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Easier said than done: Predicting downside risks to house prices in Croatia

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Predviđanje rizika pada cijena nekretnina u Hrvatskoj: lakše je reći nego učiniti

Sažetak

Nositelji makrobonitetne politike osobito su zainteresirani za praćenje dinamike cijena nekretnina zbog njihova utjecaja na financijsku stabilnost i na buduća makroekonomska kretanja. S obzirom na jedan od glavnih ciljeva makrobonitetne politike – smanjenje sistemskih rizika u financijskom sustavu – veoma je važno pratiti središnju tendenciju kretanja buduće stope rasta cijena nekretnina, a istodobno se usmjeriti i na rizike potencijalnog pada cijena nekretnina. Ovo istraživanje, prvi put za hrvatsko tržište, pokušava utvrditi i analizirati glavne činitelje rasta cijena nekretnina pri riziku (engl. *house price at risk*, HaR) za razdoblje od prvoga tromjesečja 2002. do trećega tromjesečja 2022. godine. Empirijski dio rada bavi se predviđanjem HaR vrijednosti te na osnovi rezultata kvantilne regresije zaključuje da su se HaR rizici povećali u posljednjih nekoliko godina. Pristup ovog istraživanja pruža uvid u neizvjesnost prognoziranja same dinamike rasta cijena nekretnina i u dekomponiranje rezultata na osnovi glavnih činitelja koji utječu na buduću dinamiku rasta cijena nekretnina. Rezultati istraživanja stoga imaju implikacije na različite makroekonomske politike koje mogu utjecati na tržište nekretnina.

Ključne riječi: financijska stabilnost, makrobonitetna politika, kvantilna regresija, rast pri riziku, dinamika cijena nekretnina, rizik pada cijena

JEL klasifikacija: E32, E44, E58, G01, G28, C22

Easier said than done: Predicting downside risks to house prices in Croatia

Tihana Škrinjarić and Maja Sabol[1]

Abstract: House price dynamics are particularly interesting for macroprudential policymakers due to their effects on financial stability and future macroeconomic performance. As the main goal of macroprudential policy is to mitigate systemic risks, it is essential to monitor the central tendency of future house price growth dynamics and focus on downside risks and their possible materialization. This research, the first of its kind applied to the Croatian housing market, tries to identify and capture the main drivers of house price-at-risk (HaR) for the period between 2002Q1 and 2022Q3. It also predicts downside risks to future real house price growth. Based on the quantile regression results, we conclude that downside risks on housing market have increased in recent years. The approach is found to be insightful to monitor the uncertainty of the forecasts and decomposing the drivers to house price forecasting. Our results have implications for a range of policies that influence housing markets.

Key words: financial stability, macroprudential policy, quantile regression, growth at risk, house price dynamics, downside risks

JEL classification: E32, E44, E58, G01, G28, C22

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1. INTRODUCTION

The last global financial crisis (GFC) showed that shocks originating in housing markets could profoundly affect real economic activity, especially when property investment is highly leveraged. Consequently, recessions last longer (Helbling & Terrones, 2003, ESRB, 2019). Claessens et al. (2008) show that the probability of a significant slowdown in economic activity as a result of a downturn in the housing market is three times higher compared to recessions that are not caused by adverse shocks in these markets and that more than two-thirds of 50 systemic banking crises over the last decades had boom-bust patterns in house prices (IMF, 2019). During the expansion phase of the real estate cycle, often accompanied by accelerated credit growth and easing of lending conditions, increase in household indebtedness, and increase in house prices, build-up of systemic risks can materialise (ESRB, 2019). Research also found that these unsustainable market developments can seriously threaten the stability of the financial system and economies, increasing the risk of spillovers to other markets and countries (IMF, 2019, ESRB, 2019).

Since the GFC, awareness of the need to use macroprudential policies has increased substantially. These policies, which ensure that the financial sector as a whole can withstand shocks, were deemed necessary to tackle macro-financial externalities and reduce the likelihood of systemic events. Besides, financial stability and price stability trade-offs became evident as monetary policy tools could not address financial stability risks, especially ones emerging from housing markets. Thus, it is of great importance for macroprudential authorities to monitor developments in the housing markets, as they affect financial stability from the standpoint of different stakeholders in the market. Moreover, identifying and assessing systemic risks related to the housing markets is an important part of the overall financial stability analysis in a particular country and represent the starting point for adopting macroprudential measures to mitigate these risks.

The signalling properties of house price dynamics and future (financial) crises have been documented in the literature to a great extent. The most common combination of variables whose dynamics preceded financial crises are house price overvaluations and accelerated private sector credit growth (Borio, 2012; Behn et al., 2013; Jordá et al., 2015). There is a great correlation between the two dynamics, as real estate, in general, is financed via mortgage lending. As such, mortgage lending has a great share in credit institutions' balance sheets, which implies a degree of vulnerability. Given the variations in collateral values and credit risk resulting from banks' exposure to the market, banks are vulnerable to sudden price corrections (see Tölö et al., 2018). These collateral effects amplify the response of aggregate demand to shocks in house prices (Iacoviello, 2005). Mechanism is amplified in less regulated markets where households can more easily borrow to finance their consumption.

In recent years, substantial increase in house prices in many countries across the world, as in Croatia, fuelled concerns about the potential price reversals in the short-term. Along with current inflation remaining stubbornly high, the possibility of adverse tail macroeconomic outcomes increased as well. This would, amid rising mortgage rates, increase the risk of further erosion of real disposable incomes and affect the financial position of both households and corporations. Existing vulnerabilities in the housing market may amplify negative implications for the entire financial system. In fact, recent global monetary policy tightening is making affordable housing increasingly scarce.

In some countries' housing markets, the current cooling off are evident, and a reality check has started to hit during the time of writing (spring 2023). To further deepen our understanding of analysing and quantifying future downside risks to house prices, a house price-at-risk (HaR) model for Croatia is developed in this paper. HaR approach is based on estimating quantile regressions, where the entire distribution of future real house price growth is forecasted. A special focus is paid to the left-tail ("at-risk" growth rate) of the distribution (i.e., the HaR value), which is the 10th percentile growth rate reflecting the notion of sudden downturns in house prices that impose the most significant financial stability risk. This is in line with the growth-at-risk measure (GaR) proposed by Adrian et al. (2019). Due to the short time series, we examine the 10th percentile instead of the "traditional" 5th percentile.

To the best of our knowledge this is the first study that analyses similar risks in Croatian housing market. The main aim is to obtain initial results into forecasting capabilities of HaR models for the case of Croatia and its regions (City of Zagreb, the Adriatic Coast and Other) following a similar approach by Alter and Mahoney (2020). Another key contribution of this paper is assessing the distribution of house price outcomes given the macro-financial conditions and forecasting future house price growth. By identifying the supply and demand factors affecting house price dynamics, policymakers can tailor and implement their instruments in a more suitable way. This includes different policies that may influence the housing market such as housing policies dealing with affordable housing; monetary policy affecting housing demand via interest rates; fiscal policy through property taxation and macroprudential policy that monitors vulnerabilities in the financial system.

The main findings of our analysis are that downside risks in the Croatian housing market have increased in recent years. These findings are important because of their implications for financial stability and related guidance for policymakers to tackle possible risk materialisation. Apart from that, according to the left shift of the entire real house price growth distribution, a general reduction in the outlook for house prices is evident relative to previous points in time. However, downside risks are less pronounced compared to the period before GFC.

The remainder of the paper is organized as follows. First, we present stylised facts on the Croatian housing market and key drivers of house price dynamics in Croatia and its regions in period from 2002Q1 to 2022Q3. Third section deals with literature overview after which we detail the panel quantile methodology and data. Next, the fourth section provides the main findings of our empirical analysis of house price-at-risk, including distribution fitting of forecasted house price growth. Finally, the final fifth section discusses policy implications and concludes the paper.

2. STYLIZED FACTS ON CROATIAN HOUSING MARKET

Croatia has one of the highest EU shares of homeownership recorded (91% in 2021), with Slovakia, Romania, and Hungary (Eurostat, 2023a). In light of this, Rünstler and Vlekke (2016) point out that credit and real estate cycles, in most cases, last longer than business cycles (12-18 years), especially in those countries with high rates of private homeownership. The share of young people (aged 25-34 years) living with their parents in Croatia is among the highest in the EU (Eurostat, 2023b). Croatia also recorded the oldest average age of leaving the parental home, at 30 years and over. Where entering homeownership is costly, and housing supply is scarce, younger adults are more likely to stay longer in the parental home or move to rented accommodation.

The housing market in Croatia has its fair share of specific/idiosyncratic characteristics. What other features are there in particular? Continuously strong and recently increasing foreign demand, particularly in coastal regions. At the same time, the introduction of a government subsidy programme (from 2017) contributes to demand in the landlocked parts of the country. Furthermore, the structurally favorable tax treatment of real estate property and renting activity for tourist accommodation contributes to local and foreign demand (CNB, 2022). According to Croatian National Bank's (CNB, 2023) estimates, a considerable portion of transactions in the housing market is not financed by credit.

In Croatia, alongside other many countries, pressure on house prices in recent years has been emanating from a combination of factors pushing up the demand for housing, with disruptions on the supply side as well. Low cost of borrowing after the GFC allowed households to afford ever-lower mortgages to finance their house purchases. In addition, in a low-interest rate environment, house purchases have become a desirable alternative to savings deposits to investors, being perceived as a safe investment even in crises. Besides, low interest rates in some countries, even negative deposit interest rates made saving less attractive for people[2]. Nowadays, with inflation running hot, this is more noticeable. On the supply side, rising construction costs and scarce housing supply, which after strong contraction following the GFC, was not able to adjust fast enough to the increase in demand, put up further upward pressure (ESRB, 2022 and CNB, 2022). Despite the abrupt COVID-19 shock, the housing market remained resilient, and house prices continued to grow due to the aforementioned factors.

In these circumstances, house prices in Croatia have risen steadily in the last couple of years. After growing by an annual average rate of around 8% in the last three years, their growth accelerated further in the third quarter of 2022 to 14.8% annually, with the largest annual increase recorded in the city of Zagreb. Prices in Croatia exceeded the peak in GFC in 2020 and in 2022Q3 prices were above GFC level by around 30% (Figure 1)[3]. The cumulative increase in house prices since 2017, after years of decreasing trends, is more than 50%, in line with average price dynamics across Europe. Between 2009 and 2016, amidst the recession in Croatia and deflationary pressures, a decreasing trend in both nominal and real

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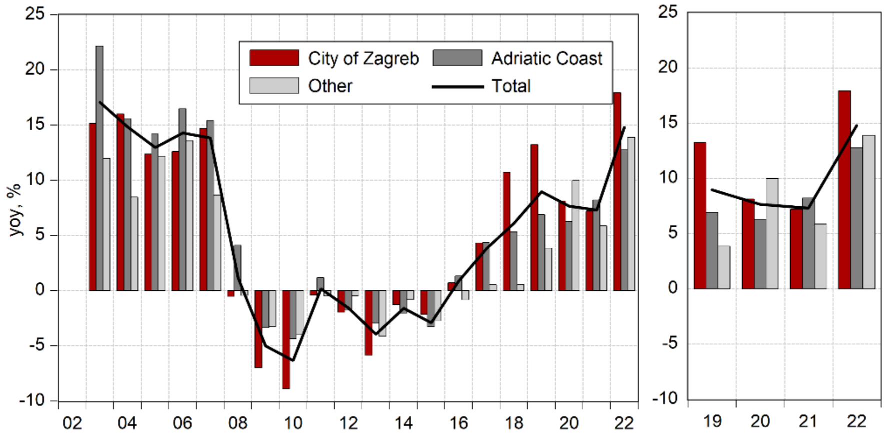
[2] Although all investors, retail and institutional seek financial assets that give higher yields, financial markets in Croatia are underdeveloped, which doesn't allow them to have a variety of different investment opportunities (see comments on the financial stress indicator in chapter 4.1.).

[3] Considering average dynamics in 2022, yoy house price growth of around 15% was recorded.

house price growth[4] was evident. In 2017, house prices started to rise more than inflation. However, this trend was reversed in the last period due to surging inflationary pressures since mid-2021.

Figure 1. House price dynamics in Croatia



Note: Figure shows yoy growth rate of nominal house price index. For more details on the construction of the nominal index, see Kunovac and Kotarac (2019). Data for 2022 refers to third quarter.
Source: Croatian National Bank and Croatian Bureau of Statistics.

Comparing the period before GFC, a similar dynamic is observed in house-price to income and house-price to hypothetical borrowing volume ratio. Continuous house price growth has led to deteriorating housing affordability in both analyzed periods (Figure 2), signaling the possible overvaluation nature of house prices. However, the adjusted housing affordability indicator that considers interest rate and mortgage credit dynamics have been relatively stable in recent years due to favorable financing conditions (Figure 3, left). Moreover, a period of low yield environment and disposable income growth kept the mortgage debt service-to-income ratio (DSR) relatively stable despite the increase in loan amounts arising from house price growth (Figure 3, right)[5]. Although DSR does not consider the distribution of debt and income, and both indebted households and those without debt are treated equally, the indicator is a good predictive indicator of upcoming financial crises (Borio et al., 2019). Historically, both household debt-to-GDP (gross domestic product) ratio (and mortgage debt) and house prices in Croatia have moved in tandem, although the relationship has strengthened over the past few years. Mortgage debt has remained generally stable following the GFC, but given the favorable financing conditions it further increased along with house prices. The overall indebtedness of the household sector is relatively low, standing at around 35% of GDP, with only about one-fifth of banks' exposures pertaining to mortgage loans (ESRB, 2022). In general, variable rate mortgages account for around the third of total housing loans (CNB, 2022). Share of mortgage loans in Stage 3 stood at around 2% with NPL (non-performing loans) coverage ratio of 62% (CNB, 2023).

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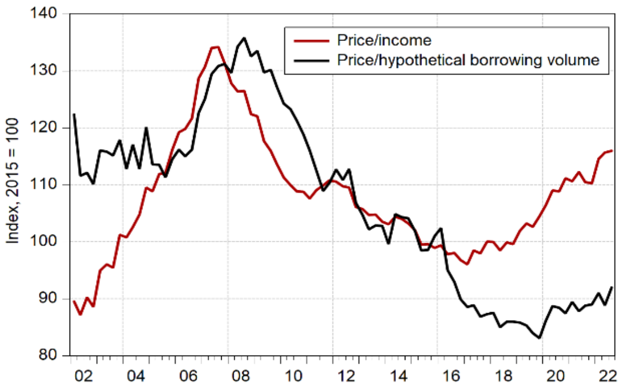
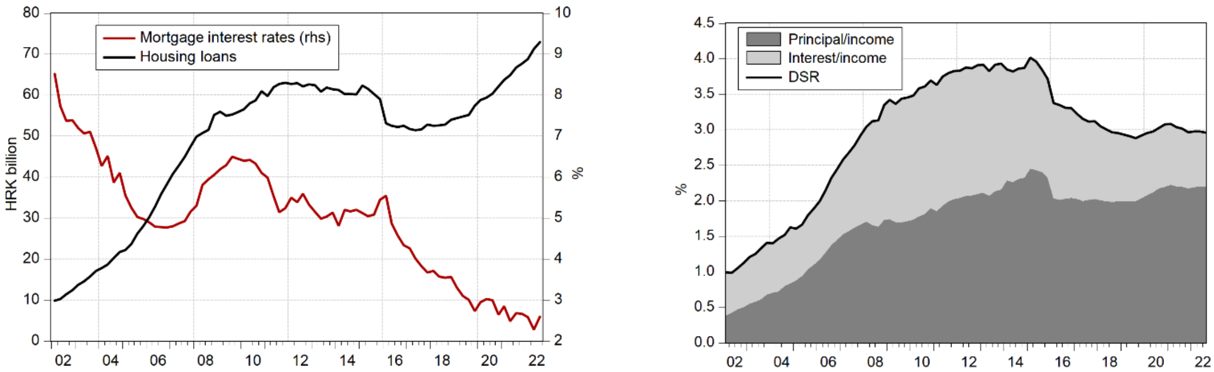
[4] See Section 4.1., Figure 4.
[5] Indicator is calculated following Drehman et al. (2015) approach available in *How much income is used for debt payments? A new database for debt service ratios.*

Figure 2. Housing affordability indicators



Note: Data for 2022 are available up to the third quarter. The hypothetical borrowing volume is defined as the maximum loan amount that households may be granted taking into consideration disposable income, interest rates on housing loans and the average maturity of housing loans with debt-service-to-income (DSTI) fixed (0,43) in the analysed period. Price to hypothetical borrowing volume ratio has been calculated in line with Hertrich (2019).
Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; authors' calculations.

Figure 3. Financial conditions (left) and mortgage debt service ratio (right)



Note: The data for 2022 is available up to the third quarter. Data on disposable household income is revised and calculated in a way that annual series are disaggregated using indicators of employee benefits and gross operating surplus and mixed income.
Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; authors' calculations.

3. LITERATURE REVIEW

3.1. Research on house-price-at-risk

Empirical research on HaR is relatively scarce, although the concept of "at-risk" measures is not a novelty, especially not in finance (the VaR, Value at Risk, measure). Other popular variables that are being forecasted via the QR (quantile regression) approach include inflation-at-risk (López-Salido and Loria, 2021), bank capital-at-risk (Lang and Forletta, 2019 2020), unemployment (Adams et al., 2020), capital flows (Eguren-Martin et al., 2021, Gelos et al., 2022), and definitely Growth-at-Risk (GaR) (Adrian et al., 2016, 2019; Aikman et al. 2018; 2019, and many others). HaR is not yet sufficiently explored due to the shorter time series of house price dynamics compared to other macro-financial variables important for macroprudential policy. Forecasting such dynamics is challenging. All of the existing research below employs quantile or panel quantile regression, in which both supply and demand side factors are included based on data (un)availability. The research is still in an early stage, and the analysis is exploratory.

Deghi et al. (2020) utilize a panel setting of 32 advanced and emerging economies to predict HaR based on data from 1990 to 2018. This is the IMF approach to modelling house-price dynamics, in which both DSGE (dynamic stochastic general equilibrium) and HaR are estimated, where the financial conditions indicator, real GDP growth, overvaluation (misalignment) indicator (house price/GDP per capita), and credit gap are used as main predictors within the panel quantile regression setting. The main results include different effects over the future house price growth distribution, with significant results of credit boom dynamics for emerging economies' HaR. Due to the sound out of sample forecasts, HaR is used as an indicator within the GaR framework.

One issue here could be using GDP dynamics as a proxy for real income growth and in the overvaluation measure that has the house price dynamics, which is already included as an explanatory variable. Alter and Mahoney (2020) show an example of another IMF study. The authors focus on a city-level analysis, i.e., 37 cities in USA and Canada are analysed in the period 1983-2018. The main variables of interest include household debt, FDI (foreign direct investment), capital flows, house price to income ratio, residential investment index, oil prices, and FCI (financial conditions index). The main results indicate that HaR has fallen for the USA, whereas it has risen for Canadian cities, which means vulnerabilities in the house dynamics sector are growing. Tighter financial conditions affect HaR in the short term, household leverage increases HaR in the long term, and city openness, defined as the share of the immigration population, is also found as an important factor affecting future price dynamics.

Galán and Rodríguez-Moreno (2020) from Banco de Espana give a good introduction to at-risk measures and their importance for macroprudential policymakers. The authors describe the quantile regression methodology and show its application on HaR and GaR for the case of Spain. HaR is estimated on a single-country analysis for the period 1981 to 2019, whereas GaR was estimated on a panel of 27 EU countries. Focusing on the HaR part of the paper, overvaluation measure, household credit gap, population growth, and lag of house price growth are used to forecast future growth distribution. Overall results indicate that overvaluation measure and credit gap have adverse effects on future HaR being stronger after two years (compared to the 1-year forecast). In contrast, the demographic trends have a positive one (stronger for the 1-year forecast). Due to goodness-of-fit tests being satisfactory, the authors contrasted the 1-year density functions for the GFC case to show how the such tool could be useful in detecting future downside risks for the case of house prices.

Cucic et al. (2022) is a similar study to the previous one in terms of showing the GaR and HaR cases, but with a focus on Denmark. The authors introduce these topics and their relevancy in the macroprudential policy decision process. As the correlation between the real economy, credit, and house price dynamics for the case of Denmark is fairly high, the prudential authority should monitor HaR. Explanatory variables include GDP growth, house prices, income dynamics, debt servicing rate, and housing investments. Additionally, BBM (borrower-based measures) are included to reflect the macroprudential stance in the forecasting procedure. Overall, the results show a trade-off effect for GDP growth and housing investments. There is a positive effect of GDP growth and a negative for investments on HaR, and on the other hand negative effect for GDP growth and a positive for investments on average price growth. The negative effects of house prices on income and debt servicing ratio are also obtained. The policy-related BBM variable is also of interest, as it has a positive impact on HaR but a negative on the median growth. Tighter BBM measures reduce median price growth, thus increasing housing affordability, and such measures increase HaR, which means that in a boom-bust cycle, materialization of downside risks should not be as substantial as without implemented measures. Finally, Cevik and Naik (2022) is the newest research paper where authors evaluate 10 countries of emerging Europe[6] for the period 1998-2022 to estimate HaR determinants. Authors found prominent effects of interest rates and income growth on future price dynamics, on the entire growth distribution. In recent period with coordinated monetary policy tightening, this is an important finding to bear in mind.

Other central banks use the HaR method regularly in their policy analyses, namely related literature includes the Financial Stability Review of Luxembourg (2022), in which HaR is estimated on mortgage credit growth, real disposable income, real interest rate, bank sector vulnerability indicator, and permits dynamics, and Central Bank of Ireland which, as shown in Financial Stability Review (edition 2020 II), estimated a model by extending existing GaR framework to assess the distribution of future house price outcomes after the COVID-19 shock in 2020. Panel analysis of 27 OECD countries from 1990Q1 to 2020Q3 generates house price distributions conditioned on house price growth rates, a misalignment indicator, financial conditions, level of systemic risk (credit gap in the case of Ireland), and market structure (FSR, Kenney and Wosser 2020). Their model is similar to that of O'Brien and Wosser (2018) and the ECB's, more distinctly a model of Lang et al. (2020) published in Financial Stability Review (May edition). Following the initial model discussed in Financial Stability Review, O'Brien et al. (2022) examine the policy implications of imposing different taxes in both Irish and other housing markets across Europe. Results indicate that the policy of recurrent property taxes is associated with a reduced magnitude of downside risks to house prices and an overall easing of house price volatility. On top of that, as an integral part of the financial stability analysis, ECB and IMF regularly report on the HaR for euro-area countries and advanced and emerging economies, respectively.

3.2. Research on house price dynamics and housing markets in Croatia

Methods to evaluate house price dynamics, identify main determinants and associated risks for financial stability in Croatia were also regularly published in CNB external publications - Financial Stability Reports (e.g., 2014 (Box 2) and 2017 (Box 2)) An error correction model (ECM) for the Croatian housing market based on supply and demand factors was analysed to capture house price deviations in period 2000-2013 (FSR, 2014, Box

[6]Croatia is not included.

2). Similarly, a composite indicator of price deviations from the long term-trend was constructed based on a multivariate methodology (principal component analysis) that includes determinants on the supply and demand side and for (in-house internal) policy decision-making. Accordingly, another vector error correction model (VECM) for period 2002 – 2021, interest rates and construction costs were the main house price determinants. A full description of the internal analyses and description of different overvaluation methods (both indicator and model approach used in CNB) is documented in Sabol (2022), but these approaches are still under development.

Apart from that, existing literature in Croatia focused more on dealing with various issues about house price dynamics. Even though these papers do not consider the approach of our research, they are important in determining the variable selection in this research. The first empirical study of house prices in European transition countries was done by Égert and Mihaljek (2007). Most papers look at macroeconomic fundamentals and their effects on house price dynamics. For instance, Lovrinčević and Vizek (2008) utilize cointegration to identify main house price determinants. Authors show that the long-term income elasticity of prices is very high and three times higher than the new supply elasticity of prices. Interest rates are also found to be essential for price dynamics in the long-term, whereas household credit dynamics are relevant in the short-term.

In a paper on examining the long-run and short-run behavior of house prices in Eastern and Western European countries (among Croatia), results suggest that with interest rates and income, house prices in both groups react in the short run to changes in the construction activity (Vizek 2010).

A unique aspect of the Croatian housing market is the government programme of subsidizing housing loans. Research by Kunovac and Žilić (2020) using an event study found that the program affects house prices – in the period of the introduction of the program in 2017, prices did increase and did reduce housing affordability, while Tica (2020) shows that the same programme increased house prices from 3 to 10 pp. above the level explained by macroeconomic fundamentals. Therefore, we expect this feature to affect our models' results.

3.3. Determinants of house price dynamics

A detailed analysis of the most important determinants of house prices on the supply and demand side is documented in various papers such as Égert and Mihaljek (2007), Glindro et al. (2011), and Algieri (2013), of which the effect of disposable income, housing stock, population growth, interest rates, and household debt (Dreger and Kholodilin, 2011) are most significant. However, most authors believe that household disposable income and interest rates play a key role in shaping house price trends. With the growth of disposable income per capita, households can allocate more to house purchases and debt servicing, thus raising demand and house price growth, especially amplified in low yield environment. Accumulating financial net wealth by households also affects the increased demand for housing units and contributes to house price increases. Claussen (2013) concludes that the contribution of disposable income in explaining price growth is around 60%, while growth in financial wealth accounts for less than 10%. Demographic trends (population growth) affect the increased demand for housing units, especially owner-occupied housing. However, population growth in the last few decades surpassed housing investment growth, which resulted in a decrease quality of housing supply.

Since real estate accounts for a significant portion of household wealth[7], the impact on aggregate demand through the wealth effect is an important factor in the increased demand for real estate. An increase in housing wealth, due to the impact on expected permanent income, should increase the personal consumption of owner-occupiers. The effect of wealth on aggregate demand, among others, was also confirmed in Croatia (Ahec-Šonje et al., 2012 and Čeh Časni, 2014). In the expansion phase of the cycle, wealth effects put further pressure on house prices, thus further stimulating credit expansion due to the increase in the value of the collateral (Bernanke and Gerlter, 1995). Moreover, consumption is reduced when house prices rise, affecting corporations and GDP on the economy's supply side. There is even evidence that the changes in house prices preceded changes in the loan market (e.g., Grinderslev et al., 2017), which may provide insight into future loan dynamics. Other relevant issues for financial stability are documented in Borio and Drehmann (2009), and Barrel et al. (2011).

4. DATA AND METHODOLOGY DESCRIPTION

4.1. Data description and choice of variables

For the empirical part of the paper, quarterly data for the period 2002 Q1[8] to 2022 Q3 on the following variables have been collected from different sources such as Croatian National Bank, Croatian Bureau of Statistics and Eurostat (2023). House price index (national/total and regional) is an official quarterly based index calculated by the Croatian National Bank and the Croatian Bureau of Statistics. Following variables are: real house prices (*rhpi*); calculated by deflating using the harmonised index of consumer prices (HICP) (2015 = 100), real GDP (*gdp*), stock of mortgage credit (*credit*), mortgage interest rates (new business) (*ir*) and building permits index (residential buildings; square meters of useful floor area, 2015 = 100) (*permits*). All of the variables have been transformed into year-on-year growth rates or differences in view of stationarity (e.g., we calculate differences for mortgage interest rates, whereas other variables are transformed into growth rates) (Figure 4) [9].

The main model presented in the paper is a result of testing several dozens of different model specifications, with respect to the variable selection process. We estimated different specifications of the house-price-at-risk model, by including variables both on the supply and demand side (see Appendix, Figure A7.). Due to short time series, we couldn't estimate a model in which a full set of variables could be used, as too many parameters would be

[7] House price changes can be a source of risk for the household sector and non-financial corporations. Due to the wealth effect, private sector vulnerabilities usually rise when house prices change substantially (see Bakker, 2015).

[8] 2002 Q1 is the earliest date for which the data on house prices is available.

[9] We first started our analysis with set of different variables – please refer to Appendix 1, alongside different model specifications that were not optimal and were therefore left out of our research scope.

estimated based on a relatively small number of observations. Thus, we opted to test different variables as substitutes for the supply and demand side, by taking into consideration the presented literature review and data availability for Croatia.

As regards the overvaluation indicator in CNB's risk monitoring framework[10] which includes the house price dynamics (i.e., real house price index and different house price ratios), we decided not to include it as it is a factor that contributes to the house price growth, as the quantile regression already includes price growth at period *t*. In that way it already contains enough information about past house price dynamics. We obtain similar finding for the domestic systemic risk indicator (d-SRI) that tracks cyclical risks (see Škrinjarić, 2022) so this variable was not considered in our analysis.

We opted to use mortgage interest rates as a proxy to financial conditions over FCI (see Dumičić and Krznar, 2013) because of the feature of underdeveloped and shallow financial markets in Croatia. Also, we believe that CSSI/HIFS (Croatian systemic stress index) as a composite indicator that synthesises the daily financial stress on several financial markets does not have a direct effect on housing market. It captures immediate sentiment and reactions of investors on financial markets, which are shallow and almost non-existent in Croatia. This specific characteristic of the Croatian markets makes it harder to obtain meaningful results if such indicator was used. While the stress caused in these markets can have an effect on bank behaviours in periods ahead, the effect on bank interest rates might not be so trivial. We tested this notion by including the variable in the model which resulted in the misleading information about the drivers of HaR and its dynamics (see Appendix, Figure A7, model e).

In addition, we wanted to see the results in case of using mortgage interest rate levels. Seeing that the interest rate has a specific dynamic, the results did not make much sense making it the main driver of the results, as other variables are in growth rates (see Figure A7, model f). As expectations are also an important feature of the housing markets, sentiment index, i.e., intention to buy or build a home in the next 12 months was considered. However, the variable was dropped because it was too volatile and available only since 2005 (see Figure A8., panel b).

Foreign demand as a specific factor which is present on the Croatian market could be something worth investigating. For that purpose, we propose a new variable that captures how much foreigners pay per transaction on the housing market, compared to domestic ones. We calculate the year-on-year difference of this variable to make it comparable in growth terms as other variables (see Figure A7, model g)[11].

Moreover, as a result of the higher correlation between variables real GDP growth and household disposable income growth, we chose to go with real GDP as a proxy for real income dynamics, and as a result of higher correlation of construction sentiment indicator and building permits, we followed the approach by Banque du Luxembourg (2022) of including a variable building permit in our models.

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[10] For more information on the indicator see *CNB Financial Stability Report, No. 18. Box 2: Divergence of real estate prices in Croatia from intrinsic value*. As an alternative, another real house price overvaluation indicator was calculated based on a Hodrick-Prescott gap (one sided filter) (see Figure A8., panel a).

[11] Inclusion of the foreign demand variable in the models follows the dynamic and conclusions about HaR similar to the main model presented below (see Figure 6.).

Variables not included in the analysis, as discussed above, could potentially have significant effects in the models and HaR dynamics, but without additional data, we cannot be sure. Namely, foreign demand makes up for approximately 10% of the total real estate transactions recently meaning that it could have a meaningful effect on the price dynamics. However, when we have used this variable in one specification, the results did not change significantly. This could be due to the used transformation, in terms of comparing how much more or less foreigners pay per transaction. Other transformations of the foreign demand were either too volatile or had dynamics that could not be explained and included in the model in the form of y-o-y growth rates. Aging and demography changes in Croatia are specific in the last couple of decades (see Appendix Figure A8, Panel c), in terms of population decline and dropping significantly at each population and housing census. This variable can only distort our results – demand is growing although population is declining, and in y-o-y growth rates, it is visible how forecasting of population dynamics between censuses is not perfect, due to spikes in specific years (after the pcensus). After a formal census, shifts of the population number are observed, and the values are not corrected retroactively, could lead to wrong estimates. Index of systemic stress is also not a suitable variable, as it is not a representative for our country. There are no alternatives to housing investments on the market, as it is the case in other countries where financial markets and market financing is more prominent.

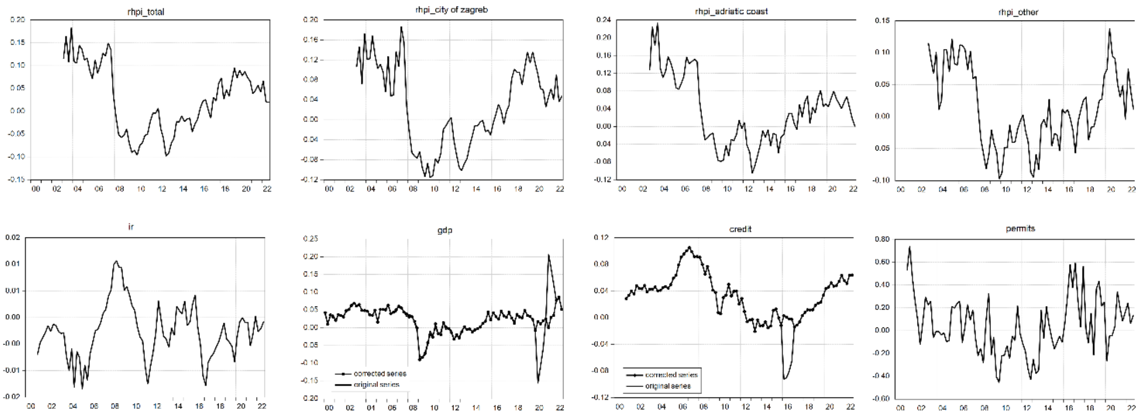
Since the Croatian housing market remained fairly resilient during the COVID-19 shock (ESRB, 2021 and CNB, 2022) a correction of the GDP series was necessary. Real GDP growth had a fairly significant drop in the second quarter of 2020, and a rebound a year later was significantly higher. Such dynamics would affect house price forecasts, which would not reflect actual realisations of house price dynamics. In order to capture these effects, we opted to correct the dynamics of GDP and income by using a simple SARIMA[12] model up to the pre-COVID period. Forecasts from that model in the COVID-19 period were used to smooth out the problematic dynamics in 2020 (see Figure 4, panel *gdp*). Due to the foreign currency mortgage conversion in 2015, the stock of mortgage credit (*credit*) might contain a level shift that would impose an issue. We expected this to affect our empirical results, so we have proposed an alternative by correcting the mortgage credit series. Several approaches were examined to smooth out credit dynamics, such as ARIMA[13] modelling and moving averages. Based on the results obtained in terms of smoothness of the resulted series, we have chosen the 4-quarter moving averages of previous credit growth rates to estimate the first quarter of 2016 that is problematic. Afterwards, the new 4-quarter moving average was calculated based on the 3 true values and the fourth estimated value from the previous step. The procedure is repeated until the end of 2016 (see Figure 4, panel *credit)*.

Figure 4. shows different variables used in our final quantile regression models. As already depicted in the chapter on stylised facts, after reaching a peak in GFC and following the largest drop of economic activity, real house prices (*rhpi*), either decreased or increased less than inflation from 2008 to about 2016, but in the recent period, have continued to grow due to the low inflationary period up to mid-2021. Interest rates (*ir*) have been influenced by broader financial conditions in the euro area. Similar studies of the ECB's monetary policy measures are reflected in subsequent spillovers to countries like Croatia (e.g., Moder, 2017). Also, the business cycle alignment and economic shock correlation between Croatia and core

[12] Seasonal autoregressive moving average.
[13] Autoregressive moving average.

euro area countries are relatively high (Kotarac et al., 2017). On the other hand, building permits (*permits*) have more volatile dynamics – they depend on various factors outside their scope (including obtaining the necessary licenses, submitting all required notifications on a local level etc.)[14]. In addition, some variables have been influenced by high inflationary pressures in the recent period, such as real GDP (*gdp*).

Figure 4. Variables used in quantile regression models



Note: rhpi_total, rhpi_city of zagreb, rhpi_adriatic coast_ rhpi_other refer to total and regional real house price indices.
Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; authors' calculations

4.2. Methodology description

Quantile regression[15] (QR) model in a basic form can be written as:

$$y_t(\theta) = \beta_0(\theta) + \sum_{k=1}^{K} x_{t,k}\beta_k(\theta) + \varepsilon_t(\theta), \tag{1}$$

where the dependent variable y_t is estimated at quantile θ, $x_{t,k}$ are conditional variables, $\beta_k(\theta)$ is *k*-th beta parameter that needs to be estimated at quantile θ, and ε_t is the error term. At every quantile $Q_\theta(y|X)$, $0 < \theta < 1$, the following minimization problem is solved:

$$\underset{\beta_k(\theta)}{\arg\min} \sum_{t:y_t \geq \hat{y}_t} \theta\left|y_t - \beta_0(\theta) - \sum_{k=1}^{K} x_{t,k}\,\beta_k(\theta)\right| + \sum_{t:y_t < \hat{y}_t} (1-\theta)\left|y_t - \beta_0(\theta) - \sum_{k=1}^{K} x_{t,k}\,\beta_k(\theta)\right|, \tag{2}$$

where $\hat{y}$ is the estimated value of y. If we want to utilize QR to predict house prices, then, the dependent variable is defined as:

$$y_{t+h} = 100\% \cdot \left(\frac{r\_RHPI_{t+h}}{r\_RHPI_t} - 1\right) / \frac{h}{4}, \tag{3}$$

[14] For reasons on time variation of building permits, please see Jovanović et al. (2016).
[15] For an introduction into QR, with advantages and shortfalls, see Koenker (2005), Davino et al. (2013), or Koenker and Bassett (1987).

where RHPI stands for real house price index, and growth y_t is calculated h quarters ahead, h = 1, ..., 16. In the GaR literature, the common approach is to observe all h quarters ahead. For the case of HaR, one year ahead (h = 4) is commonly observed.
We look at several model specifications of forecasting y_{t+h} with h = 4:

$$y_{t+h}(\theta) = \beta_0(\theta) + \beta_1(\theta)y_t + \beta_2(\theta)ir_t + \beta_3(\theta)credit_t + \beta_4(\theta)gdp_t + \beta_5(\theta)permits_t, \tag{4}$$

where y_t is the house price growth rate at horizon h, ir_t mortgage interest rates as yoy change, $credit_t$ is yoy growth of stock of mortgage credit, gdp_t is yoy real growth and $permits_t$ is building permits index yoy growth. Due to having relatively short time series for *rhpi* indicator, we opt to determine the lowest percentile in the estimation the 10th percentile one, instead of the 5th percentile. The several specifications of model (4) include the nominal and real terms of variables, as well as including both original values of GDP without COVID-19 corrections and a corrected version, and original and corrected values of mortgage credit.

Each model is compared to a QR without regressors, i.e., a constant on each quantile is estimated as a benchmark model, and for every specification of the model in (4) we calculate pseudo-R squared at each quantile:

$$R_\theta^2 = 1 - \frac{RASW_\theta}{TASW_\theta}, \tag{5}$$

in which we calculate $RASW_\theta$ as the residual absolute sum of weighted deviations of real values to the estimated ones, and $TASW_\theta$ as the total absolute sum of weighted deviations.

After obtaining the estimated quantiles from the QR, the usual approach is to fit a skewed t-distribution density of Azzalini and Capitanio (2003):

$$f(y; \mu, \sigma, \alpha, \upsilon) = \frac{2}{\sigma} t\left(\frac{y-\mu}{\sigma}; \upsilon\right) T\left(\alpha \frac{y-\mu}{\sigma} \sqrt{\frac{\upsilon+1}{\upsilon\left(\frac{y-\mu}{\sigma}\right)^2}}; \upsilon + 1\right), \tag{6}$$

where are the probability density function is $t(\cdot)$,cumulative density function is $T(\cdot)$, μ, σ, υ, and α are the location, scale, fatness, and the shape parameter respectfully. The following model is optimised so that the parameters could be estimated:

$$\underset{\mu,\sigma,\alpha,\upsilon}{\arg\min} \sum_\theta \left(\hat{Q}_{y_{t+h}} - F(\theta; \mu, \sigma, \alpha, \upsilon)\right)^2, \tag{7}$$

where the quantiles of the skewed t-distribution are matched to the empirical quantiles from the QR model. Empirical quantiles that are used in (7) are 5, 25, 75 and 95 if more data is available.

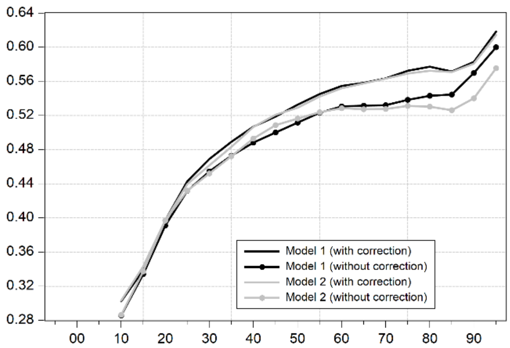
5. EMPIRICAL FINDINGS

5.1. Model comparisons

In our approach, we focused on different models that refer to total price index (including GDP corrections for the COVID-19 period, and including mortgage credit corrections in 2016[16]) depending on whether inflation is captured in certain variables, e.g., interest rates. More specifically, in *Model 1*, we use nominal mortgage interest rates, and in *Model 2*, real mortgage interest rates are deflated by HICP (harmonized index of consumer prices). This resulted in a total of four model variations: *Model 1* without corrections, *Model 1* with the correction, and *Model 2* without and with correction of GDP and mortgage credit series.

Figure 5 shows that the models' differences are very small. However, the models with corrections have higher pseudo-R squares for the right part of the distribution. It is also evident that the model finds it challenging to model the lower tail of the growth distribution, meaning that our results regarding the HaR, i.e., the 10th percentile growth, should be taken with some caution. Reasoning on why this is the case could be found in shorter time series that do not capture more cycles in house prices, and lack of other variables that would be able to capture some specific effects on downturn risks.

Figure 5. Pseudo-R squared values for all models over quantiles



Note: x-axis depicts quantiles (from 10th to 95th) and y-axis the value of the pseudo-R squared. Results refer to the total price index and after all corrections mentioned in the main text.
Source: Authors' calculations.

Further, we examine how many realized values of the real house price growth rate have "stayed within" the HaR and median value, respectively, for the forecasted horizons of 4 to 16 quarters of each model. A "good" model should capture approximately 10% of true values below the 10th percentile and 50% for the median. According to Table 1, we can see that all of the models come very close. Both corrected models have a slightly better performance, but this is just numerically speaking.

[16] See Figure A2. and A3. for Model 1 & Model 2 that capture original series of mortgage credit. Furthermore, appendix A1 gives an overview of different model specifications which were analyzed in our first attempt. The model's performance or interpretations of the contributing factors were not satisfactory.

Table 1. Share of real values of house price growth not exceeding the HaR or median values

Horizon	Nominal, not corrected		Real, not corrected		Nominal, corrected		Real, corrected	
	10th percentile	Median	10th percentile	Median	10th percentile	Median	10th percentile	Median
4	0,08	0,48	**0,11**	**0,49**	0,08	**0,49**	0,08	**0,51**
8	0,08	0,48	0,08	0,48	0,08	**0,49**	0,08	**0,51**
12	**0,09**	0,48	**0,09**	0,48	**0,09**	**0,49**	**0,09**	**0,49**
16	0,08	0,48	0,08	0,48	0,08	0,48	0,11	**0,49**

Note: Bolded values indicate best performance by row for 10th percentile or median value. Values should be multiplied with 100% for percentage interpretation. Results refer to the total price index.
Source: Authors' calculations.

5.2. Main findings

In this part, the main empirical findings are presented with a focus on identifying drivers of both house price-at-risk value (HaR) and median house price growth. In addition, due to regional heterogeneity of the market, we also analyse both HaR and median house price growth for three regions: the City of Zagreb, the Adriatic Coast, and Other. Identifying individual factors/contributors to house price risks is an important part of monitoring framework. Factors affecting house price-at-risk (HaR) and median house price growth from *Model 1 (with corrections)* are depicted in Figure 6[17]. The main findings can be summarized as follows[18].

Mainly, the autoregressive component for national/total house price index is positive and greater for median house price growth, which is expected and consistent with related HaR and GaR literature. Interest rate changes affect the median value in particular and, to a smaller extent, the HaR dynamics. This is in line with ECB (2022), where authors found that the average house price in the euro area declines about 5% to a one percentage point shock in mortgage interest rates after almost two years, and Iossifov et al. (2008), who find sizeable effects of mortgage interest rates on house price dynamics in a panel setting. When exploring the non-linear nexus between house prices and interest rate changes, evidence points to the fact that in a low interest rate environment (feature of period 2015-2021), non-linearities in house price changes to interest rate changes are actually important compared to results obtained in a linear model (Dieckelmann et al., 2023). The authors show that an increase of real interest rates by 0.1. pp could have an effect on downward pressures on real house prices about -2.4% and -1.2% which is four to eight times larger than literature suggests. Via its effects on money and credit, interest rates can significantly influence the occurrence of

[17] We also put the comparisons of the estimated values for the quantile regression (QR) case and the OLS one in Appendix, in Figure A1, where it can be seen that the estimates differ not only when comparing the QR case to the OLS, but between the two quantiles as well.
[18] Although the 10^{th} and 50^{th} percentiles are shown in forthcoming figures, that does not mean that house price growth is simultaneously obtained in both values. Figures show the dynamics of both percentiles, which could have been achieved with a certain level of probability. These probabilities are visible in Figure 8 and Figure 9 as an example.

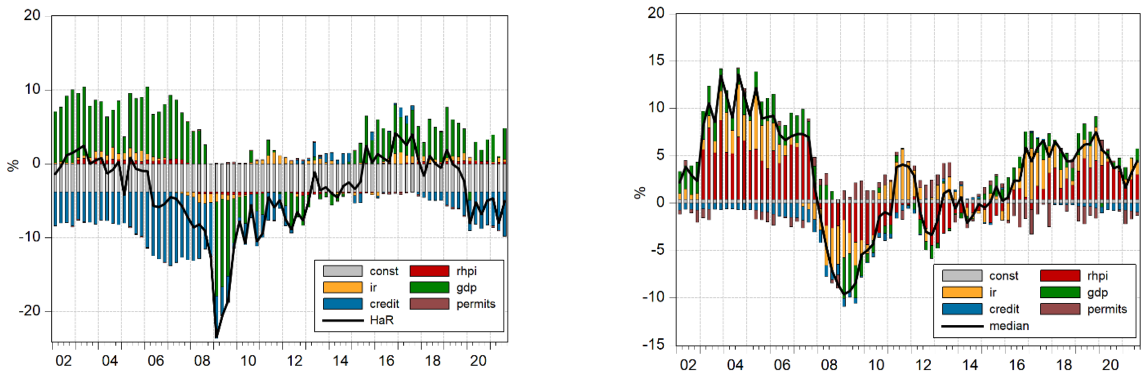
booms and busts in the market (Agnello and Schuknecht, 2009). On the other hand, smaller effects of interest rate dynamics on HaR dynamics are consistent with the results of Deghi et al. (2020) and IMF (2017). Authors also find that effects of monetary policy reflected in the dynamics of mortgage interest rates are limited to downside risks of future house prices. This notion is important for policymakers in the current conjecture of monetary policy normalisation in the euro area. A study by Cevik and Naik (2023) on city-level analysis of house price cycles in Lithuania shows a significant relationship between financial conditions and real house price growth.

Real GDP growth positively affects HaR and median growth dynamics, with a more significant effect on the 10th percentile. This conclusion is consistent with Cevik and Naik (2022), who estimate a quantile regression in examining the factors affecting housing prices in selected CEE countries (Croatia was not included). Although average house price growth increased during GDP growth, it also contributed to lowering decreasing future downside risk as the entire distribution shifted to the right. The correlation between credit dynamics and median growth is insignificant but sustainably greater for HaR values. Such results capture the significance of the surge in credit growth in the pre-GFC era, which is in line with Goodhart and Hoffman (2008). Authors find that credit dynamics have a stronger effect on house prices when house price growth is booming than otherwise. Gerlach and Peng (2003) analyse the short- and long-term relationship between house prices and mortgage credits and found similar results: credit is not a significant determinant of house price movements[19].

Although we recognize that new mortgage lending might be a better measure of credit growth, compared to change in credit stock (see Plašil et al. (2015) and Biggs et al. (2009)), it is not possible to use the series in our case because flow of credit (new mortgage lending) is only available since 2011, so we opted to use change of stock. We realise this is a problem in the analysis and future work should address this. The feedback loop from house prices to credit growth is strongest in countries where variable-rate mortgages are widespread (Tsatsaronis and Zu, 2004), which is not the case in Croatia (see chapter on stylised facts). In contrast, empirical research on apartment prices in the Czech Republic by Hlavaček and Kalabiska (2022) revealed a positive effect of mortgages on prices. The effect of building permits on downside risks to house prices is statistically insignificant in the 10th percentile, while median price growth has been influenced by this supply-side factor only partially. This is in line with Abraham and Hendershott (1996), Hort (1998), and Malpezzi (1999), who argue that the supply side may have small effects on house prices of existing house stock, which is largely affected by the household income, interest rates, and lag of house prices (again, in line with our findings).

[19] Dees et al. (2017) propose to use the growth rate of the credit flow instead of changes in the credit stock. Similar choice of variable was used by central bank of Luxembourg in their study. However, this is not possible in our case because flow of credit (new mortgage lending) is only available since 2011. Moreover, Plašil et al. (2015) acknowledge that the stock of loans consists of bad (non-performing) loans, and use series of new loans instead, while Biggs et al. (2009) on theoretical basis show why this approach is more suitable.

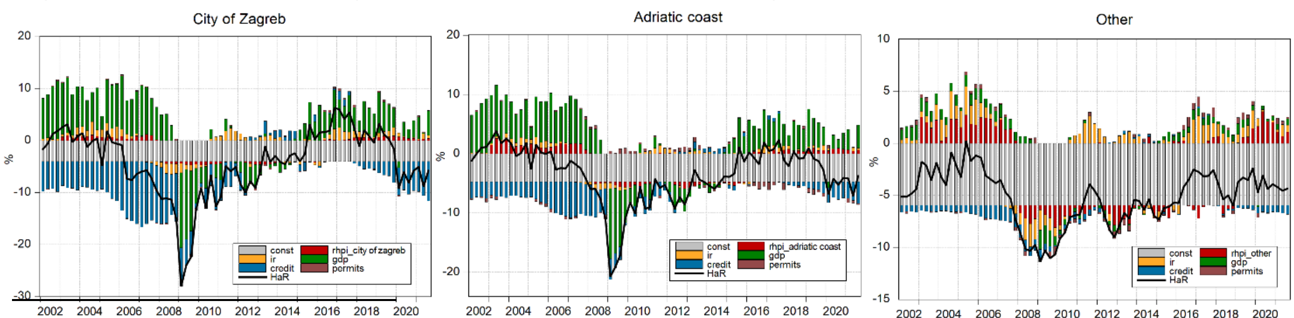
Figure 6. Factors affecting house price-at-risk (HaR) (left) and median house price growth (right) in Croatia



Note: Const = constant, rhpi = yoy growth real house prices, ir = yoy change of mortgage interest rates, gdp = yoy real GDP growth, credit = yoy mortgage credit growth, permits = yoy growth building permits, HaR = house-price-at-risk (10th percentile).
Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; authors' calculations.

The main results for regional indices can be summarised as follows (Figure 7a). The model is consistent for the City of Zagreb and the Adriatic Coast, with some deviations for the Other. This could lead us to the fact that other factors, apart from analysed ones, may affect the house prices in the rest of Croatia and that there is a huge heterogeneity in the market that our model cannot capture entirely, so future work should expand upon this with the inclusion of variables on a regional level[20]. This is noticeable in the most significant value of the constant in the model (Figure 7a, panel Other) and lower contributions of the main explanatory variables. Therefore, although we observe a similar dynamic of the HaR in this region, results should be taken cautiously. Moreover, concerning median growth and its contributors, overall results of median dynamics follow the same pattern as the national index results (see Figure 7b & Figure A4 in Appendix) except for region Other in which financial conditions (interest rates) have a substantially greater impact. In addition, the City of Zagreb experienced greater median growth in the model at the end of the observed period (see also Figure A5 in Appendix) in comparison to other regions because a significant portion of both domestic and foreign demand is concentrated in this region, so it is reflected in house price growth.

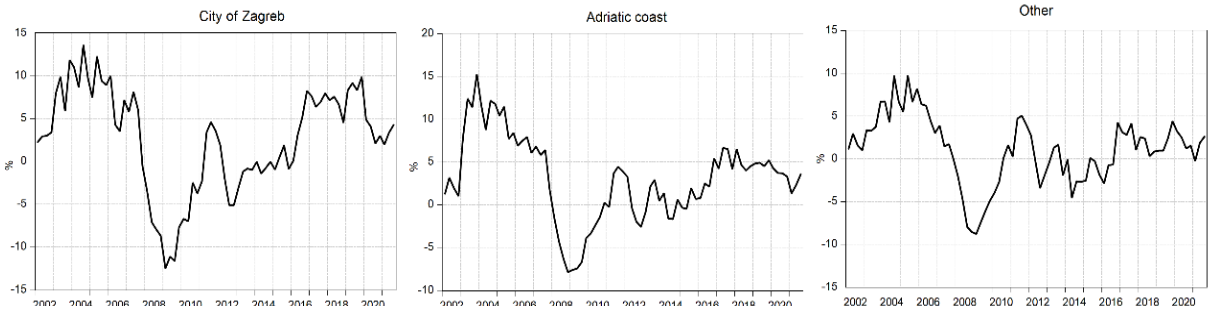
Figure 7a. Factors affecting house price-at-risk (HaR) in regions



[20] Our attempt of finding a suitable set of variables that correspond to the specific region was unsuccessful, as we could not find the optimal combination that could reflect regional country-specific features of the housing markets (e.g., proxy for regional GDP (industrial production, employment), interest rates and credit)

Note: Const = constant, rhpi = yoy growth real house prices, ir = yoy change of mortgage interest rates, gdp = yoy real GDP growth, credit = yoy mortgage credit growth, permits = yoy growth building permits, HaR = house-price-at-risk (10th percentile).
Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; authors' calculations.

Figure 7b. Median house price growth in regions



Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; authors' calculations.

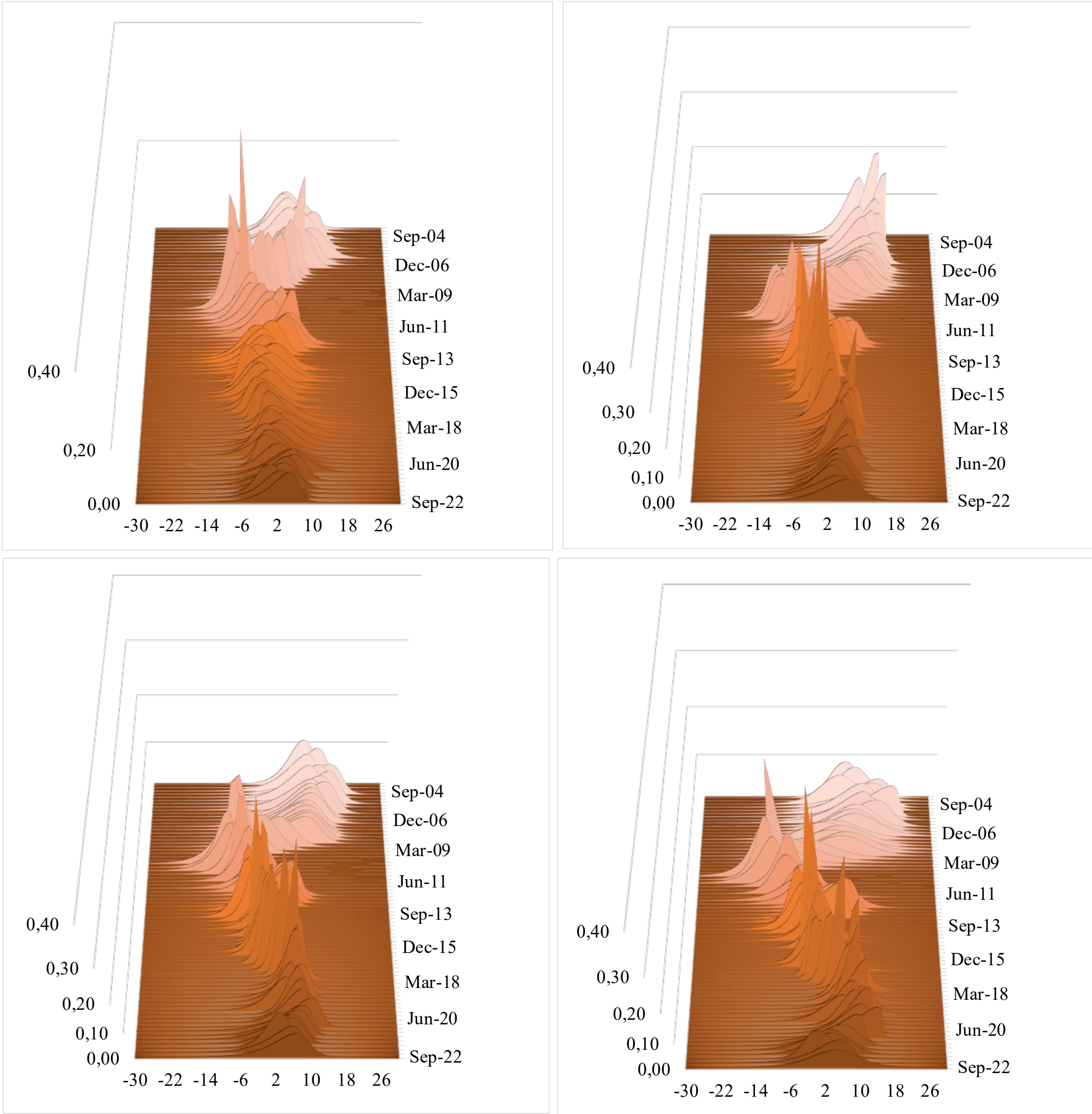
House price-at-risk gradually worsened in the early 2000s, leading to the period before GFC. This finding and following can be applied to both national and regional case (Figure 6 and Figure 7a). Over time, past house price movements and credit also started to have a negative effect, partially offset by the positive effect of GDP growth. After GFC, the downturn in economic activity and tightening of financial conditions weighed negatively on house prices at risk. After years of sustained house price growth and decreasing downside risks, since 2017, house price-at-risk appears to have deteriorated gradually due to high credit growth and the indirect effect of looser financial conditions (low yield environment). The largest effects actually coincide with the introduction of government subsidies in Croatia.

More broadly, contributing factors to both HaR and median house price growth in the Croatian housing market support the view that the increase in house prices in Croatia that started in 2017 was mostly in line with movements of other house price cycles across Europe and international financial cycle during analysed period (see Kunovac and Žilić, 2020). Overall, contributing factors to median house price growth are more aligned with recent developments in the market, especially since COVID-19, as presented in the section on stylised facts.

5.3. Estimating distribution of real house price growth

To present the possibility of using such an approach to house price forecasting, we estimate the dynamics of the entire forecasted distribution of one-year ahead growth (h=4). Skewed t-distributions for every quarter from *Model 1* were fitted as described in the methodology section. Skewed t-distributions are presented for the total and regional indices (Figure 8).

Figure 8. Fitted house price growth distributions of total and regional indices, h = 4



Note: X axis (the front one) denotes growth values in %, y axis (left one) refers to the probability. Upper left shows Total index, upper right Adriatic Coast, lower left Other, lower right City of Zagreb.
Source: Authors' calculations.

In general, a left shift of the entire distribution, relative to some earlier point in time, corresponds to a general reduction in the outlook for house prices. Depending on various macro-financial drivers, the tail can move to a greater or lesser extent. Figure 8 distinctly shows the shifting and evolving dynamics of the growth distribution over time. While the abrupt shifts to the left are seen in both pre-GFC and in the GFC period, the recovery of forecasted distribution after was rather slow. Moving to a recent period, in the last couple of quarters, we can observe that the distributions started to move left again, even with the COVID-19 correction of the GDP series. Their tails became fatter compared to a couple of years prior. This broadening distribution dynamics increases the likelihood of tail events and indicates possible price corrections in the near term. Cevik and Naik (2022) noticed this trend already in other Central and Eastern Europe (CEE) countries in the second half of 2022. However, downside risks are much smaller compared to the GFC period, indicating a healthier macro-financial environment in the Croatian economy.

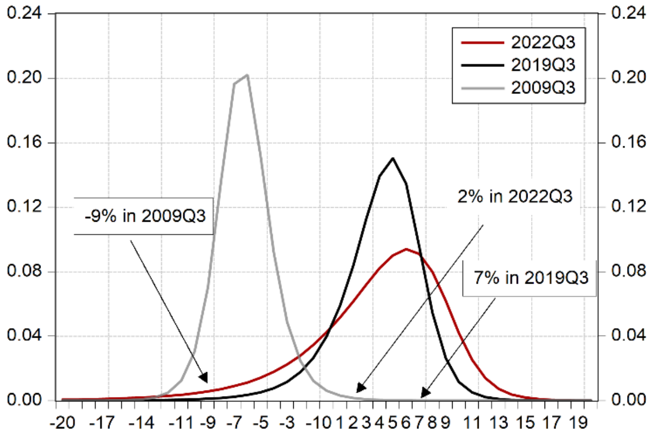
At last, we extract several distributions from Figure 8 to present an additional way of monitoring the dynamics of house price growth over time. Distributions in Figure 9 refer to what was forecasted for each quarter with the data available the previous year (for example, the forecast for 2022Q3 is done with available data from 2021Q3). The following points in time were selected to compare it to the most recent data:

i) the GFC period of 2009 (2009 Q3),
ii) pre COVID-19 period in 2019 (2019 Q3), and
iii) the last data point in our estimation (2022 Q3).

Actual realizations of real house price growth are also given to see their location in the distribution. We observe three things. First, the actual realizations of price growth are close to the distribution centres, which means that the most probable forecasts and those close to them are useful for forecasting purposes; this feature could be a helpful starting point in prudential monitoring. Second, the distribution shift over time matters, as seen when comparing the GFC point to others. This refers to point estimates that could not be sufficient enough meaning that using only point estimates as it is usually done with other approaches could be misleading, as in that case we cannot be sure what the probability of that particular estimate is. By using approach in this paper, we are more comfortable when talking about specific points from the estimated distribution. With such additional information on the distribution shifts, the policymaker obtains better positioning on where his point estimates lie. Last but not least, distribution width is an important feature. Indication of a bust in the housing markets according to relevant factors/drivers caused the narrowing of distribution and shrinking its tail (2009Q3). On the other hand, when comparing pre-COVID-19 distribution to the recent one, the latter is wider, probably due to greater uncertainty[21]. Monitoring national and regional real house price dynamics given in Figure 8 also gives insights into the characteristics of each distribution over time. Real house price growth before the GFC was very prominent and concentrated on the right tail for the case of Adriatic Coast, which is not the case for region Other. Greatest drop in prices and left tail concentration in GFC is prominent for City of Zagreb. Other similar comments and analyses can be made to reach conclusions about differences in the price behaviour between the three regions.

[21] Another forecast is shown in Appendix, Figure A6, as the average growth for the period 2022Q4-2023Q3. We depict average distribution due to the uncertainty of inflation forecasting, which affects the results. Another question is the right choice of the deflator, which is a topic under consideration in EU discussions about the issue of deflating nominal values due to the period of high inflation currently taking place. This is way beyond the scope of this paper, and we have left this topic for future explorations.

Figure 9. Comparisons of selected probability distributions of forecasted real house price growth



Note: X axis denotes growth values in %, y axis refers to the probability. Refers to total price index.
Source: Authors' calculations.

6. DISCUSSION AND CONCLUSION

Taking into account channels through which (in)stabilities in housing markets affect financial stability, it is of utmost importance to continuously improve the identification and monitoring of associated risks and thus develop suitable models and approaches. Monitoring the median house price growth dynamics and related downside risks is essential, as they are crucial for the overall monitoring toolkit and stress testing. Moreover, the macroprudential policy has to be forward-looking, so such an approach of forecasting the entire distribution of future house price growth could give additional insights into doing so.

This paper is the first one attempting to predict downside risks of future real house price growth in the Croatian housing market due to the importance for financial stability analysis and macroprudential policymaking. This paper finds that a variety of factors influence house price risks. Our results indicate that downside risks to house price growth have increased in the recent period, increasing the likelihood of tail events and price corrections. The work should be seen as a starting point for enhancing the methodology that will enable informed decision-making based on expert judgment. The empirical part of the paper confirms that it is challenging to model HaR dynamics as it is reflected in the title of our paper, so our results should be treated with caution. In general, there should be a consensus on which variables are the best choice for such analyses. Down the line, the choice of approach is determined by the purpose of the researcher and the institution, the availability of data, the length of the time series at their disposal, the complexity of house price dynamics, and its interaction with various macro-financial variables.

This study is subject to a few limitations because specific issues with Croatian data make the modelling process a challenge. This includes the unavailability of some series that still need to be appropriately defined, as is the case of specific overvaluation indicators and other demand and supply factors. In that manner, introducing a more suitable factor on the supply side for instance real housing investment (instead of building permits or production volume), should be a priority, as well as identifying a *proxy* variable for strong foreign demand in different regions.

Next, structural characteristics of the economy change over time, which is true for the Croatian case. For example, different characteristics of the housing markets have changed, and the banking sector's resilience has grown in the last couple of years compared to the pre-GFC period. Introducing a variable that reflects bank exposure to housing market is also justified.

With regard to model specifications, some other nonlinearities could not have been explored in the analysis, as short time series prevent it from doing so. With regard to heterogeneity of the market, future work inter alia should focus on analysing and capturing factors that could affect different regional indices separately. Structural differences between and within the housing markets should be taken into a consideration (as it is shown in case of region *Other*) as well as the choice of the appropriate deflator to capture differences in price dynamics within a country. Region-specific variables such as regional GDP or issued building permits for that region could be a more suitable way to analyse house price drivers/determinants.

The framework of this paper could be utilized as one of the main indicators for financial stability risks captured by the HaR model. Further findings could help forecast risks to GaR as presented in Deghi et al. (2020). Empirical findings could also help determine the effects of macroprudential measures (e.g., borrower-based measures that are tightened to better safeguard the household sector against unexpected shocks could be introduced in the model as a *policy* variable next to other supply and demand determinants). This is vital given the existence of (only) implicit borrower-based measures in Croatia that could alleviate build-up of risks related to housing market. Calibration of such policy measures and phasing-in should consider a country's economic, housing, and financial cycle position.

Moreover, monetary policy measures affecting interest rates could be fed into the model to see the effects on the HaR or median price growth. Both standard and non-standard monetary policy shocks could influence the latter and, given Croatia's recent accession to the euro area, could affect how policymakers analyse transmission channels. However, the ability of monetary policy to alleviate downside risks to house prices beyond its impact on financial conditions so far seems restricted (Deghi et al. 2020).

Several general lessons emerge from our results. From a policy perspective, we tried to suggest that identifying and assessing systemic risks associated with unsustainable movements in housing markets, as was the case in GFC, is and should stay an integral part of the overall financial stability analysis and presents a ground for adopting macroprudential measures. However, more than macroprudential policy measures are often required to address the abovementioned risks. Due to the complexity of risks arising in housing markets, the connection with other parts of the economy, and the availability and quality of data, it is necessary to turn to other policies. In reality, macroprudential policy, unlike other economic policies, must invest more work and focus in identifying the risks and vulnerabilities, especially when communicating to the general public about the possible effects of the measures. Nevertheless, it is possible getting the messages across about the risks associated with the housing market in a timely manner.

References

1. Abraham JM, Hendershott PH (1996): Bubbles in metropolitan housing markets. *Journal of Housing Research*, 7(2): 191-207.
2. Adams PA, Adrian T, Boyarchenko N, Giannone D (2020): Forecasting Macroeconomic Risks. FRBNY Staff Reports, No. 914, Federal Reserve Bank of New York.
3. Adrian T, Boyarchenko N, Giannone D (2016): Vulnerable growth, FRBNY Staff Report, No. 794, Federal Reserve Bank of New York.
4. Adrian T., Boyarchenko N, Giannone D (2019): Vulnerable growth, *American Economic Review*, 109(4): 1263-1289.
5. Agnello L, Schuknecht L (2009): Booms and busts in housing markets: Determinants and implications. ECB Working Paper No. 1071. European Central Bank.
6. Ahec ŠA, Čeh Časni A, Vizek M (2012): Does housing wealth affect private consumption in European post transition countries? Evidence from linear and threshold models, *Post-Communist Economies*, 24(1):73-85.
7. Aikman D, Bridges J, Burgess S, Galletly R, Levina I, O'Neill C, Varadi A (2018): *Measuring risks to UK financial stability*, BoE Staff Working Paper No. 738, Bank of England.
8. Aikman D, Bridges J, Hoke SH, O'Neill C, Raja A (2019): *Credit, capital and crisis: a GDP-at-risk approach*, Staff Working Paper No. 824, Bank of England.
9. Algieri B (2013): House Price Determinants: Fundamentals and Underlying Factors. *Comparative Economic Studies*, 55:315-341.
10. Alter A, Mahoney EM (2020): *Household Debt and House Prices-at-risk: A Tale of Two Countries*. IMF Working Paper WP/20/42, International Monetary Fund.
11. Azzalini A, Capitanio A (2003): Distributions Generated by Perturbation of Symmetry with Emphasis on a Multivariate Skew t-Distribution, *Journal of the Royal Statistical Society*: Series B (Statistical Methodology), 65(2):367–389.
12. Bakker B (2015): The role of wealth in the financial crisis. Available at: https://www.weforum.org/agenda/2015/02/the-role-of-wealth-in-the-financial-crisis/.
13. Banque centrale du Luxembourg (2022): *Financial Stability Review*, Banque centrale du Luxembourg.
14. Barrell R, Davis EP, Karim D, Liadze, L (2011): Bank Regulation, Property Prices and Early Warning Systems for Banking Crises in OECD Countries. *Journal of Banking and Finance*, 34 (9):2255–2264.
15. Behn M, Detken C, Peltonen T, Schudel W (2013): *Setting Countercyclical Capital Buffers Based on Early Warning Models: Would It Work?.* ECB Working Paper No 1604. European Central Bank.
16. Bernanke BS, Gerlter M (1995): Inside the black box: the credit channel of monetary policy transmission. *Journal of economic perspectives*, 9(4):27-48.
17. Biggs M, Mayer T, Pick A (2009): *Credit and Economic Recovery*, DNB Working Paper, No 218.

18. Borio C, Drehman M, Xia D (2019): *Predicting recessions: financial cycle versus term spread*, BIS Working Papers. No. 818, Bank for International Settlements.
19. Borio C (2012): The Financial Cycle and the Marco-economy: What have we learnt, BIS Working Paper Series, No 395. Bank for International Settlement.
20. Borio C, Drehmann M (2009): Assessing the Risk of Banking Crises - Revisited. *BIS Quarterly Review*, 29–46. Bank for International Settlement.
21. Cevik S, Naik S (2023): *Bubble Detective: City-Level Analysis of House Price Cycles*. IMF Working Paper, WP/23/33. International Monetary Fund.
22. Cevik S, Naik S (2022): *Don't Look Up: House Prices in Emerging Europe*. IMF Working Paper, WP/22/236. International Monetary Fund.
23. Claessens S, Kose M, Terrones M (2008): *What Happens During Recessions, Crunches and Busts?*. IMF Working Paper, No. 8, International Monetary Fund.
24. Claussen C (2013): An error-correction model of Swedish house prices, *International Journal of Housing Markets and Analysis*, 6(2):180-196.
25. Croatian Bureau of Statistics (2023): Database.
26. Croatian National Bank (2023): Internal database.
27. Croatian National Bank (2023): Financial Stability Report, No 24.
28. Croatian National Bank (2022): Financial Stability Report, No 23.
29. Croatian National Bank (2017): Financial Stability Report, No 18.
30. Croatian National Bank (2014): Financial Stability Report, No 12.
31. Cucic D, Framorze Møller N, Georgieva Yordanova I, Gade Søndergaard S (2022): *Evaluating the macroprudential stance in a growth-at-risk framework*, Economic Memo, No. 14, Danmarks Nationalbanks.
32. Central Bank of Ireland (2020): Financial Stability Review.
33. Čeh Časni A (2014): Housing Wealth Effect on Personal Consumption: Empirical Evidence from European Post-Transition Economies. *Czech Journal of Economics and Finance*, 64(5):392-406.
34. Davino C, Furno M, Vistocco D (2013): *Quantile regression: theory and applications*. John Wiley & Sons.
35. Dees S, Henry J, Martin R (2017). STAMP€: Stress-Test Analytics for Macroprudential Purposes in the euro area. European Central Bank.
36. Deghi A, Katagiri M, Shahid S, Valckx N (2020): *Predicting Downside Risks to House Prices and Macro-Financial Stability*, IMF Working Paper WP/20/11, International Monetary Fund.
37. Dieckelmann D, Hempell HS, Jarmulska B, Hannes JL, Rusnak M (2023): *House prices and ultra-low interest rates: exploring the non-linear nexus.* ECB Working Paper No 2789. European Central Bank.
38. Drehmann M, Illes A, Juselius M, Santos M (2015): *How much income is used for debt payments? A new database for debt service ratios*, BIS Quarterly Review.
39. Dreger C, Kholodilin A (2011): *Speculative Bubble on Housing Markets: Elements of an Early Warning System. DIW Economic Bulletin*, DIW Berlin, German Institute for Economic Research, 1(4):3-9.
40. Dumičić M, Krznar I (2013): *Financial Conditions and Economic Activity*. Croatian National Bank Working Papers W-37.

41. ECB (2022): *The impact of rising mortgage rates on the euro area housing market, ECB Economic Bulletin*. Issue 6/2022, European Central Bank.
42. Égert M, Mihaljek D (2007): *Determinants of house prices in central and eastern Europe*, BIS Working Papers, No. 236, Bank for International Settlement.
43. Eguren-Martin F, O'Neill C, Sokol A, von dem Berge L (2021): *Capital Flows-at-Risk: Push, Pull and the Role of Policy*, ECB Working Paper, No. 2021/2538, European Central Bank.
44. ESRB (2022): Vulnerabilities in the residential real estate sectors of the EEA countries. European Systemic Risk Board.
45. ESRB (2019): Methodologies for the assessment of real estate vulnerabilities and macroprudential policies: residential real estate. Working group on real estate methodologies. European Systemic Risk Board.
46. Eurostat (2023): Database, available at: https://ec.europa.eu/eurostat/data/database
47. Eurostat (2023a): Distribution of population by tenure status, type of household and income group - EU-SILC survey, available at: https://ec.europa.eu/eurostat/databrowser/view/ILC_LVHO02__custom_137548/bookmark/map.
48. Eurostat (2023b): Share of young adults aged 25-34 living with their parents by age and sex – EU-SILC survey, available at: https://ec.europa.eu/eurostat/databrowser/view/ilc_lvps08/default/table?lang=en.
49. Galán J, Rodríguez-Moreno M (2020): *At-risk measures and financial stability*, Financial Stability Review, Issue 39, Banco de España.
50. Gelos G, Gornicka L, Koepke R, Sahay R, Sgherri S (2022): Capital flows at risk: taming the ebbs and flows, *Journal of International Economics*, 134, 103555.
51. Gerlach S, Peng W (2005): Bank lending and property prices in Hong Kong, *Journal of Banking & Finance*, Elsevier, 29(2):461-481.
52. Glindro E, Subhanij T, Jessica S, Zhu H (2011): Determinants of House Prices in Nine Asia-Pacific Economies. *International Journal of Central Banking*, 7(3):163-204.
53. Goodhart C, Hoffman B (2008): *House Prices, money, credit and the macroeconomy*, ECB working paper, No. 888, European Central Bank.
54. Grinderslev OJ, Kramp P, Lassenius K, Anders F, Pedersen J (2017): *Financial cycles: What are they and what do they look like in Denmark?*. Danmarks Nationalbank Working Papers, No. 115, Danmarks Nationalbank.
55. Helbling T, Terrones M (2003): *Real and Financial Effects of Bursting Asset Price Bubbles*, World Economic Outlook.
56. Hertrich M (2019): *A Novel Housing Price Misalignment Indicator for Germany.* Deutsche Bundes Bank, Discussion Paper No. 31.
57. Hlavaček M, Kalabiska R (2022): Regional Determinants of Housing Prices in the Czech Republic. *Czech Journal of Economics and Finance*. 72(1):2-29.
58. Hort K (1998): The Determinants of Urban House Price Fluctuations in Sweden 1968-1994, *Journal of Housing Economics*, 7(2):93-120.
59. Iacoviello M (2005*):* House prices, borrowing constraints, and monetary policy in the business cycle, *American Economic Review,* 95 (3):739–764.

60. IMF (2019): Global Financial Stability Report. Downside Risks to House Prices, International Monetary Fund.
61. IMF (2017): Increasing Resilience to Large and Volatile Capital Flows: The Role of Macroprudential Policies. IMF Policy Paper, Washington DC, International Monetary Fund.
62. Iossifov P, Čihák M, Shanghavi A (2008). *Interest Rate Elasticity of Residential Housing Prices*, IMF Working Paper, WP/08/247, International Monetary Fund.
63. Jordá, O, Schularick O, Taylor AM (2015): Leveraged Bubbles, *Journal of Monetary Economics*, 76, (Supplement), S1–S20.
64. Jovanović T, Aristovnik A, Rogić Lugarić, T (2016): A comparative analysis of building permits procedures in Slovenia and Croatia: development of a simplification model, *Theoretical and Empirical Researches in Urban Management*, 11(2):5-23.
65. Kennedy G, Wosser M (2020): *Box C: House prices at risk*. Financial Stability Review. Central Bank of Ireland.
66. Koenker RW (2005): *Quantile regression*, Cambridge university Press.
67. Koenker RW, Bassett G (1978): Regression Quantiles, *Econometrica*, 46(1):33–50.
68. Kotarac K, Kunovac D, Ravnik R (2017): *Coherence of Business Cycles and Economic Schocks between Croatia and Euro area Member States*. Croatian National Bank Working Papers, W-53.
69. Kunovac D, Kotarac K (2019): *Residential Property Prices in Croatia*. Croatian National Bank Surveys, S-37.
70. Kunovac D, Žilić I (2020): *Home sweet home: The effects of housing loan subsidies on the housing market in Croatia*. Croatian National Bank Working Papers W-60.
71. Kupiec P (1995): Techniques for verifying the accuracy of risk measurement models, *Journal of Derivatives*, 2:173-184.
72. Lang JH, Forletta M (2019): *Bank capital-at-risk: measuring the impact of cyclical systemic risk on future bank losses*, ECB Macroprudential Bulletin 9, European Central Bank.
73. Lang JH, Forletta M (2020): *Cyclical systemic risk and downside risks to bank profitability*, ECB Working Paper Series, No. 2405, European Central Bank.
74. Lang JH, Pirovano M, Rusnak M, Schwarz C (2020): *Trends in residential real estate lending standards and implications for financial stability*, Financial Stability Review. European Central Bank.
75. López-Salido D, Loria F (2021): *Inflation at Risk*, FEDS Working Paper No. 2020-013, Finance and Economics Discussion Series, The Federal Reserve.
76. Lovrinčević Ž, Vizek M (2008): House price determinants in the Republic of Croatia and potential effects of housing market liberalization. *Economic Review*, 59:723-740.
77. Malpezzi S (1999): A simple error correction model of house prices, *Journal of Housing Economics*, 8:27-62.
78. Moder I (2017): *Spillovers from the ECB's non-standard monetary policy measure on south-eastern Europe*. ECB Working Paper 2095.
79. O'Brien M, Staunton D, Wosser M (2022): *Recurrent Property Taxes and house price risks*. Economic Letter No.4. Central Bank of Ireland.

80. O'Brien M, Wosser M (2018): *An Early Warning System for Systemic Banking Crises – A Model-Robust Approach*, Research Technical Paper Series No. 9, Central Bank of Ireland.
81. Plašil M, Konečny T, Seidler J, Hlavač P (2015): *In the Quest of Measuring the Financial Cycle*, CNB Working Paper Series.
82. Rünstler G, Vlekke M (2016): *Business, Housing, and Credit Cycles*, ECB Working Paper Series, No. 1915, European Central Bank.
83. Sabol M (2022): *Estimates of the deviation of residential real estate prices from the long-term level in Croatia*. Croatian National Bank, Mimeo.
84. Škrinjarić T (2022): *Introduction of the composite indicator of cyclical systemic risk in Croatia: possibilities and limitations*. Croatian National Bank Working Papers W-68.
85. Tica J (2020): Factors of the housing prices movements in Croatia. *Proceedings of the Faculty of Economics and Business in Zagreb*, 18(2):15-33.
86. Tsatsaronis K, Zhu H (2004): *What Drives Housing Price Dynamics: Cross-Country Evidence*, BIS Quarterly Review. Bank for International Settlements.
87. Tölö E, Laakkonen H, Kalatie S (2018): Evaluating Indicators for Use in Setting the Countercyclical Capital Buffer. *International Journal of Central Banking*, 14(2):51-111.
88. Vizek M (2010): Short-run and Long-run Determinants of House Prices in Eastern and Western European Countries. *Privredna kretanja i ekonomska politika - Economic Trends and Economic Policy*, 20(125):27-60.

Appendix

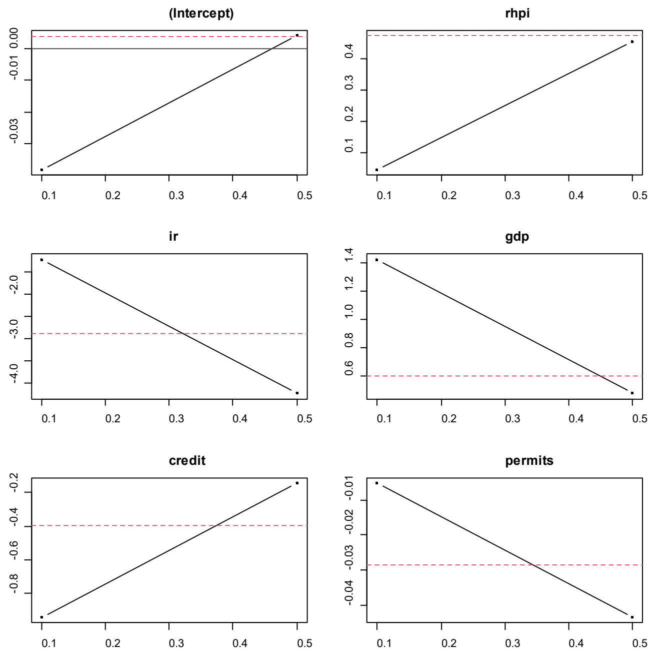
Table A1. Literature review

Authors	Country & year	Model & variables	Result
Deghi et al. (2020)	32 AE and EE, 1990-2018	Panel, FCI, real GDP growth, overvaluation indicator, credit gap	Selected QR approach is good for HaR forecasting. HaR is used in GaR forecasting. This is the IMF approach for country specific analysis in reports as well.
Alter and Mahoney (2020)	USA and Canada, 1983-2018	Panel, city level; household debt, FDI, capital flows, house price to income ratio, residential investment index, oil prices, FCI	FCI has effects on HaR in the short-term, household leverage in the long term. Differences in HaR dynamics exist between the US and Canadian cities.
Kenney and Wosser (2020)	Ireland, 1990Q1-2020Q3	Panel; house price misalignment indicator, financial conditions, systemic risk, market structure	Distribution of house price forecasts somewhat flatter and further to the left than compared to end 2020.
European Central Bank	Euro area, 2018-2022	Panel, overvaluation measure, systemic risk indicator, consumer confidence indicator, financial market conditions indicator, government bond spread, euro area financial corporate bond spread, interaction of overvaluation and FCI	Short-term downside risks to euro area RRE prices have increased significantly, especially in countries where overvaluations are more stretched.
Galán and Rodríguez-Moreno (2020)	Spain, 1981-2019	Overvaluation measure, household credit gap, population growth	Overvaluation measure found to have negative effects on HaR after 2 years, population dynamics positive in short-term.
Cucic et al. (2022)	Denmark, 1985-2021	GDP growth, house prices to income dynamics, debt servicing rate, housing investments, BBM	BBM measures introduced in the forecasting model. Results interesting: tighter BBM increases housing affordability, reduces future HaR as well.
Cevik and Naik (2022)	10 European countries, 1998-2022	Panel, long and short-term interest rates, income growth, population growth, REER, stock market returns, debt to income ratio, unemployment rate	Economic, financial and demographic factors important for house price dynamics determination. Interest rates and income growth best predictors.
Central bank of Luxembourg (2022)	Luxembourg, 1980Q1-2022Q1	Mortgage credit growth, real disposable income, real interest rate, bank sector vulnerability indicator, construction permits	A small box in financial stability review publication, just a few distributions shown. In 2023 it is expected that a shift toward left will be realized.
O'Brien et al. (2022)	Ireland, 1990-2020	Panel; house price misalignment indicator, financial conditions, systemic risk, market structure, different type of taxes (total, property, taxation, income and sales).	Recurrent property taxes are associated with reduced magnitude of downside risks to house prices and overall easing of house price volatility.

Note: AE – advanced economies, EE – emerging economies, FCI – financial conditions index, FDI – foreign direct investment, HaR – house price at risk, GaR – growth at risk, BBM – borrower-based measures, REER – real effective exchange rate, RRE – residential real estate market.

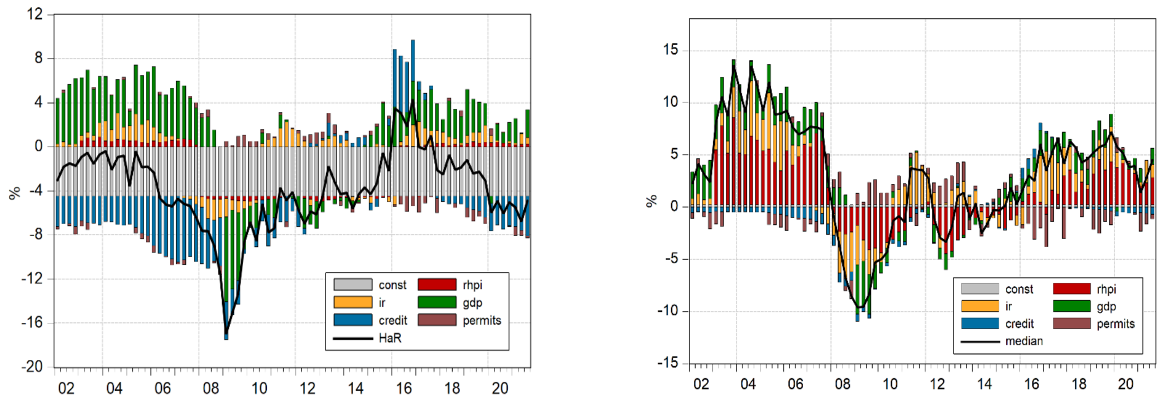
Source: Authors' compilation based on references.

Figure A1. Estimated coefficients of Model 1, 10th percentile compared to median



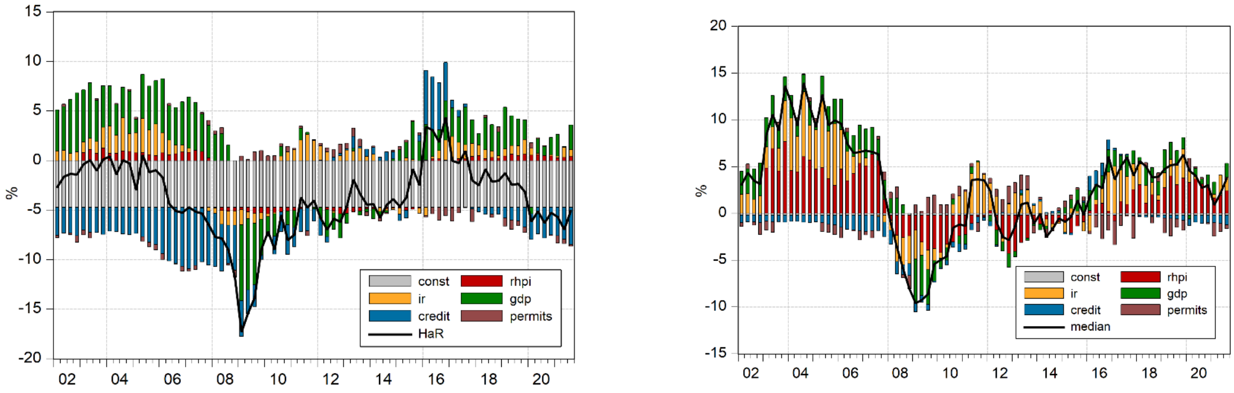
Note: Estimated values for each quantile are depicted with black dots, and a line connects them. The red dashed line is the OLS estimated value. Rhpi = yoy growth real house prices, ir = yoy change of mortgage interest rates, gdp = yoy real GDP growth, credit = yoy mortgage credit growth, permits = yoy growth building permits.
Source: Authors' calculations.

Figure A2. Factors affecting house price-at-risk (HaR) (left) and median house price growth (right) in Croatia (Model 1)



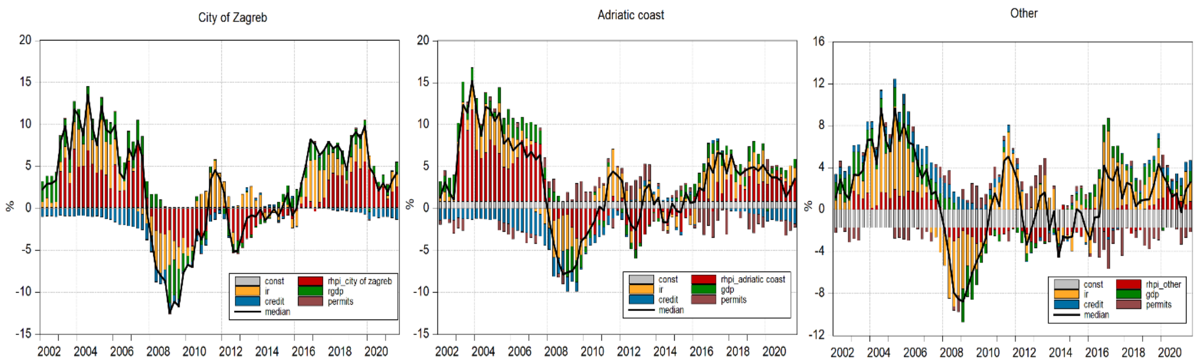
Note: Const = constant, rhpi = yoy growth real house prices, ir = yoy change of mortgage interest rates, gdp = yoy real GDP growth, credit = yoy mortgage credit growth, permits = yoy growth building permits, HaR = house-price-at-risk (10th percentile).
Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; author's calculations.

Figure A3. Factors affecting house price-at-risk (HaR) (left) and median house price growth (right) in Croatia (Model 2)



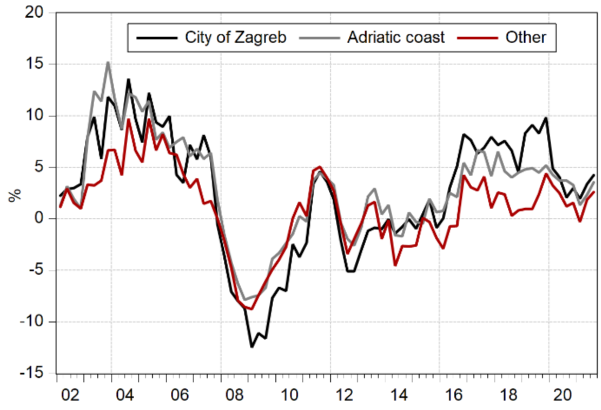
Note: Const = constant, rhpi = yoy growth real house prices, ir = yoy change of mortgage interest rates, gdp = yoy real GDP growth, credit = yoy mortgage credit growth, permits = yoy growth building permits, HaR = house-price-at-risk (10th percentile).
Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; author's calculations.

Figure A4. Factors affecting median house price growth in regions



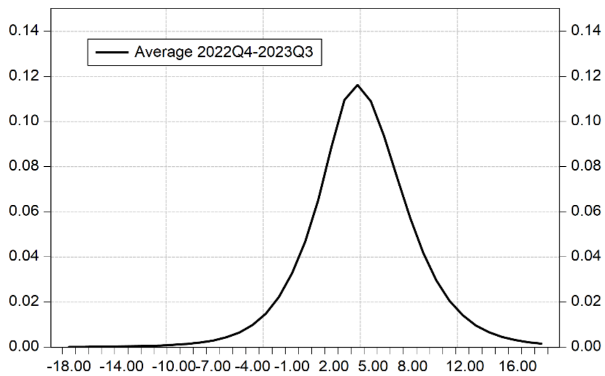
Note: Const = constant, rhpi = yoy growth real house prices, ir = yoy change of mortgage interest rates, gdp = yoy real GDP growth, credit = yoy mortgage credit growth, permits = yoy growth building permits
Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; author's calculations.

Figure A5. Median house price growth in regions



Source: Croatian National Bank, Croatian Bureau of Statistics; author's calculations.

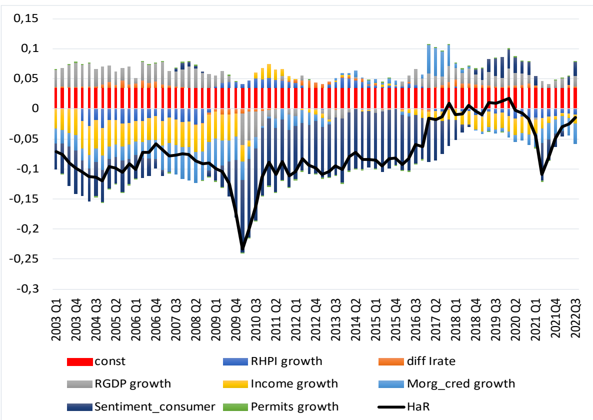
Figure A6. Selected probability distributions of forecasted real house price growth



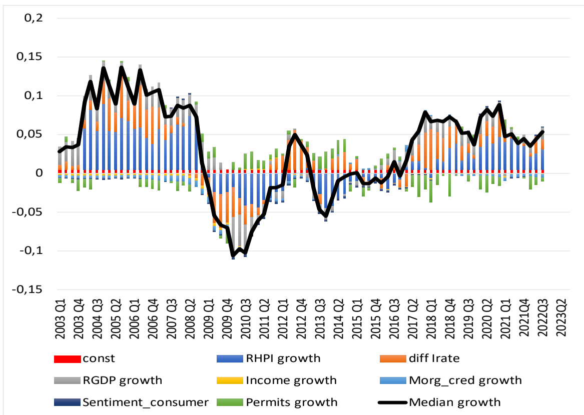
Note: X axis denotes growth values in %, y axis refers to the probability. Refers to total price index.
Source: Authors' calculations.

Figure A7. Different model specifications

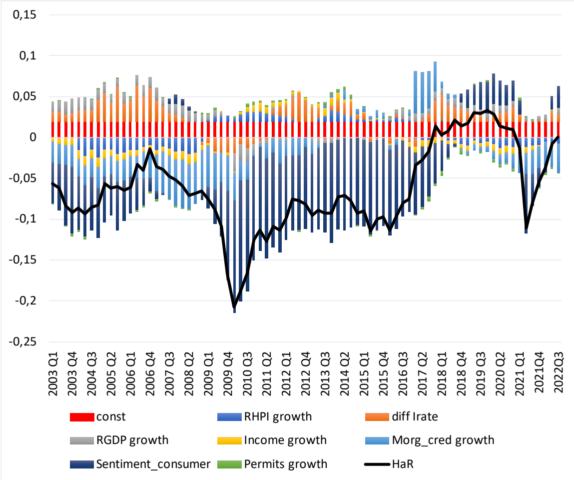
Model a. HaR, nominal income growth, sentiment included



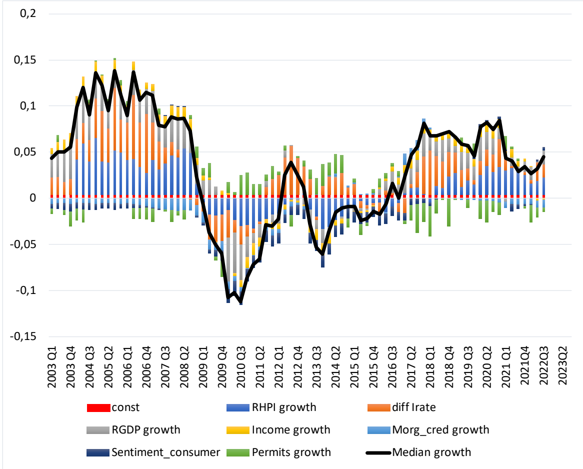
Model a. Median, nominal income growth, sentiment included



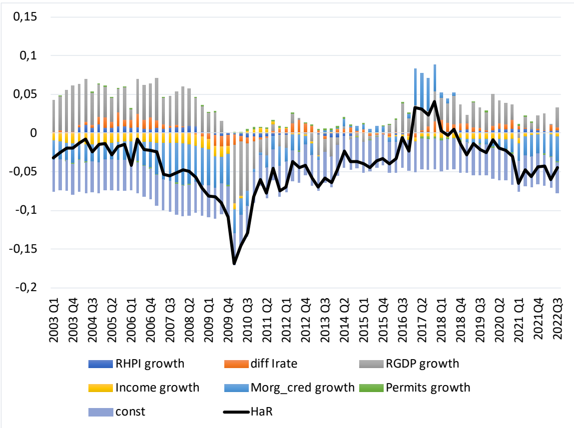
Model b. HaR, real income growth, sentiment included



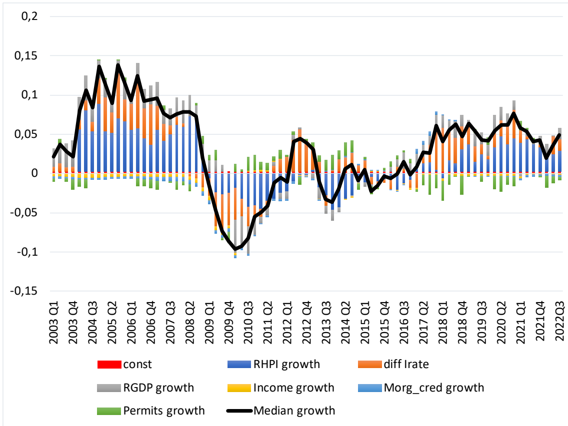
Model b. Median, real income growth, sentiment included



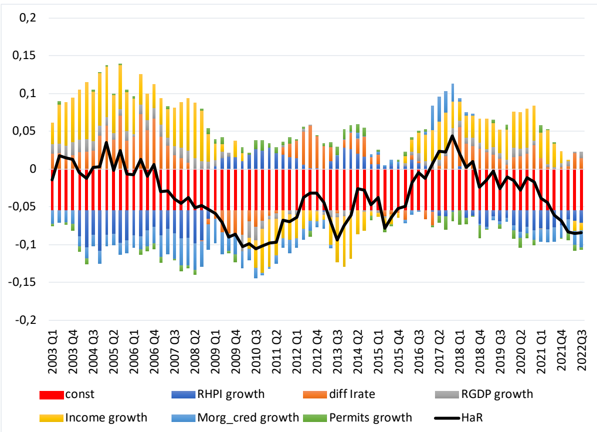
Model c. HaR, nominal income growth, no sentiment



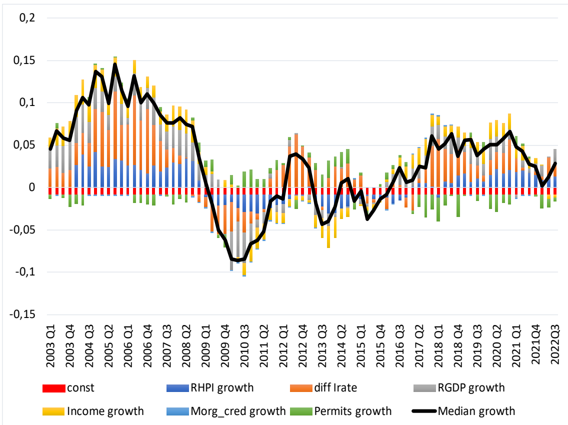
Model c. Median, nominal income growth, no sentiment



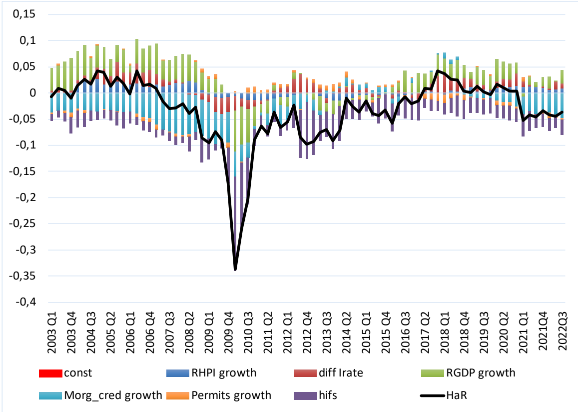
Model d. HaR, real income growth, no sentiment



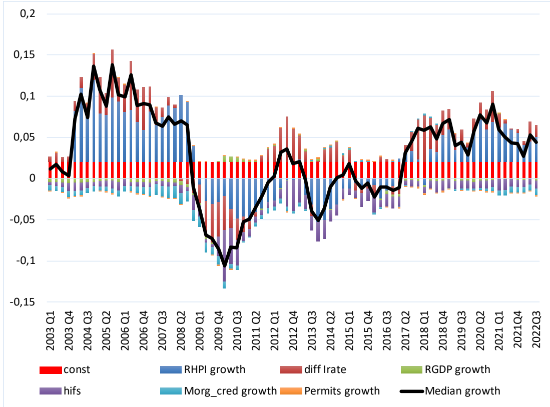
Model d. Median, real income growth, no sentiment



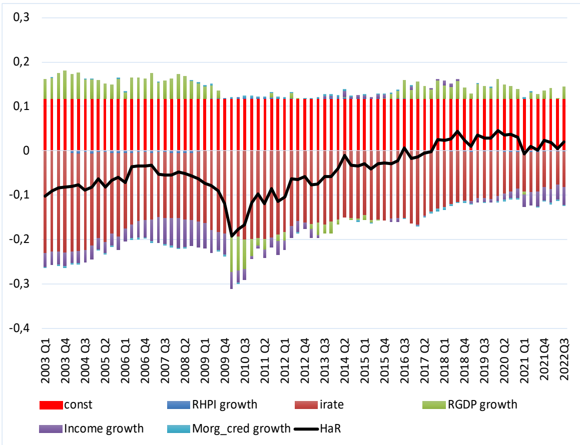
Model e. HaR, HIFS included



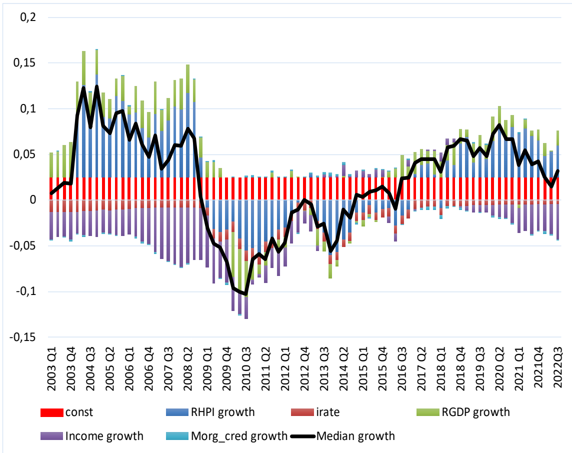
Model e. Median, HIFS included



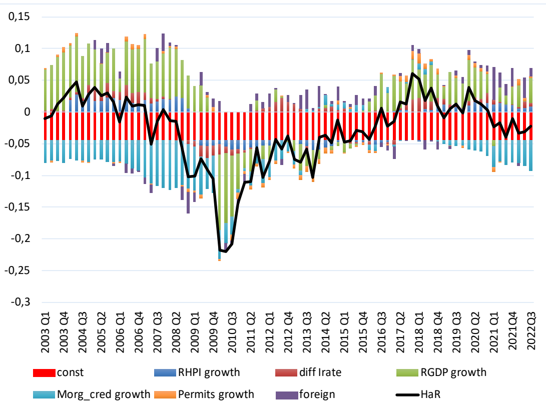
Model f. HaR, intrest rate instead of change



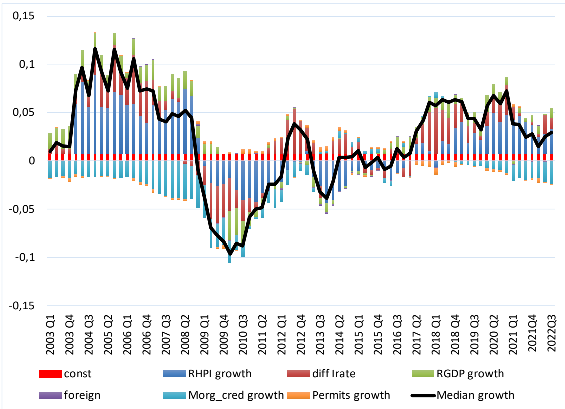
Model f. Median, interest rate instead of change



Model g. HaR, foreign demand effects



Model g. Median, foreign demand effects

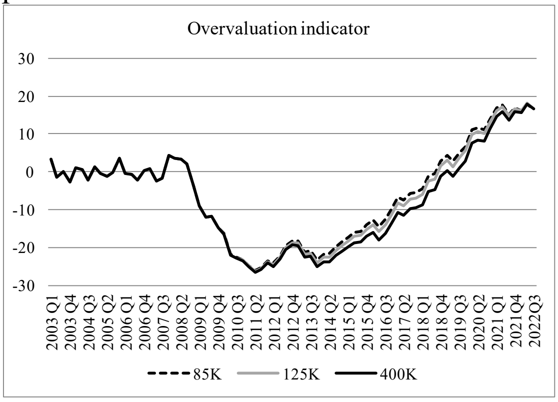


Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; author's calculations.

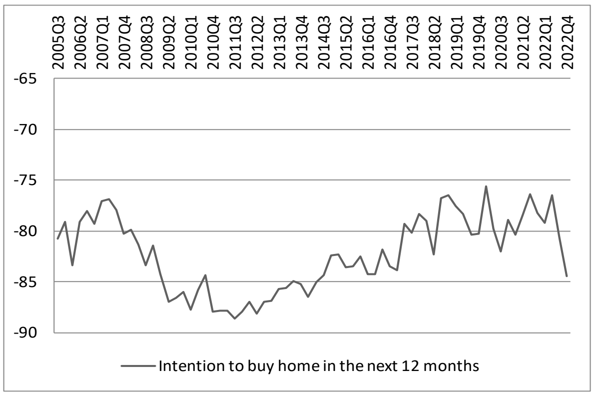
Note: For interpretation and comparison to the Figures in the main text values should be multiplied by 100

Figure A8. Selected variables dynamics

Panel a. Overvaluation indicator, real house prices

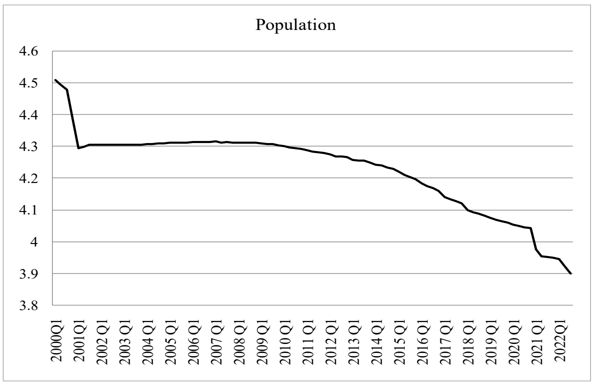


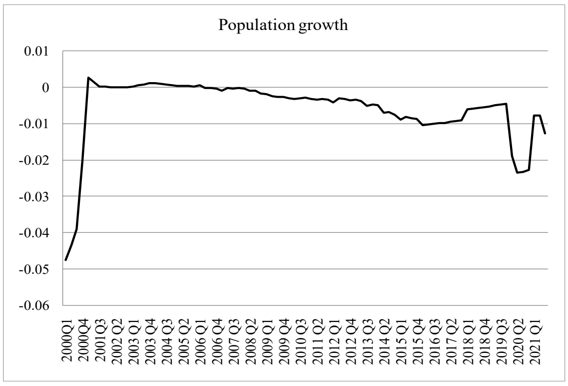
Panel b. Intention to buy or build a house in the next 12 months



Source: Croatian National Bank, Croatian Bureau of Statistics and Eurostat; author's calculations.

Panel c. Population





Source: Eurostat; author’s calculations

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