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# HOUSE-PRICE-AT-RISK MODEL FORECASTING DOWNSIDE RISK FOR THE SWEDISH HOUSING MARKET

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## Abstract

This work project investigates the predictability of downside risks in the Swedish housing market using the House-Price-at-Risk (HaR) approach. Amidst the uncertainty posed by recent global crises and the critical need for robust economic forecasts, the study examines the efficacy of the HaR model, partly inspired by the Growth-at-Risk (GaR) framework. Representing a substantial part of the national wealth, the Swedish housing market's stability is imperative for economic stability. By analyzing and assessing relevant variables' influence on the potential downside risk of housing prices, this research provides insights important for developing effective strategies to mitigate financial risks in adverse market scenarios.



**Keywords:** House-Price-at-Risk, Growth-at-Risk, Quantile Regressions, Macroeconomics



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## 1. Introduction

Future macroeconomic developments are subject to substantial uncertainty. Using the correct tools to forecast the macroeconomic environment will help bolster financial stability. The recent global challenges, including the financial crisis, the COVID-19 pandemic, and geopolitical tensions, have highlighted the critical need for robust economic models capable of forecasting risks in various sectors. The Swedish housing market, representing a significant portion of the nation's wealth, is no exception. This study introduces the House-Price-at-Risk (HaR) approach as a vital tool for policymakers and financial institutions to anticipate and mitigate risks in this volatile market.

Over the recent years, at-risk models have started to become an alternative solution to monitor and manage risks on different indicators. A growth-at-risk framework developed by Adrian, Boyarchenko and Giannone (2019) has inspired multiple countries and institutions to develop their own frameworks for monitoring potential downside risk of GDP-growth conditional on macro-financial conditions.

The concept of Growth-at-Risk (GaR) has garnered considerable attention in macroeconomic research, especially within the ambit of financial stability and policymaking. Lang et al. (2023), with the support of the European Central Bank (ECB), applies the GaR framework using vulnerability indicators on medium-term GDP-growth. The model's results show increased downside risk to the real GDP growth. Prasad et al. (2019) also utilizes the GaR framework published by the International Monetary Fund (IMF) to show how the framework can enhance IMF surveillance by early identifying downside risk to macroeconomic and financial stability. The extensive literature on the approach has highlighted its importance for policymakers worldwide to understand and assess macroprudential policies. The intention of this framework is to increase the effectiveness in mitigating financial risks and ensuring sustainable economic stability.

Expanding upon the fundamental GaR framework, the HaR model provides a detailed method for comprehending the dynamics of the housing market. It surpasses conventional analysis by prioritising the potential downside risk, taking into account different macroeconomic and financial variables. This study aims to investigate the predictive capabilities of the HaR model, considering the distinctive features of the Swedish housing market. This work project aims to gain a comprehensive understanding of the factors affecting the Swedish housing market by analysing various economic indicators. Assessing this is necessary for formulating efficient strategies to uphold financial stability and avert possible declines in the housing market.

The residential market amounts to 33% of the assets in the Swedish national balance sheet (Statistics Sweden) showcasing the importance it has on the overall economy of the country. Although the implementation of the HaR framework at the national level is currently limited, a thorough review of the specific implementations of the HaR framework will be provided in section 2. Further research on the applications of the HaR framework will enhance the development of a more resilient and anticipatory model to assess the likelihood of a significant drop in house prices based on macroeconomic and financial factors.

## 2. Literature Review

Monitoring macroeconomic conditions' effect on financial stability has been extensively researched over the past years. Adrian et al. (2019) introduced an innovative framework to study the conditional distribution of GDP growth as a function of various economic and financial variables using quantile regression. The methodology enabled them to prove that the estimated lower quantiles of the GDP growth distribution vary more with the financial conditions. Their framework has since inspired multiple researchers to further develop the framework and create new frameworks such as HaR.

Although there exists extensive research on the applications of GaR, the HaR literature is smaller. Using the same methodology as the GaR framework there has been some applications of HaR at an international-, continental-, and country-level.

On the application of HaR at an international level, Adrian et al. (2020) examines the predictive patterns in real estate markets of 32 advanced and emerging markets, specially focusing on potential negative fluctuations. This study explores the predictive capacity of different macroeconomic and financial indicators in forecasting forthcoming declines in real house price growth. Adrian et al (2020) employ a quantile regression methodology to estimate the 5th percentile, which represents the tail risk of the distribution of home price growth. This approach enables a more nuanced comprehension of the elements that contribute to significant decreases in house values. The study's strength is emphasised by the utilisation of different panel quantile estimators, which provide valuable insights into early warning signs for policymakers and analysts focused on financial stability.

The research brings attention to the noteworthy role played by variables such as GDP growth, credit conditions, and financial stability indicators in the prediction of house-price growth. This contributes to the existing body of literature that underscores the significance of macro-financial connections in evaluations of the housing market. The findings of Adrian et al. (2020) hold significant importance in the advancement of policy instruments designed to address systematic risks and improve macro-prudential frameworks.

Jarmulska et al. (2022) studied residential real estate market vulnerabilities in the Euro zone. In order to find the market drivers of the housing market and its relationship to macro-financial conditions, the authors use both Bayesian vector autoregressive (VAR) models and quantile regression. The article focuses on variables such as housing and mortgage supply, income, and monetary policy shocks. Jarmulska et al. (2022) emphasise that the models used help explain the intricate dynamics of the housing market, yet only represent a simplified version of reality.

The application of HaR on country-specific housing markets is recent and few. Cucic et al. (2022) were among the first to apply HaR to a country-specific housing market. The economic memo published by Danmarks Nationalbank applies GaR on the Danish housing market. They estimate macroprudential policies, the cyclical and structural risks on future house price growth's median and $5^{th}$ percentile development. They capture the macroprudential policies by a borrower-based measure. This measure captures the first-year debt cost of a first-time home buyer. This is meant to identify effects of policies like the loan-to-value (LTV) limit, and other policies affecting the macroprudential environment. The cyclical risks are identified through the ratio between house valuation and household income. The authors also include investments in the housing market in relation to GDP to capture the size of the real estate sector. This variable is then used to describe the structural factors in the model.

Cucic et al. (2022) find that house prices in relation to household income has a negative effect on both the tail and the median indicating that a higher house price to income ratio will increase the risk of a downturn in house prices due to affordability of the households. In the memo they also present some interesting findings based on tail and median results. The effects of the housing investment variable seem to affect the tail negatively, but the median positively. This indicates an increased tail risk in house prices with more investments, as there could be more housing supply than demand which in turn can drop house prices fast, especially in a downturn. Lastly, the results that tightening borrower-based measures boosts the 5th percentile of house price growth, decreasing the risk in housing price drops. This is an important finding as policymakers then can precent housing price drops by tightening these measures.

Another study using HaR was published by Ganics & Rodriguez-Moreno (2022). Using quantile regressions, they focused on the left tail to showcase the potential downside risk of the Spanish housing market with respect to different macroeconomic, financial, and structural factors. Ganics & Rodriguez-Moreno's (2022) application of HaR to the Spanish housing market provides several key findings. The model, which includes the quarterly growth of the house price index, a measure of house price misalignment, and the consumer confidence index as explanatory variables, demonstrates accurate forecasting for up to two years. It effectively monitors the downside risk by focusing on nominal terms rather than real terms, a perspective that aligns with household decision-making and bank balance sheet practices.

The study's results indicate that the overvaluation measure is particularly effective in forecasting, as models including this variable consistently presented correct calibration across various quantiles. This underscores the significance of house price misalignment measures in monitoring the Spanish residential real estate market, especially concerning downside risks. The model also takes into account factors such as financial stress, GDP growth, disposable income, consumer confidence, and population growth, highlighting their positive impact on house prices.

Interestingly, inflation rate did not emerge as a strong predictor in the context of the last decade's low and stable inflation, which could have limited its predictive power. HaR also demonstrated its utility by reflecting the accumulation of downside risk during the pre-crisis period of 2006-2008 and indicating a subdued downside risk in the most recent quarter analysed.

The latest addition to HaR was published by Bowe et al. (2023). This Staff Memo focused on the Norwegian economy, also using quantile regressions in their analysis. The authors use GaR to showcase the flexibility of the framework, applying it to identify GDP uncertainty, inflation uncertainty, and house price uncertainty. Bowe et al.'s (2023) analysis uses quantile regressions with a broad spectrum of uncertainty indicators against a backdrop of a skewed-t distribution. This integration is especially relevant for HaR since it enables the model to effectively account for uneven risks and time-dependent fluctuations in the forecasted distribution of housing prices. These details are often overlooked in conventional econometric models because they assume symmetric uncertainty and ignore tail risks that are crucial to HaR analysis.

Bowe et al.'s (2023) results indicate that financial market variables have a significant short-term effect on house prices, while disposable income, misalignment measures, credit and interest rate are more of importance in the longer run.

## 3. Methodology

### 3.1 Theoretical Framework

HaR is characterized as a metric for assessing the potential fluctuations in house prices over a specified time frame. The framework can, as mentioned in the introduction be used to predict the potential decline in house prices conditional on explanatory variables as further specified in Section 4.

The potential downturn of house prices is of particular interest for policymakers and governments. The focus of the model will therefore be on the lefthand-side quantiles forecasting the negative house price growth rates. While the methodology can be extended to encompass other percentiles within the distribution, the primary focus in the baseline model centres on the 10$^{th}$ percentile. This choice aligns with the core results of other related papers discussed in Section 2, which is to examine downside risks and its implications for financial stability, thereby capturing the most adverse house price scenarios.

The approach used is taking inspiration from the two-step procedure proposed by Adrian et al. (2019) and by using quantile regression, following the methodology of (Koenker og Bassett 1978), i.e.,

$$Q_{y_{t+h}}(\tau|X_t) = X_t'\beta_\tau. \tag{1}$$

In (1), $\tau$ denotes the specific quantile analyzed, $y_{t+h}$ is the house price index $h$ quarters after the starting point of the forecast $t$, $X_t$ represents a vector of predictor variables, and $\beta_\tau$ represents the vector of quantile specific coefficients.

The application of quantile regression enables the evaluation of the impact of explanatory variables on various parts of the distribution of house price growth. This approach demonstrates a high level of proficiency in assessing the impact of modifications in a conditioning variable on the lower or upper tails of the distribution within a multivariate regression framework. By employing this methodology, it becomes possible to understand the effects of cyclical vulnerabilities and macroeconomic factors on the lower end of house price inflation. This technique provides valuable insights into the impact of the explanatory variables on the $\tau^{th}$ conditional quantile of the distribution of the dependent variable. This implies that it offers an in-depth analysis of how various variables, such as monetary policies or market conditions, significantly affect the upper or lower extremes of the housing price growth spectrum, as opposed to solely the average impact.

To estimate the complete predictive density for various time periods, Jones and Faddy's (2003) skew-t distribution can be used by minimizing the squared distance between the quantile estimates and the quantile values of the skew-t distribution, i.e.,

$$\{\hat{\mu}, \hat{\sigma}, \hat{a}, \hat{b}\} = argmin_{\mu,\sigma,a,b} \sum_{\tau} \left(\hat{Q}_{y_{t+h}}(\tau|X_t) - F^{-1}(\tau; \mu, \sigma, a, b)\right)^2, \tag{2}$$

where $\mu \in \mathbb{R}$ and $\sigma$, a, b $> 0$.

The aim is to identify the optimal skew-t distribution that accurately represents the data. The skew-t distribution is a versatile distribution capable of capturing both skewness (asymmetry) and heavy tails (more extreme values than a normal distribution) in the data.

An alternative method for measuring the predictive density across different time periods is explained by Węglarczyk (2018) using Kernel Density Estimation (KDE). KDE is a non-parametric technique that calculates the probability density function (PDF) of a random variable without making any assumptions about its specific distribution. KDE applies a smoothing kernel function to each data point, aggregating these to form a continuous density curve. The bandwidth parameter in KDE is crucial as it dictates the level of smoothness. Larger values result in a smoother and more generalized density curve, while smaller values make the curve more responsive to fluctuations in the data. specifically,

$$\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} K(\frac{x-x_i}{h}) \tag{3}$$

where $\hat{f}(x)$ is the estimated PDF at point $x$, $n$ is the number of data points, $h$ is the bandwidth parameter and $K(\frac{x-x_i}{h})$ is the kernel function.

## 3.2 Explanatory Variables

The HaR approach considers a comprehensive set of explanatory variables to accurately forecast potential risks and movement in the Swedish housing market, drawing inspiration from the extensive literature on HaR and GaR. Due consideration was given to the predictive ability and relevance to the market dynamics of these variables. For shorter time horizons Alter & Mahoney (2021) show in their study the importance of including financial conditions in the framework. They show evidence proving that tighter financial conditions appear to increase the downside risks to house prices but has diminishing effect over time. The evidence is also supported by the findings of Bowe et al. (2023) proving that financial market variables are of particular importance in the short-run, while income, house price misalignment, credit and interest rate variables are more significant in the long-run.

Although there are some mutual findings in the research, it is also important to consider the difference in countries and their respective economic structures, regulatory environments, and housing market dynamics. For instance, countries with more developed financial markets may exhibit a quicker response to financial variables, whereas those with tighter regulatory frameworks around credit and housing may find long-term variables playing a more decisive role. Additionally, cultural factors and preferences in housing can significantly influence the relative importance of these variables.

When assessing the housing market in Sweden, one has to consider multiple factors affecting the price and market growth. The financial condition of the overall economy is captured through a financial conditions index (FCI). A high FCI can be interpreted as expansionary with favourable financial conditions, while a low FCI might indicate tighter financial conditions.
The Swedish housing market is also highly linked with household debt as housing makes up 80% of household debt (Reuters, 2023). As most households finance the purchase of houses using loans, the mortgage rate is of high interest, but due to the lack of public data on the different mortgage rates, the model then incorporates the policy rate as a proxy. The policy rate is interlinked with mortgage rates as an increase in the policy rate would increase the expected mortgage rate (Jou et al., 2013). The model also includes the consumer price index (CPI) as a proxy for the inflation rate. Unemployment rate is included to capture the influence labor has on house price growth. Structural factors such as population growth is incorporated in nominal GDP per capita. In order to capture the housing supply effect on house prices, the model uses construction costs. Detailed information regarding the variables under study is provided in Table 1, located in the Appendix.

### 3.3 House Price Misalignment

The results of Ganics & Rodriguez-Moreno (2022) show the significance of including a misalignment variable in the model. Creating a misalignment variable for house prices will uncover and explain any discrepancy between the real house price and a fundamental price calculated based on different variables. There is extensive research on this topic, and most tend to use the historical rent-price ratio or income-price ratio averages to predict expected house prices. This model focuses on various variables believed to be of importance for the Swedish HPI. Running a regression with the HPI as a dependent variable and explanatory variables that are statistically significant at the normal levels might not be sufficient as the explanatory variables may be non-stationary. Using the first differences of the explanatory variables will in this case fix the non-stationarity problem as the purpose of the misalignment variable is to uncover the short-term dynamics rather than the long-term equilibrium.

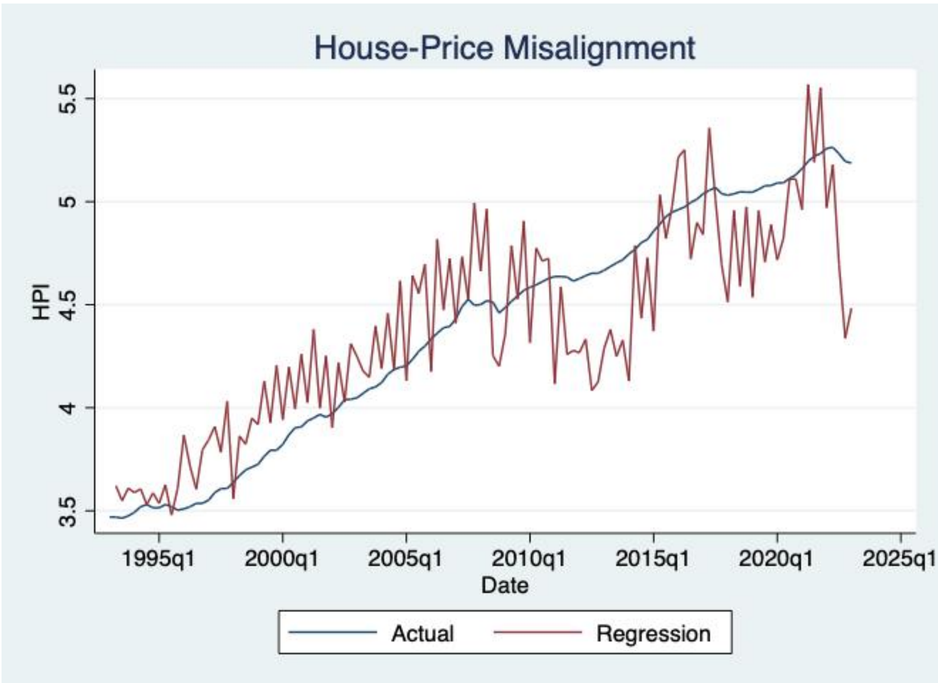


Figure 1: House-Price Misalignment Variable

3.4 Financial Conditions Index

Zheng & Wang (2014) show that creating the FCI helps accurately explain the holistic financial situation of a country by aggregating various economic indicators into a single composite metric. This index serves as a proxy to assess the overall state of the economy, incorporating many factors including credit conditions, performance of the stock market, interest rates, and foreign currency rates.

This analysis provides significant perspectives for policymakers, investors, and analysts to evaluate the degree of flexibility or stringency in financial conditions, which subsequently has the potential to impact economic growth and stability. The utilization of a FCI facilitates a comprehensive understanding of the intricate financial structures at play. This deeper understanding empowers policymakers to make more educated choices, encompassing modifications to monetary policies. The approach used is inspired by Alsterlind et al. (2020). They estimated an FCI with the purpose of creating an accurate and robust parameter to represent the Swedish economic state.

The FCI used includes four different sub-markets to capture the different sides of the Swedish economy excluding the housing market as this will be captured separately. The variables are presented nominally and quarterly.

To capture the movement of the stock market and its volatility, the Stockholm Stock Exchange's 30 most traded companies (OMX30) are gathered in an index that represents the general movements of the exchange. An increase of the stock market is likely representing an expansionary policy and hence might indicate a positive impact on the financial conditions of Sweden. The OMX30 is divided by GDP in order to interpret the movements in relation to the general economy. The Stockholm Stock Exchange is also known to be moving similarly to the US Stock Exchanges (Alsterlind et al., 2020), therefore The Chicago Board Options Exchange (CBOE) Volatility Index (VIX) is employed to measure the degree of fluctuation in the stock market. The Index is computed by the CBOE and quantifies the anticipated volatility in a 30-day period on the US stock exchange S&P 500. The computations rely on the prices of stock options.

To capture the conditions of the Swedish money market, the 3-month STIBOR has been applied. This is the Stockholm Interbank Offered Rate which serves as a reference rate for various financial contracts including an interest rate. The level of the 3-month STIBOR is therefore an important condition when understanding credit risk involving the Swedish Krona. It can also give an understanding of the general liquidity of the money market. The disparity between the 3-month STIBOR and the 3-month treasury bills provides further insight into the workings of the money market. While the 3-month treasury bills are not influenced by the overall liquidity of the money market, any disturbances in the interbank market are reflected in the differential, leading to an increase in the disparity. Another factor to assess the conditions of the money market is the disparity of the lending and deposit rates. The differential can contain significant information about the markets credit supply and bank's profitability which in turn affect the general money market.

Assessing the differential between a 10-year government bond and the 3-month treasury bills will represent both the interest rate expectations, and compensation for the risk of fluctuations in the interest rate yields. These are important metrics in the bond market. The difference of mortgage-backed bonds and government bonds will also capture the markets perception to risk. A high spread may suggest that the market views the mortgage market as having a greater likelihood of default, potentially resulting from factors such as decreasing real estate prices or economic downturns. On the other hand, a narrow spread could indicate a stable or expanding economy (Alsterlind et al., 2020).

Another indicator of the financial conditions would be comparing the interest levels of different countries. If the difference between interest levels are low, given the level of exchange rates, then it could indicate confidence in the financial system and a stable inflation. To capture this the FCI includes the differential between the Swedish 5-year government bonds and the German 5-year government bonds. The FCI also includes the nominal effective exchange rate (KIX) of Sweden. Capturing the weakening of the Swedish Krona could imply a more expansionary financial condition as Swedish export companies contribute more than import companies (Statistics Sweden).

After defining the relevant explanatory variables for the FCI of Sweden, Alsterlind et al. (2020) suggest that a simple approach to model the index is equally accurate as a more comprehensive approach. The FCI is estimated by normalizing the variables to improve comparability and handle outliers (Hatzius et al., 2010). The approach consists of taking variable's $(x_{i,t})$ deviation from its mean $(\mu_i)$ and divide it by its standard deviation $(\sigma_i)$,

$$x_{i,t} = \frac{x_{i,t} - \mu_i}{\sigma_i}. \tag{4}$$

The variable takes the form of an indicator which can be interpreted in relation to the number of standard deviations from its mean value. By standardizing the variables, they can be compared on an equal basis. After normalizing all relevant variables, an index for the different sub-markets is created by taking the average of the respective normalized variables. The composite FCI is then estimated by the average of the different sub-markets representing the different aspects of the Swedish financial condition as discussed above.

**4. Data Analysis**

Transforming the HPI into its logarithmic form is a widely used technique in economic and financial data analysis, mainly because it offers several significant benefits. Initially, applying a logarithmic transformation may help in standardizing data that has an uneven distribution, particularly when working with skewed datasets commonly found in housing markets. In addition, the application of the log transformation allows the smoothing of exponential growth patterns, which are frequently observed in housing prices. This, in turn, simplifies the process of modelling relationships and interpreting the obtained results.

This feature is especially beneficial in the analysis of time series, where the focus tends to be on relative percentage changes rather than absolute values. Applying the logarithm of the HPI enables the model to more precisely capture and evaluate the fluctuations of the housing market, resulting in more informed decision-making and accurate predictions. The purpose of the analysis is to examine quarterly and annual house price growth at different periods and quantiles.

4.1 Stationarity

To continue the analysis, the assumption of stationarity must hold. This involves testing the stationarity of the different variables using the Dickey-Fuller test. The test was conducted twice for each variable, once without a trend component and once with it. In both cases, zero lags were used in the test regression. The test results showed statistical significance at the 1% level. This indicates whether there is a unit root present or not in the respective series. These findings indicate that certain variables are not stationary, implying the necessity of applying first differences to achieve stationarity. The importance of this approach comes from understanding that stationarity is often a necessary condition for precise time series analysis and modelling.

Based on the results of the Dickey-Fuller test, interest rate, CPI, household liabilities, GDP per capita, construction costs, and FCI all seem to vary over time and hence be non-stationary. To address this issue, the HaR approach will be using the first differences of the variables for analysis. After confirming the stationarity of the transformed explanatory variables, an examination of the explanatory power of the variables is needed.

Each variable is regressed alone with the lead annualized growth rate as the dependent variable. This univariate regression analysis assesses each explanatory variable's relationship with the lead annualized growth rate. It captures the strength and direction of the variables. This assessment helps understand the dynamics of the model before making it more complex.

4.2 Predictive Power

To further investigate the dynamics of the explanatory variables, various combinations of the variables are run. The purpose of the explanatory power testing is to examine the robustness of the model and examine which combinations of variables help explain house price growth at different quantiles.

First a train test split is conducted to see how the model responds to new data. The threshold is set at the first quarter of 2006 in order to see if the model is able to predict the upcoming financial crisis of 2007/2008. This will validate the predictive power of the model on out-of-sample data. The training set is then used to create baseline metrics by estimating the $10^{th}$, $50^{th}$ and $90^{th}$ percentiles of the lead annualized house price growth rate. These baseline metrics help create an understanding of the distribution of the growth rate.

Using quantile regression, the relationship between the lead annualized growth rate and combinations of the explanatory variables is displayed at the different quantiles. Pseudo R-squared values are calculated to assess the degree to which the models explain the variation in the data compared to a baseline model. This provides a measure of how well the models fit the data and is suitable for quantile regressions. First the model assesses the pair-wise combination of explanatory variables and the quarterly house price growth rate, i.e.,

$$Q_{y(t+4)}\left(\tau \middle| \Delta y_t, X_{i,t}, X_{j,t}\right) = X_t' \beta_\tau. \tag{5}$$

A second model is run to test the explanatory power using one variable and the quarterly growth rate. The models are also run without the inclusion of the quarterly growth rates to test the robustness of the explanatory variables. Excluding a dominant variable like the first difference of HPI while keeping the model's predictive power can illustrate the power of the explanatory variables. This also helps avoid short-term prediction volatility as the quarterly house price growth can be volatile and be subject to sudden shifts due to short-term events.

The results of running the various models show that the combination of the first difference of FCI, the first difference of the construction costs and the misalignment variable are giving an indication of being good predictors of the downside risk of house price growth. The final model therefore is,

$$\Delta y_{t+h,\tau} = \beta_{0,h,\tau} + \Delta y_t \beta_{1,h,\tau} + \Delta FCI_t \beta_{2,h,\tau} + \Delta CCost_t \beta_{3,h,\tau} + misal_t \beta_{4,h,\tau} + \varepsilon_{t+h,\tau}. \tag{6}$$

4.3 Forecasting

Once having the explanatory variables' predictive power examined, the quantile regression can be extended to test the 5$^{th}$, 25$^{th}$ , 50$^{th}$ ,75$^{th}$ and 95$^{th}$ percentile. The model predicts the fitted values of the different quantiles. The regression also assesses the effect of the explanatory variables on the distribution of growth rates at various quantiles. An alternative version of this model is employed, which disregards the quarterly house price growth rate, in order to enhance the reliability of the variables, that is,

$$\Delta y_{t+h,\tau} = \beta_{0,h,,\tau} + \Delta FCI_t \beta_{1,h,\tau} + \Delta CCost_t \beta_{2,h,\tau} + misal_t \beta_{3,h,\tau} + \varepsilon_{t+h,\tau}. \quad (7)$$

Using the model defined in (7) a quantile regression is run on $\tau$ = 5, 25, 50, 75, and 95 percentiles, using a forecast horizon of 1 to 4 quarters ahead $(h = 1, 2, 3, 4)$. This approach showcases the impact that the explanatory variables have short-term as well as long-term.

The comprehensive analysis is useful for interpreting the potential results in various market scenarios and identifying significant variables during different housing market cycles. The results provided are necessary for understanding the distribution of the variables. This detailed range of quantile predictions can be used to construct KDE. This is used to estimate a PDF of the predicted values of the house price growth four quarters ahead.

## 5. Empirical Findings

The effect of the explanatory variables is illustrated in Figure 2. The green bar Y1 captures the predictive power of the FCI. The red bar seems to explain the predicted downturn in house prices well and is constructed from Y1 and the construction cost. Lastly, the blue bar Y3 captures the culminating effect of all the explanatory variables in the model.

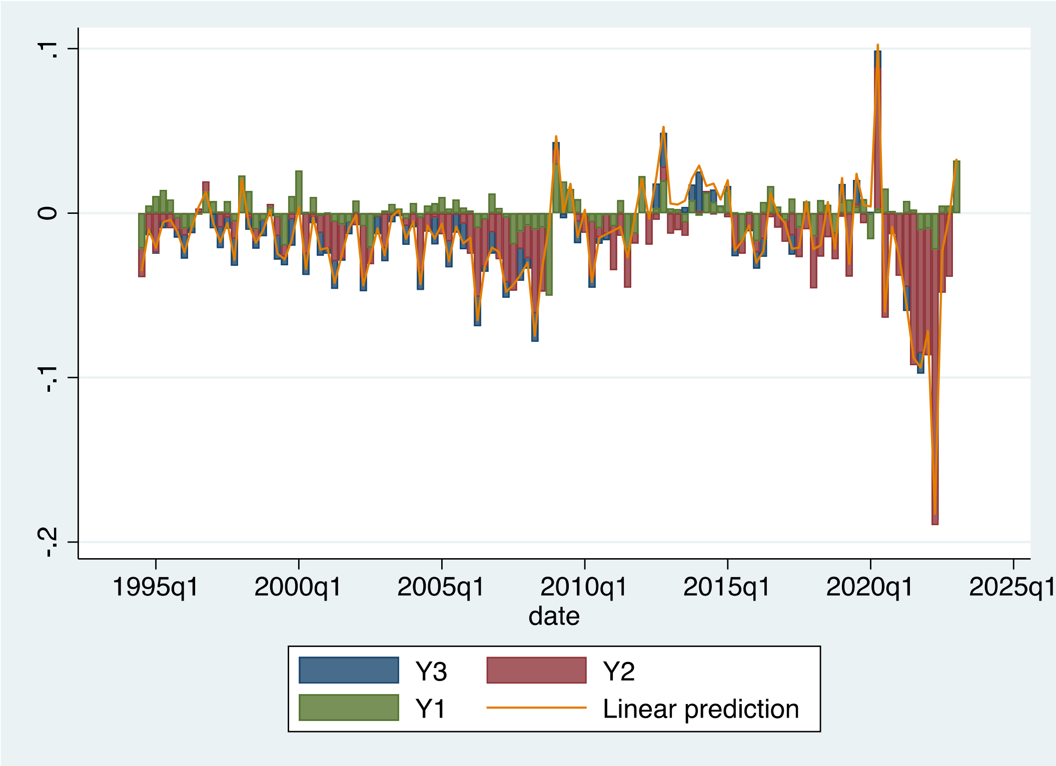


Figure 2: Explanatory Variables Performance

Figure 3 illustrates the accuracy of HaR in predicting the observed growth rate of house prices over time. In general the forecasted models have a more conservative volatility, but do capture some of the observed movements. The forecast applying the 5th percentile appears to closely align with the lower limits of the actual growth rate, suggesting that it effectively captures periods of decline or slower growth. This could be highly beneficial for monitoring downside risk, as it has the potential to detect periods of diminishing growth in advance. The 25th percentile forecast provides a more prudent estimate that is generally lower than the actual rates.

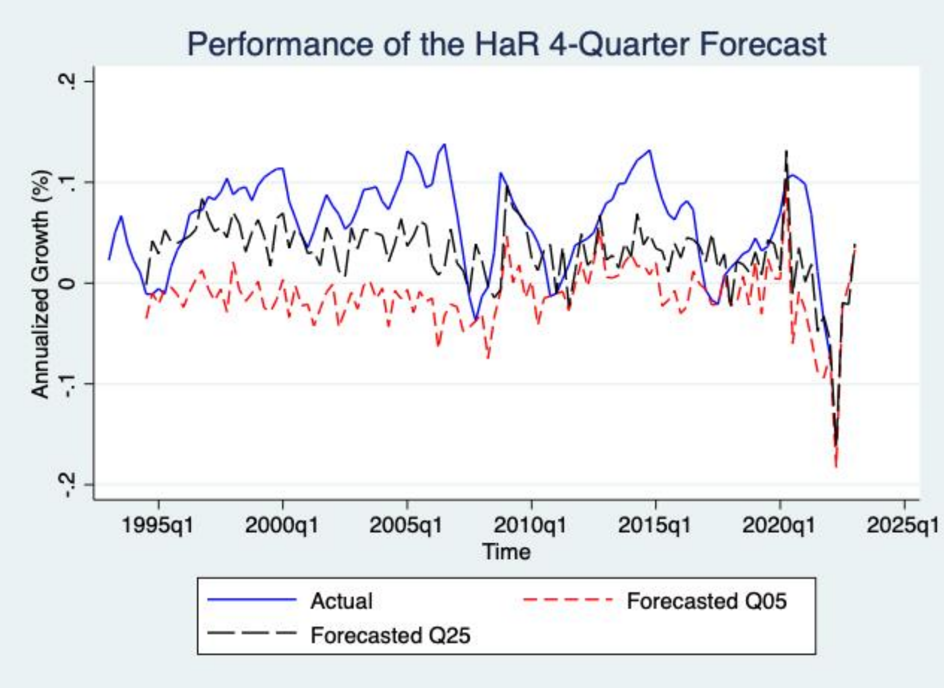


Figure 3: Performance of HaR

The 5th and 25th percentile forecasts seem to be fairly accurate in predicting their direction. This implies that the model is successfully capturing significant factors that influence the growth of house prices, particularly when it comes to negative trends.

During the upcoming first quarter, the financial conditions index indicates a positive correlation with house price growth. However, the relationship is not statistically significant, implying that looser financial conditions may only weakly contribute to higher future house price growth at the 5th percentile. The variable representing the construction costs indicates a negative and statistically significant impact, suggesting that higher construction costs are linked to reduced growth in house prices during unfavourable circumstances. The misalignment variable also indicates a negative effect, although it is not statistically significant. This suggests that a higher degree of misalignment may be associated with lower growth in house prices.

As we advance through the upcoming quarters, specifically the second, third, and fourth, the patterns become more noticeable and clearer. The negative effects of construction costs are increasingly prominent and consistently significant throughout all quarters, further supporting the idea that escalating costs consistently hinder the growth of house prices in the left tail. Starting from the second quarter, the misalignment variable shows a significant negative trend, indicating a stronger and more reliable connection with lower growth in future house prices. This suggests that misalignment, which may indicate overvaluation, poses a risk for future price corrections or slower growth.

The significance of the coefficients of the FCI diminishes as we extend our analysis into the future, possibly indicating the rising uncertainty and the diminishing impact of current financial conditions on long-term house price growth. Meanwhile, the pseudo-R-squared exhibit an upward trend from the first to the second quarter, followed by a slight decline. This indicates that the model's ability to explain the variation in lower-tail house price growth varies across different time periods, but overall captures a moderate proportion of the variance.

These findings highlight the significance of construction expenses and market misalignment as crucial elements that impact the likelihood of decreased growth in house prices. This has implications for policymakers and investors who are concerned with the potential negative risks in the housing market.

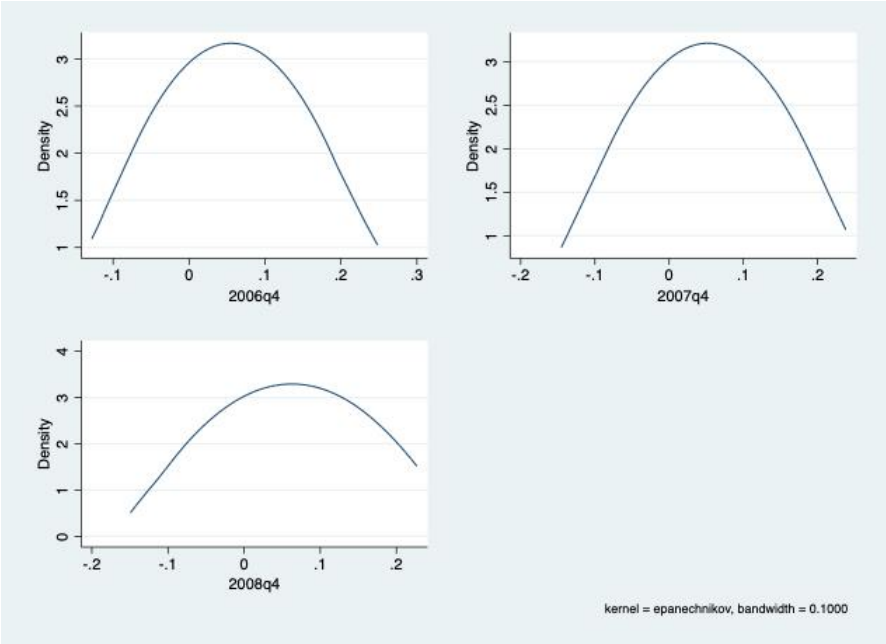


Figure 4: Kernel Density Estimations for last quarter 2006-2008

Figure 4 presents the KDE which illustrates the estimated PDFs of the predicted lead annualised growth rate for the last quarters of 2006, 2007, and 2008 using quantiles from 1st to 99th percentile. In the last quarter of 2006, the KDE displays that the most common prediction of the annualized growth rate is between zero and 1% growth. The actual lead annualized growth rate was ~1%, indicating a moderate prediction, but giving the correct indication of a period of growth. In the last quarter of 2007, the KDE shows the most probable growth rate to be closer to zero as the peak of the density curve is narrower. This is also giving a good prediction as the actual lead annualized growth rate is ~0%. The KDE in 2008Q4 is much wider and seem more uncertain about its prediction. The KDE plot illustrates a peak closer to 1% which is in line with the actual annualized growth rate also being ~1%.

## 6. Conclusion

The application of the House-Price-at-Risk model to the Swedish housing market provides compelling evidence regarding the key factors that affect the risk of experiencing negative house price growth. The empirical results of this study highlight the significance of financial conditions, construction costs and a misalignment measure, specifically their role in raising the likelihood of a decrease in house prices, as observed in the lower percentiles of the distribution. The construction costs can have an instant impact on the Swedish housing market, while the effect of the misalignment variable can be seen a little later as the market adjusts.

The research results suggest that adding HaR into the macroprudential toolkit is important. HaR provides a detailed evaluation of risks in the housing market. The model's capacity to measure risks linked to adverse market scenarios enables more informed decision-making and preventive risk management. The findings will have important consequences for policymakers, who may use the knowledge to improve their monitoring of financial risks and implement preventive measures to the housing market. HaR's predictive output provides an accurate resource to navigate the unpredictable fluctuations of the housing market with increased confidence.

The literature emphasizes the need to continuously improve HaR by incorporating more predictive variables and employing more advanced econometric techniques to enhance its accuracy. The primary objective is to create a robust and forward-thinking system that can withstand the impact of new economic challenges and guarantee the ongoing stability of the housing market. HaR, with focus on the left tail of the distribution of house price growth represents a new approach in analyzing the housing market and assessing risk.

## 7. Limitations and Future Work

This work project has shed light on HaR's adeptness in evaluating potential downside risks within the Swedish housing market. Nevertheless, it is important to recognise and acknowledge various limitations.

Firtsly, the small size of the dataset employed in this study may pose a potential restriction. A more extensive dataset would not only improve the accuracy of the quantile estimates but also enhance the robustness of the model's predictions. Incorporating historical data starting from before 1990 would allow for HaR to capture the financial crisis of Sweden from 1990 – 1994.

Furthermore, while the model illustrates capability in predicting adverse risks, its capacity to forecast positive risks is still somewhat constrained. Considering upside risks is crucial for a holistic understanding of market dynamics, and future research should therefore concentrate on enhancing HaR's capacity in predicting the right tail to develop a more nuanced understanding of the Swedish housing market.

Moreover, the presence and availability of specific variables can greatly impact the results of these models. The Swedish central bank, for instance, may possess access to a wider range of data, such as mortgage rates and more extensive measures of housing market misalignment. Incorporating these variables could offer a more detailed perspective on the state of the housing market and potentially enhance the predictive precision of the model.

Further research could examine the incorporation of additional data, depending on its availability. It would also be advantageous to broaden the range of the dataset to encompass post-pandemic market behavior, given that the present worldwide circumstances have presumably had a substantial impact on housing market dynamics.

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**Appendix**

Table 1: Explanatory Variables

| | | |
|---|---|---|
| House Price Index | Nominal selected residential property prices. Showing the most representative property price indicator. | Bank for International Settlements (BIS) |
| Unemployment Rate | % of total labor force. | World Bank & International Labour Organization |
| Construction Cost Index | Estimated from multi-dwelling buildings, collectively built one- or two-dwelling buildings and agricultural buildings. | Statistics Sweden |
| CPI | Consumer Price Index. | Statistics Sweden |
| GDP per Capita | Nominal GDP divided by Population. | OECD |
| Household Liabilities | Total credit from all sectors to households and NPISH at market value nominated in SEK. | BIS |
| Interest rate | Long-Term Government Bond Yields: 10-Year: Main (Including Benchmark). | Federal Reserve Economic Data (FRED) |
| Stock Market | The OMX Stockholm 30 is the index representing the 30 most traded stocks on the Stockholm Stock Exchange. | Nasdaq OMX Nordic |
| STIBOR 3M | Stockholm Interbank Offer Rate 3 month. | Riksbanken API<br>ECB (2020Q1-2023Q2) |
| VIX | Chicago Board Options Exchange (CBOE) Volatility Index. | CBOE |
| Deposit | Interest rate offered by Swedish Central Bank to banks for deposits. | Riksbanken API |
| Lending | Interest rate offered by Swedish Central Bank to banks for loans. | Riksbanken API |
| 5-year Government Bond Germany | The yield of a 5-year government bond in Germany | Riksbanken API |

| | | |
|---|---|---|
| 5-year Government Bond Sweden | The yield of a 5-year government bond in Sweden | Riksbanken API |
| 10-year Government Bond Sweden | The yield of a 10-year government bond in Sweden | Riksbanken API |
| KIX | Nominal effective exchange rate | Riksbanken API |
| 5-Year Mortgage Bond | The yield of a 5-year mortgage bond in Sweden | Riksbanken API |
| Treasury Bill | Short-term debt obligation | Riksbanken API |
| GDP | Nominal Gross Domestic Product | FRED |

Figure 5: Lead Annualized Growth and Explanatory Variables

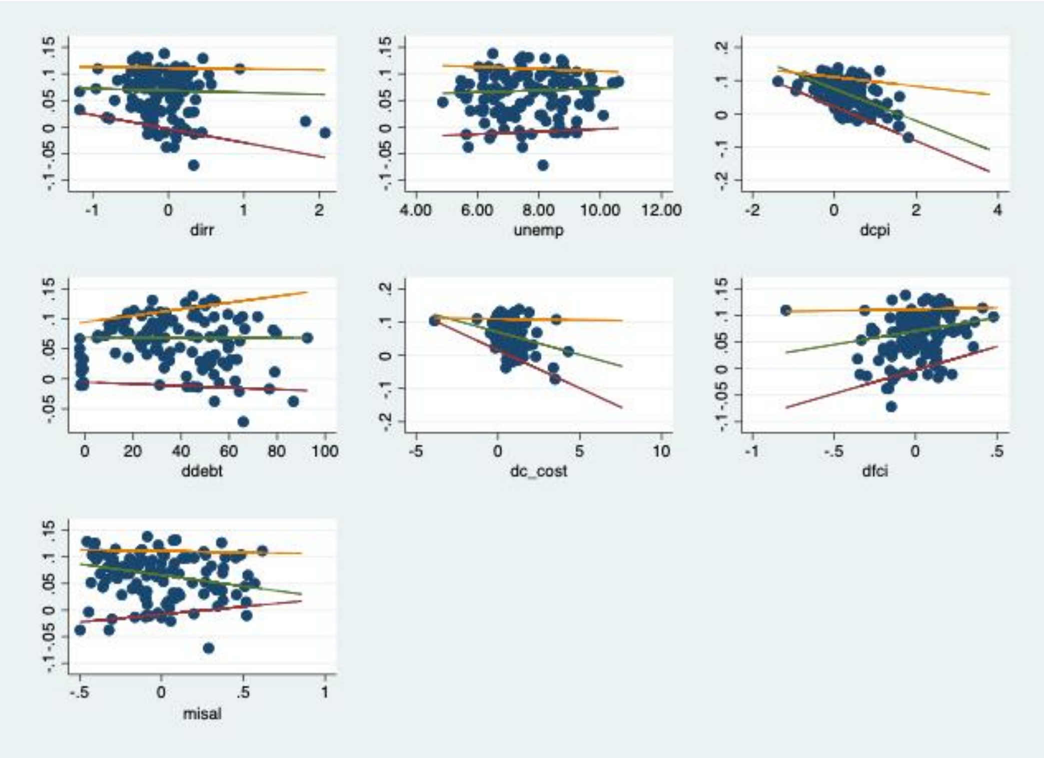

Figure 6: Annualized Growth Rate - Histogram

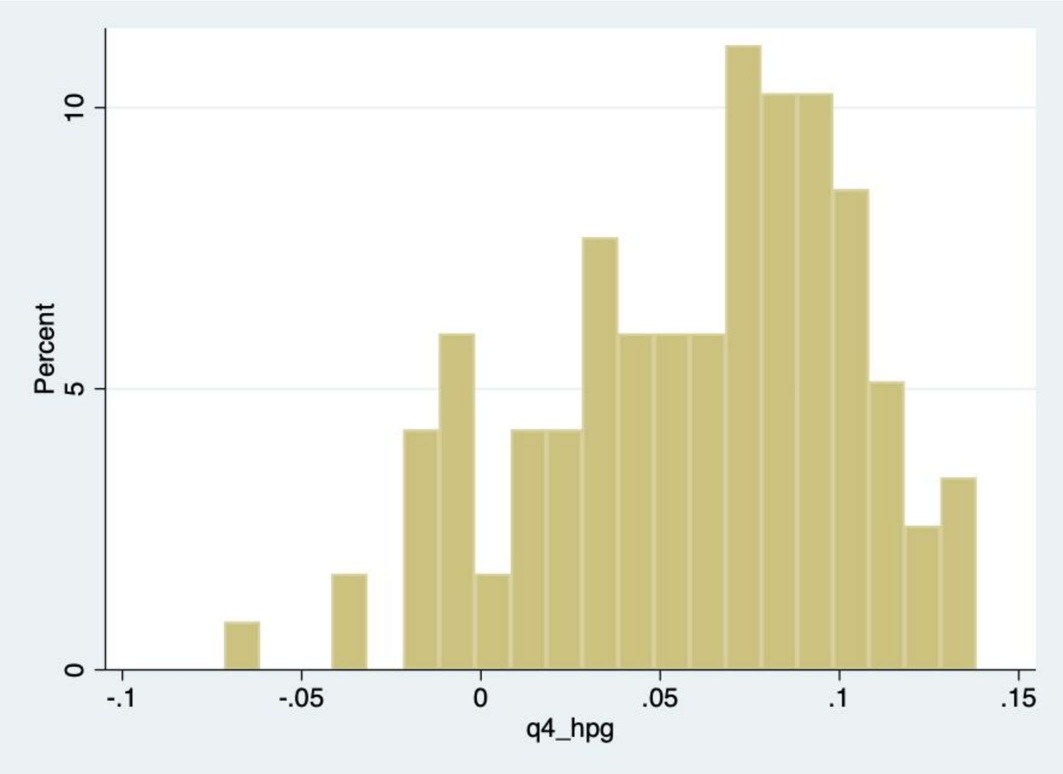


Figure 7: Decomposition of effect 4 quarters ahead

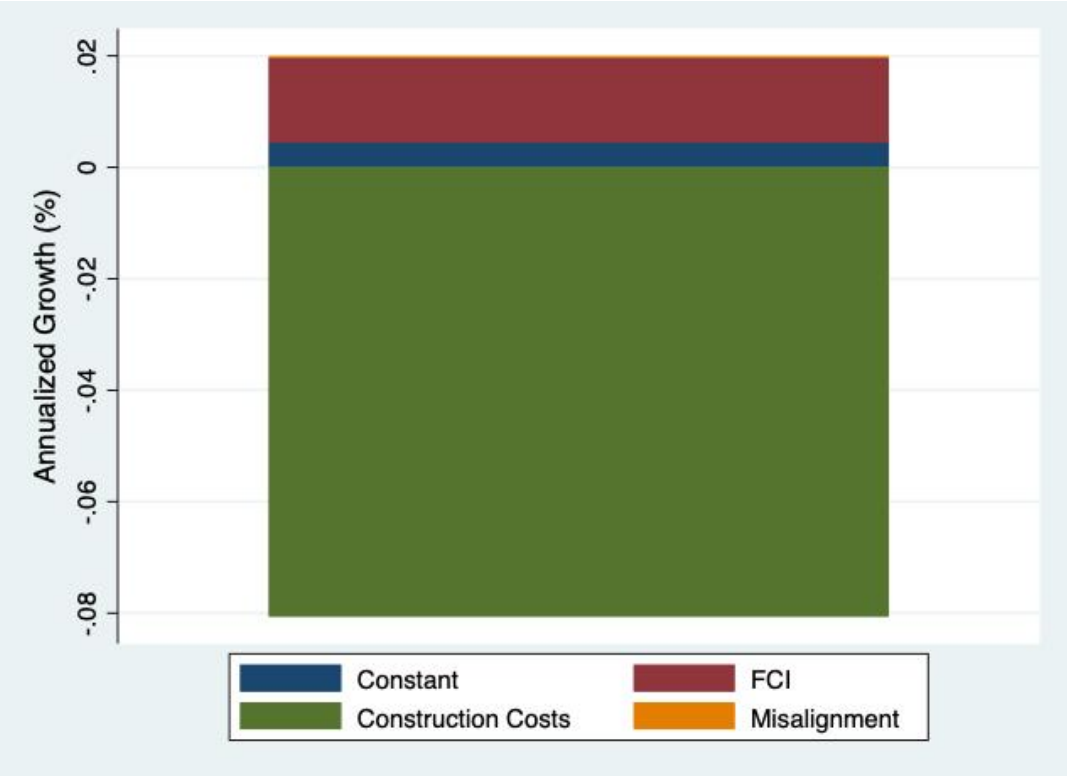

Figure 8: Decomposition of effect 4 quarters ahead without quarterly growth