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Easier Said than Done: Predicting Downside Risks to House Prices in Croatia

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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 materialisation. 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.

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).

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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 bank 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). This mechanism is amplified in less regulated markets where households can more easily borrow to finance their consumption.

In recent years, a 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. Moreover, with the 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, global monetary policy tightening is making affordable housing increasingly scarce.

In some countries' housing markets, the current cooling off is evident, and a reality check might start to hit in the upcoming months. So, 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 regression, where the entire distribution of future 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. 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. Moreover, 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 policies 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 housing market in Croatia in and key drivers of house price dynamics in period from 2002Q1to 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.

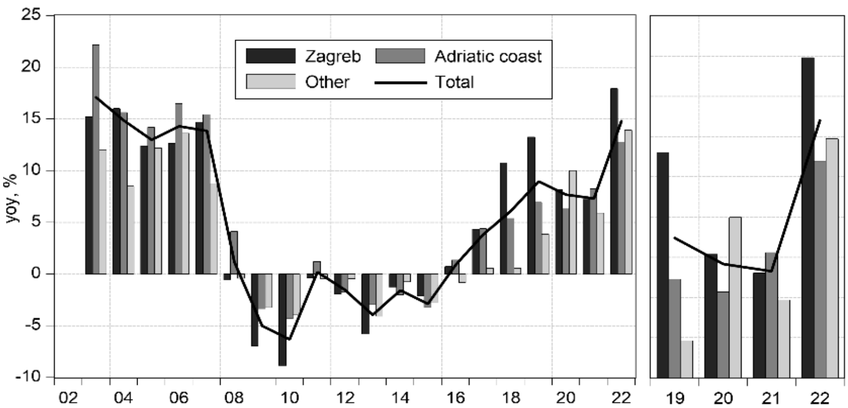
2. Stylized Facts on Croatian Housing Market

The housing market in Croatia has its fair share of specific/idiosyncratic characteristics. First, 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. 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, as is the case in Croatia. 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. Other characteristics are 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 favourable 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) estimates, a considerable portion of transactions in the housing market is not financed by credit.

In many countries, as in Croatia, pressure on house prices 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 in some countries, even negative deposit interest rates made saving less attractive for people. 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. The prices in Croatia exceeded the peak in GFC in 2020 and in 2022Q3 prices were above GFC level by around 30% (Figure 1)[1]. 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 house price growth[2] 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 Growth Dynamics in Croatia



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

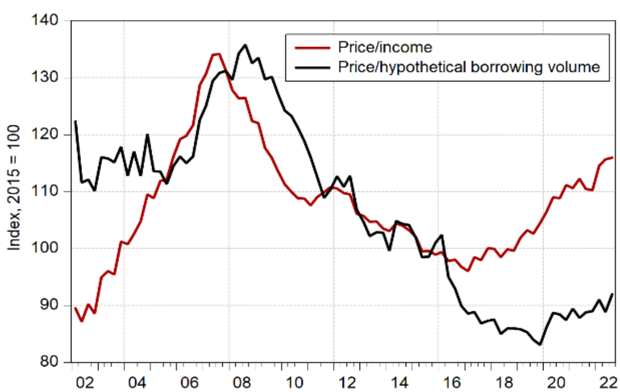
Source: Croatian National Bank and Croatian Bureau of Statistics.

[1] Considering average dynamics in 2022, yoy house price growth is most likely to be above pre-pandemic levels (10% in 2019).

[2] See Section 4.1., Figure 4.

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 analysed periods (Figure 2), signalling the 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 favourable 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)[3]. 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 favourable 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).

Figure 2 Housing Affordability Indicators

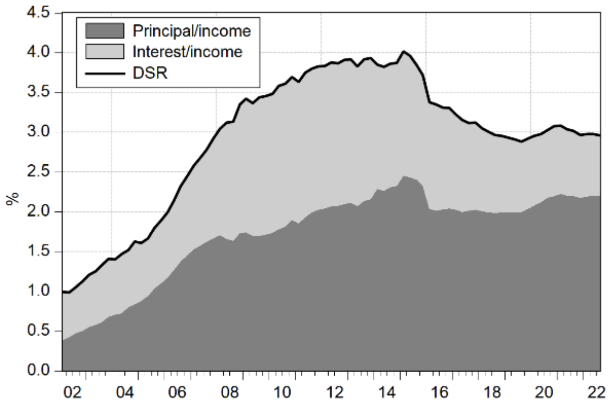


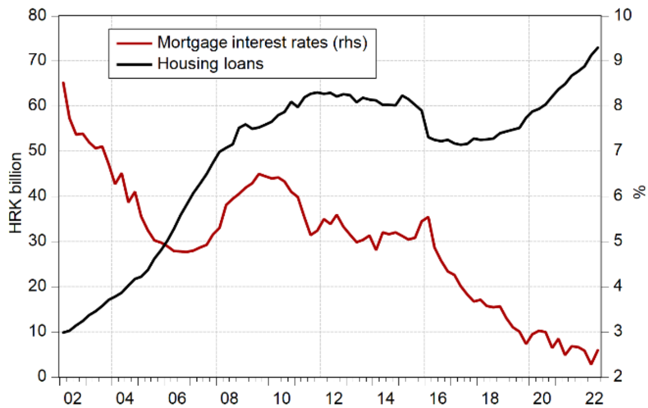
Notes: Data for 2022 are available up to the third quarter. The hypothetical borrowing volume is defined as the maximum loan amount that households may be granted taking into consideration disposable income, interest rates on housing loans and the average maturity of housing loans with debt-service-to-income (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.

[3] 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 3 Financial Conditions (Up) and Mortgage Debt Service Ratio (Down)





Notes: 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

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). Since real estate accounts for a significant portion of household wealth, 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).

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. One needs to have in mind that this conclusion cannot be applied to Croatian case as the ratio between population and the number of housing units is growing in favor of housing units.

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 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.

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, materialisation 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 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, Kennedy 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.

Methods to evaluate house price dynamics, identify main determinants and associated risks for financial stability in Croatia were also regularly published in CNB publications - Financial Stability Reports (e.g., 2014 and 2017). 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. 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) policy decision-making. Moreover, according to 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 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 behaviour 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 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.

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[4] 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 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 (*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 (e.g., we calculate differences for interest rates, whereas other variables are transformed into growth rates) (Figure 4).

Our rational for the choice of the variables and model specification has been the following 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. 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 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 the entire analysed period 2002-2022.

As regards the overvaluation indicator in CNB's risk monitoring framework[5] which includes the house price dynamics (i.e., real house price index and different house price ratios), we opted 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. Similar is found in the case of domestic systemic risk indicator (d-SRI) that tracks cyclical risks (see Škrinjarić, 2022). Furthermore, 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

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[4] 2002 Q1 is the earliest date for which the data on house prices is available.

[5] For more information on indicator see *CNB Financial Stability Report, No. 18. Box 2: Divergence of real estate prices in Croatia from intrinsic value*.

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. 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 but due to being too volatile and available only since 2005, the variable was dropped. Finally, 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. Foreign demand as a specific factor which is present on the Croatian market could be something worth of investigating. For that purpose, we propose a new variable that captures how much do foreigners pay per one transaction on the housing market, compared to domestic ones by calculating the year-on-year difference of this variable to be comparable in growth terms as other variables. 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). Thus, adding this variable to the model did not have an added value.

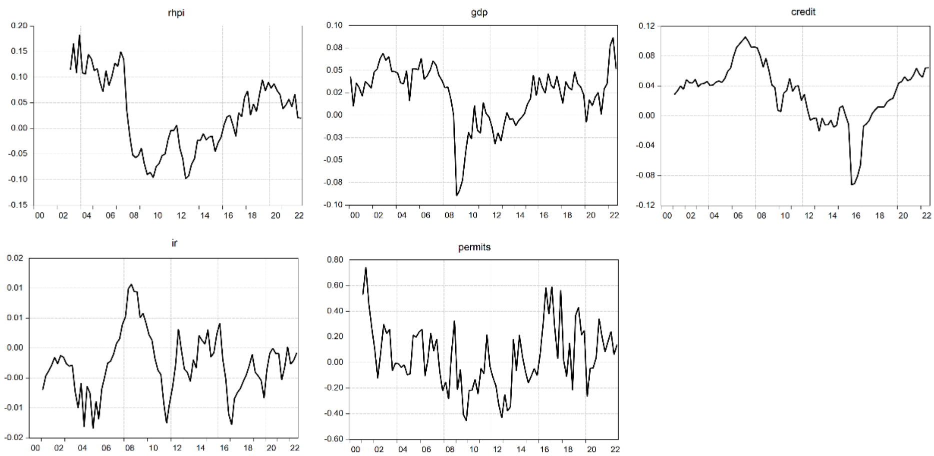
Moreover, since the housing market remained fairly resilient during the COVID-19 shock (ESRB, 2021 and CNB, 2022) a correction of the GDP series was necessary. The real GDP growth had a fairly significant drop in the second quarter of 2020, and a rebound a year later was significantly higher. Such dynamics would affect the house price forecasts, which would not be a reflection of the true house price dynamics. In order to capture these effects, we opted to correct the dynamics of GDP and income by using simple SARIMA[6] 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*). Although there are more suitable ways to correct the problem, this attempt reduces the growth volatility in 2020 and 2021.

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 have either decreased or increased less than inflation, but in the recent period, have continued to grow due to 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 euro area countries are relatively high (Kotarac et al., 2017). On the other hand, building 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.) [7]. In addition, some variables have been influenced by high inflationary pressures in the

[6] Seasonal autoregressive moving average.
[7] Other problems can be found in Jovanović et al. (2016).

recent period, such as real GDP (*gdp*). Due to foreign currency mortgage conversion in 2015, variable stock of mortgage credit (*credit*) might impose an issue, and we expect to affect our empirical results.

Figure 4 Variables Used in Quantile Regression Models



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

4.2 Methodology Description

Quantile regression[8] (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:

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

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:

[8] For an introduction into QR, with advantages and shortfalls, see Koenker (2005), Davino et al. (2013), or Koenker and Bassett (1987).

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

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. By taking this approach, it means that we are doing what majority of related literature is using, the local projection approach. We choose this approach, as it is flexible and does not constrain the shape of the projected values (IMF, 2019); and as shown in the original Jordà (2005) paper, are simple to estimate, more robust to misspecifications, inference is simple, and important for multivariate analysis can accommodate nonlinearity experimentation.

We look at several model specifications of forecasting y_{t+h}:

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

$$+\beta_4(\theta)gdp_t + \beta_5(\theta)permits_t,$$

and 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 original values of GDP without COVID-19 corrections and a corrected version. This makes in total four versions of the model itself. Finally, in our checking of the significance of estimated results, we check the bootstrapped standard errors of estimates, as in Koenker (2005).

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. One other possible goodness-of-fit measure that will be used in the empirical part of the paper is the UC (unconditional coverage) of Kupiec (1995). UC null hypothesis assumes that, on average, the conditional quantile is a correct coverage of the lower percentile of the forecasted distribution. For details on this test, please see Dumitrescu et al. (2012).

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 $T(\cdot)$, $\mu, \sigma,\ \upsilon,$ and α are the location, scale, fatness, and the shape parameter respectfully. The following model is optimised so that the parameters could be estimated:

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

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. Interested readers on the topics about quantile regressions and general quantile approach of modelling can look more details in Gilchrist (2000), Buchinsky (1998), and Yu and Jones (1998), alongside Koenker (2017) for specifics on quantile autoregression. In the end, we emphasize that the model is used for forecasting purposes, and that we are not talking about causality. Since many of the variables are endogenous, we talk about observing some correlations, and look if the price dynamics could be better predicted with one variable or the other. Finally, for more info about characteristics and the data assumptions for quantile regression analysis, i.e. not having to impose some assumptions as in OLS approach, please refer to Koenker (2005).

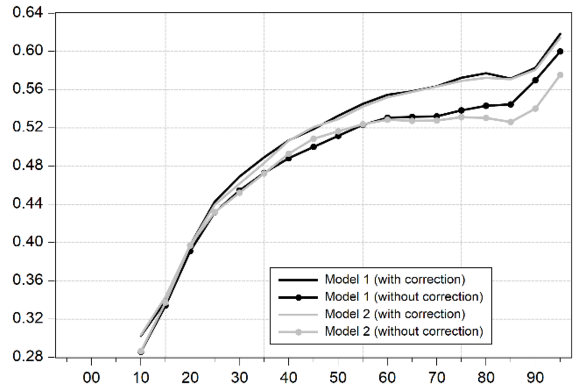
5. Empirical Findings

In this part, the main empirical results are presented with a focus on identifying drivers of both house price-at-risk value (HaR) and median house price growth. In our approach, we focused on different models, with and without GDP corrections for the COVID-19 period, 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. This resulted in a total of four model variations: *Model 1* without COVID correction, *Model 1* with the correction, and *Model 2* without and with correction of GDP for the COVID-19 period.

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 the downturn risks.

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.

Figure 5 Pseudo-R Squared Values for All Models over Quantiles



Notes: x-axis depicts quantiles (from 10th to 95th) and y-axis the value of the pseudo-R squared.

Source: Authors' calculations.

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**

Notes: Bolded values indicate best performance by row for 10th percentile or median value. Values should be multiplied with 100% for percentage interpretation.

Source: Authors' calculations.

Identifying individual factors/contributors to house price risks is an important part of monitoring framework. The impact of factors is generally more pronounced at the median of the house price distribution than the left tail. Factors affecting house price-at-risk (HaR) and median house price growth from *Model 1* are depicted in Figure 6, while the estimation results of *Model 2* are shown in Appendix[9]. The main findings, presented in Figure 6, can be summarized as follows.

Mainly, the autoregressive component is positive and greater for the median price growth, which is expected and consistent with related HaR and GaR literature. Interest rate changes have greater coefficient at the median in particular and are rather small at 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

[9] 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.

find sizeable effects of mortgage interest rates on house price dynamics in a panel setting. Via its effects on money and credit, interest rates can significantly influence the occurrence of 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). 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 recalibration 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 has positive correlation with HaR and median growth dynamics, with a greater coefficient at 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 omitted). Although average house price growth increased during GDP growth, the future downside risk lowered 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[10]. Gerlach and Peng (2003) look at 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. Moreover, the aforementioned problem with the credit dynamics in 2016 distorts the result[11]. 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. 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 coefficient besides the building permits in the downside risks part of the analysis is statistically insignificant in the 10th percentile, while median price growth has somewhat been influenced by this supply-side factor. 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).

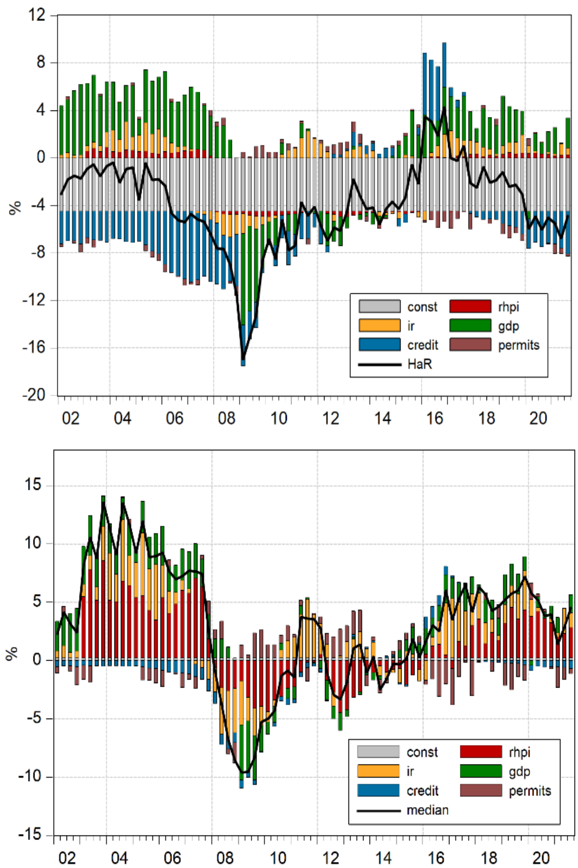
House price-at-risk gradually worsened in the early 2000s, leading to the period before GFC. Over time, past house price movements and credit also started to have a negative effect, partially offset by the positive effect of GDP growth. After GFC, the downturn in economic activity and tightening of financial 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

[10] This conclusion should be treated with caution due to a structural break in mortgage credit growth owing to foreign currency mortgage conversion. Another option is to use the growth rate of new mortgage lending.

[11] See Figure A4 in Appendix, which compares the scatterplots with and without 2016 data between the credit and house price growth. Deleting the 2016 data increases the performance of the OLS model and the correlation between the two series. Future research should tackle this problem.

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.

Figure 6 Factors Affecting House Price-At-Risk (HaR) (Up) And Median House Price Growth (Down) in Croatia (Model 1)

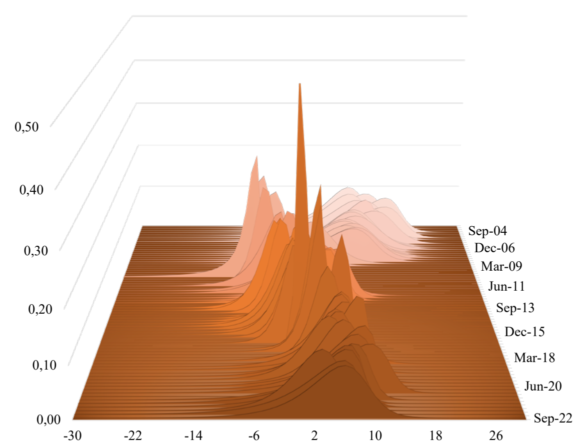


Notes: Const = constant, rhpi = yoy growth real house prices, ir = yoy change of mortgage interest rates, gdp = yoy real GDP growth, credit = yoy mortgage credit growth, permits = yoy growth building permits, HaR = house-price-at-risk (10th percentile).

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

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. Skewed t-distributions for every quarter from Model 1 were fitted as described in the methodology section. 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 7 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.

Figure 7 Fitted House Price Growth Distributions from Model 1, h = 4



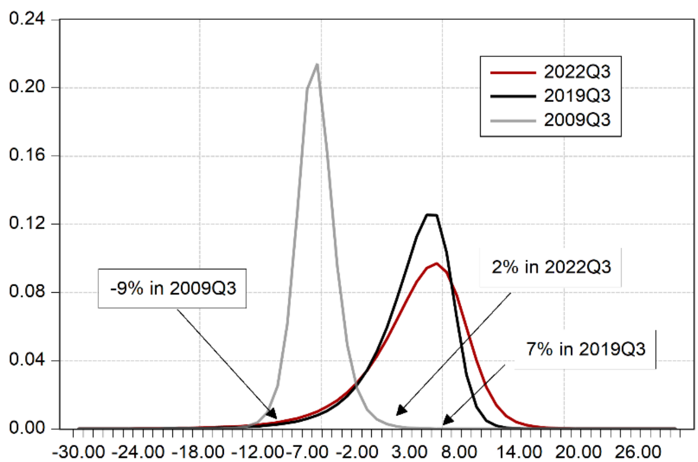
Notes: X axis (the front one) denotes growth values in %, y axis (left one) refers to the probability.

Source: Authors' calculations.

Finally, we extract several distributions from Figure 7 to present an additional way of monitoring the dynamics of house price growth over time. Distributions in Figure 8 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, ii) pre COVID-19 period in 2019, and iii) the last data point in our estimation. 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. 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[12].

Figure 8 Comparisons of Selected Probability Distributions of Forecasted Real House Price Growth



Notes: X axis denotes growth values in %, y axis refers to the probability.
Source: Authors' calculations.

6. Discussion and Conclusions

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 average 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.

[12] Another forecast is shown in Appendix, figure A3, as the average growth for the period 2022Q4-2022Q3. 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 work.

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 foreign demand. Thirdly, 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. Also, some other nonlinearities could not have been explored in the analysis, as short time series prevent it from doing so.

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 could be tightened to better safeguard the household sector against unexpected shocks). This is vital given the existence of (just) 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. 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.

Several general lessons emerge from our results. From a policy perspective, we tried to shed the light on the following. Identifying and assessing systemic risks associated with unsustainable movements in housing markets, as was the case in GFC, is 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.

APPENDIX

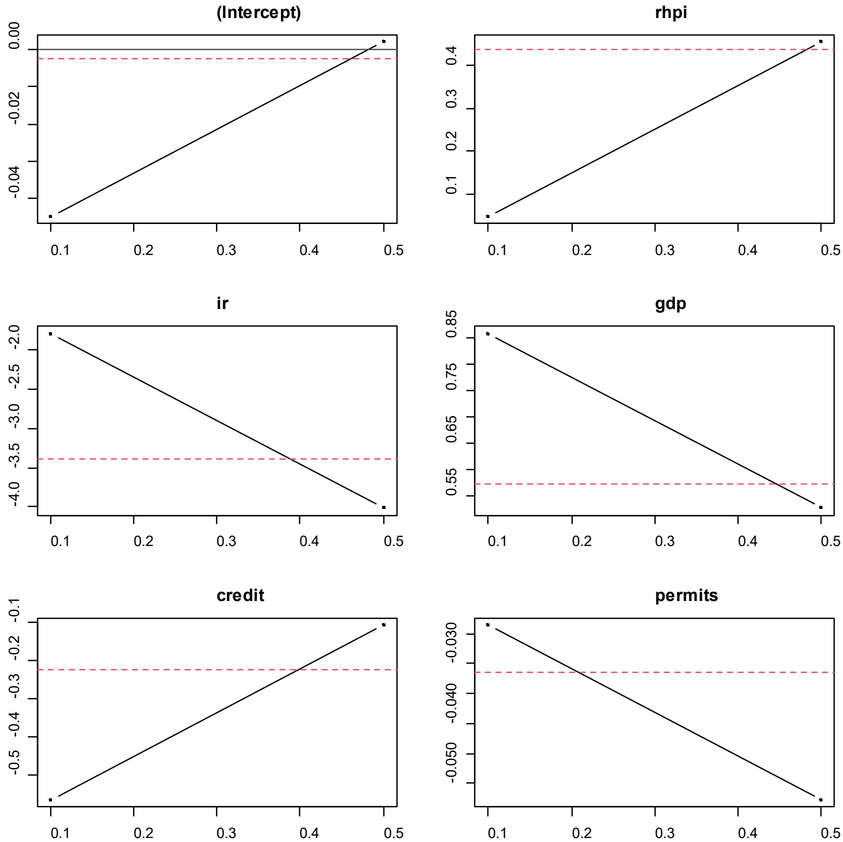
Table A1 Literature Review

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.

Notes: 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.

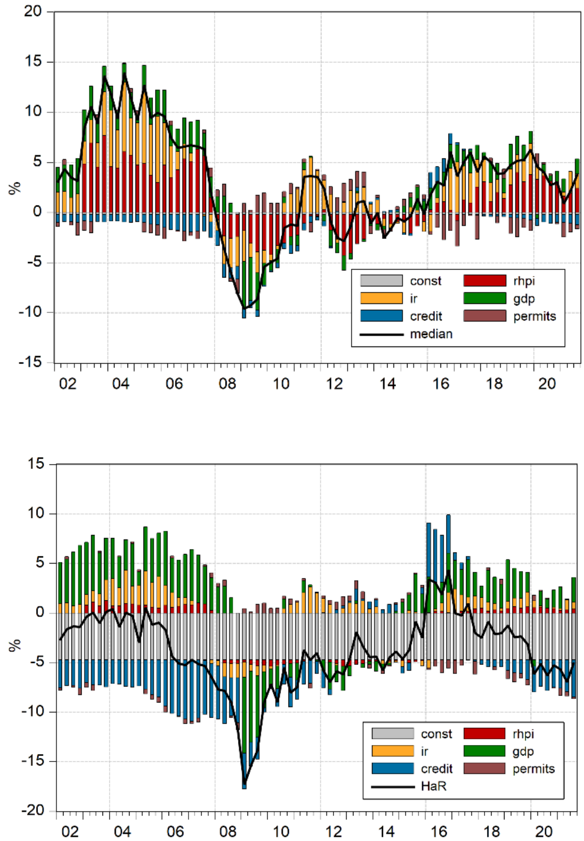
Figure A1 Estimated Coefficients of Model 1, 10th Percentile Compared to Median



Notes: 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.

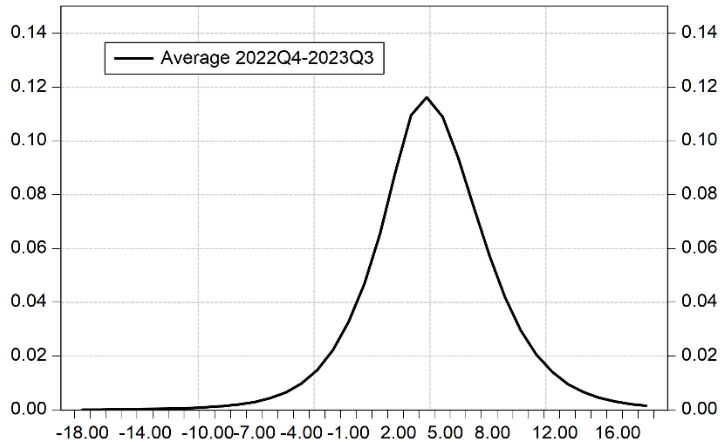
Figure A2 Factors Affecting House Price-At-Risk (HaR) (Up) And Median House Price Growth (Down) in Croatia (Model 2)



Notes: 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.

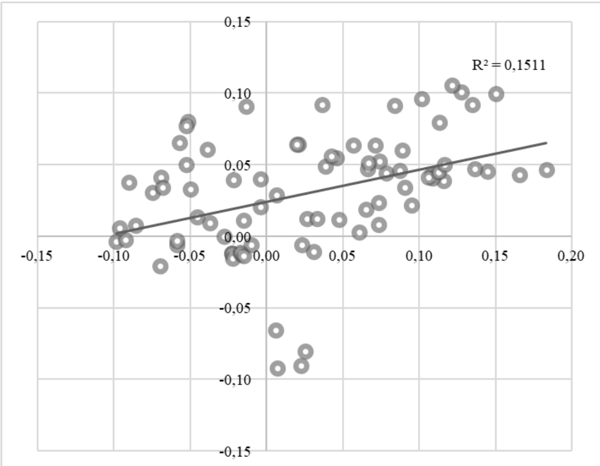
Figure A3 Selected Probability Distributions of Forecasted Real House Price Growth



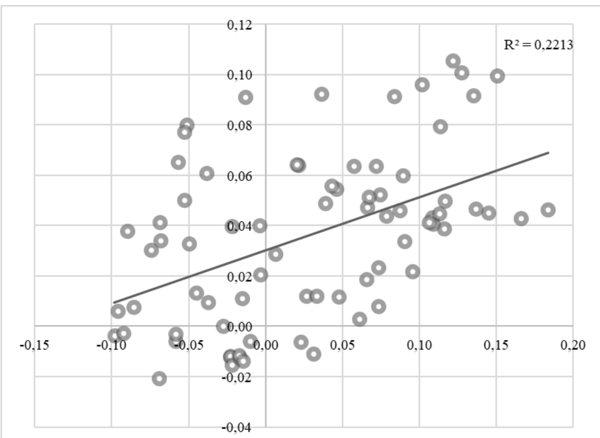
Notes: X axis denotes growth values in %, y axis refers to the probability.
Source: Authors' calculations.

Figure A4 Comparison of Correlation between House Price and Mortgage Credit Dynamics

Panel a. With 2016 data



Panel b. Without 2016 data



Source: Authors' calculations

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