary Fund, Washington DC.

Rubio-Ramirez, J. F.; Waggoner, D. F. & Zha, T. (2010). "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference. " *The Review of Economic Studies*, 77(2): 665–696.

Turk, R. (2015). "Housing Price and Household Debt Interactions in Sweden." *IMF Working Paper No. 2015/276*, International Monetary Fund, Washington DC.

Valderrama, L.; Gorse, P.; Marinkov, M. & Topalova, P. (2023). "European Housing Markets at a Turning Point Risks: Household and Bank Vulnerabilities, and Policy Options." *IMF Working Paper No. 2023/076*, International Monetary Fund, Washington DC.

Warisse, C. (2017). "Analysis of the Developments in Residential Property Prices: Is the Belgian Market Overvalued." *Economic Review*, 4, National Bank of Belgium (NBB), Brussels.

Appendix 1: Overview of variables for model calibration

The table below provides an overview of the variables used for calibrating the model, their assigned values and the sources from which they were obtained.

Variable	Mark	Value	Source
LTV threshold	λ_{max}	85%	Decision on macroprudential instruments for the quality of household credit demand ("Official Gazette of the Republic of North Macedonia" Nos 2/23, 96/23 and 193/23)
DSTI threshold	α_{max}	50%	
LTV indicator	λ_t	Calculated ¹	Authors' calculations based on data from the commercial banks
DSTI indicator	α_t		
Average maturity of housing loan	s_t		
Nominal interest rate	p_t		
Amount of housing loan	L_t		
Average floor area of traded residential properties in m ²	H_t		Authors' calculations based on data from the real estate agencies
Market price of housing unit per m ²	P_t		Authors' calculations based on data from the State Statistical Office
Household income	Y_t		
Expected income growth rate	g_t		
Expected initial rate fixation period	m		5 years
Expected period with variable interest rate	n	$n = s - m$	
Expected rate of return	$\bar{\rho}$	3.0% annually	
Expected nominal interest rate during the period with variable interest rate	\bar{p}	6.5% annually	

Notes: ¹ The value is calculated based on the market movements of the variables. More details regarding the calculation methodology are provided in Appendix 2.

Appendix 2: Methodology for calculating the values of the variables

This appendix explains the methodology for calculating the values of some of the key variables used for calibrating the model.

The average amount of housing loan L_t is calculated as

$$L_t = \frac{\sum_{i=1}^I L_{i,t}}{I} \quad (1)$$

where $L_{i,t}$ is the amount of newly granted housing loan per borrower and I is the total number of new borrowers.

The average maturity of housing loan s_t in quarters is calculated as

$$s_t = \left\lfloor \frac{\sum_{i=1}^I L_{i,t} s_{i,t}}{\sum_{i=1}^I L_{i,t}} \right\rfloor \quad (2)$$

where $s_{i,t}$ is the original maturity of the newly granted housing loan. It should be noted that the amount on the right side of the equation is rounded to the nearest integer, because we are working in discrete time with quarterly data.

The expected income growth rate \bar{g}_t is calculated as

$$\bar{g}_t = \frac{\sum_{c=1}^{20} g_{t-c}}{C} \quad (3)$$

where g_{t-c} is the nominal income growth rate and $C = 20$ represents the five-year period used to calculate the expected rate.