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# From boom to bust: Predicting turning points in house prices based on deviations from fundamentals

Nini Barth
Jeanette Fjære-Lindkjenn

HOUSING LAB
Nasjonalt senter for boligmarkedsforskning

# From boom to bust: Predicting turning points in house prices based on deviations from fundamentals*

Nini Barth[†] and Jeanette Fjære-Lindkjenn[‡]

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## Abstract

This paper tests empirically whether deviations from fundamental prices, defined as the price that can be explained by disposable income, the housing stock and the user cost of housing, have predictive power on turning points in house price cycles on a regional level. We apply the Bry and Boschan (1971) algorithm to identify booms and busts in house prices for 14 municipalities in Norway, using quarterly data over the period 2003 to 2021. A cointegrated vector autoregressive model is used to identify long-run drivers in local house prices. We find that there is considerable heterogeneity in the timing, duration and amplitude of booms and busts in real house prices across municipalities. We also find substantial heterogeneity in the response to long-run fundamentals, particularly in the response to a change in the user cost. The model is utilized to investigate if the real house price gap; the difference between actual and model-implied prices, can help detect turning points in house prices. We find that an increase in the price gap from 0 to 15 percent increases the probability of a peak (and an ensuing downturn) in house prices by 7 percentage points.

**JEL-codes:** *E32; R31*
**Keywords:** *Boom-bust cycle; House prices; Regional Housing Markets*

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[†]Phd-candidate at Housing Lab, Oslo Met. Email: ninibart@oslomet.no
[‡]Phd-candidate at Housing Lab, Oslo Met. Email: jeasf@oslomet.no

# 1 Introduction

Excessive growth in house prices and household credit in a boom has shown to amplify economic downturns (Anundsen et al., 2016; Jorda et al., 2013; Mian et al., 2017; Reinhart & Rogoff, 2009). Furthermore, busts in housing investments have proven to be a reliable predictor of downturns in the real economy (Leamer, 2015; Leamer, 2007). A broad set of countries have experienced a house price boom in the post financial crisis era (Wetzstein, 2017). However, the price growth has not been evenly distributed across regional markets and there has been growing attention on regional heterogeneity. Especially, house price growth in metropolitan areas has received attention, see for example Gyourko et al. (2013) and Glaeser and Gyourko (2018). Regional house price cycles have welfare implications, which motivates the need to better understand how house prices in different municipalities and regions evolve and how they respond to changes in fundamentals[1].

We use Norwegian data at municipality level to investigate drivers of regional housing cycles, using a cointegrated vector autoregressive model (CVAR). We test empirically the models' predictive power of peaks and troughs in house prices. We start by applying the Bry and Boschan (1971) and Harding and Pagan (2002) algorithm to identify observed booms and busts in house prices for Norway as a whole and at the municipality level for 14 of the largest municipalities between 2003 and 2021. Second, we use a cointegrated vector autoregressive model (Johansen, 1988) to estimate the link between real house prices and fundamentals, defined as real mortgage rates, real disposable income, and the housing stock, in each municipality. Lastly, we perform a panel regression to investigate whether the real house price gap, defined as the difference between actual and fundamental prices, has predictive power on turning points in house price cycles. Fundamental house prices are given by the house price path implied by the evolution of the underlying fundamentals and the

[1]With fundamentals we mean factors that are considered to impact house prices in the long run. We define these fundamentals as household disposable income, the user cost of housing and the housing stock. We use a cointegrated vector autoregressive model to find that these factors cointegrate, meaning that a linear combination of them are stationary. The user cost of housing is defined as the tax adjusted, real mortgage rate, adjusted for depreciation and expected house price growth.

long-run coefficients estimated by the CVAR model.

Our findings show that there is considerable heterogeneity in house price cycles when analyzing Norway as a whole and the 14 municipalities over the period 2003 to 2021. Although house prices follow a similar pattern across municipalities over time, there is variation in both the timing and duration, as well as the amplitude of booms and busts. There is also heterogeneity in the long-run drivers of house prices, particularly in the response to a change in the real user cost, defined as the tax adjusted, real mortgage rate. For Norway as a whole, the results indicate that a 1 percentage point increase in the real user cost is associated with a decline in real house prices of 9.9 percent in the long run. For the capital, Oslo, the response to a change in the user cost is larger than for the country as a whole. The differences between regions in the sensitivity to the user cost seem to drive much of the variation in the fundamental house price path. We find that house price sensitivity to the user cost seems to be positively associated with debt-to-income.

The results show that the long-run effect of a change in disposable income on real house prices is of a more similar size across the regions with an elasticity of between 1 and 2, meaning that an increase in income of 1 percent is associated with an increase in real house prices of 1 to 2 percent in the long run. Fluctuations in disposable income vary between the regions, which means that differences in disposable income are still important for heterogeneity in house price cycles across regions.

Our results show that an increase in the real house price gap increases the probability of a house price peak. We find that an increase in the real house price gap from 0 to 15 percent is associated with an increase in the probability of a peak in house prices of about 7 percentage points to 9 percent.

To test the robustness of our results, and to assess if the house price gap is a reliable predictor of turning points, we do an out-of-sample exercise in which we estimate the model from 2003q1-2013q4 and perform the panel regression on the out-of-sample period from 2014 to 2021. This exercise yields results in line with the baseline in which a price gap of 15 percent is associated with a probability of a peak of around 10 percent.

This paper contributes to three strands of the literature. First, it relates to the literature analyzing long-run drivers of house prices and house price bubbles (Agnello & Schuknecht, 2011; Anundsen, 2019; Phillips et al., 2015), and booms and busts in housing markets (Aastveit et al., 2023; Croce & Haurin, 2009). Our paper contributes to this literature by connecting a regional version of the model of Anundsen (2019) with the Bry and Boschan (1971) algorithm to predict peaks and troughs in regional housing markets.

Second, the findings are related to the literature concerned with regional house-price models (Meen, 1990, 1999; Oikarinen et al., 2018). While Meen (1999) documents regional heterogeneity in the adjustment parameters, resulting in heterogeneity in return to fundamental prices, we also document substantial regional heterogeneity in the long-run relationships between real house prices and fundamentals. We contribute by deepening our understanding of regional house price cycles, by documenting heterogeneity at the municipality level and by showing how differences both in the response to changes in fundamentals and developments in fundamentals can explain this heterogeneity.

Third, the paper is related to the literature on predicting house price cycles (Bauer, 2017; Chen et al., 2014; Duca et al., 2021). We contribute to this literature by exploiting regional variation in house price cycles and their fundamental drivers to predict turning points in house prices. In addition to a more standard CVAR-model at the regional level, we use the Bry and Boschan (1971) algorithm to detect turning points, which allows us to perform a panel regression to assess the probability of a turning point in house prices.

The paper is also relevant for central banks' work with financial stability. Here, we relate to a literature concerned with credit cycles, see for example Borio (2012), Kiyotaki and Moore (1997) and Jorda et al. (2013). We also contribute to the literature on *leaning against the wind*, see for example Schularick et al. (2021) and Svensson (2017), since we deepen our understanding of the housing cycle at the regional level.

The rest of the paper is structured as follows. Section 2 describes regional house price cycles and historical booms and busts. Section 3 presents results from the cointegration model and we estimate fundamental house price paths at the regional level. Section 4 combines observed house prices and turning points with the fundamental house price paths to predict turning points in real house prices. Section 5 concludes.

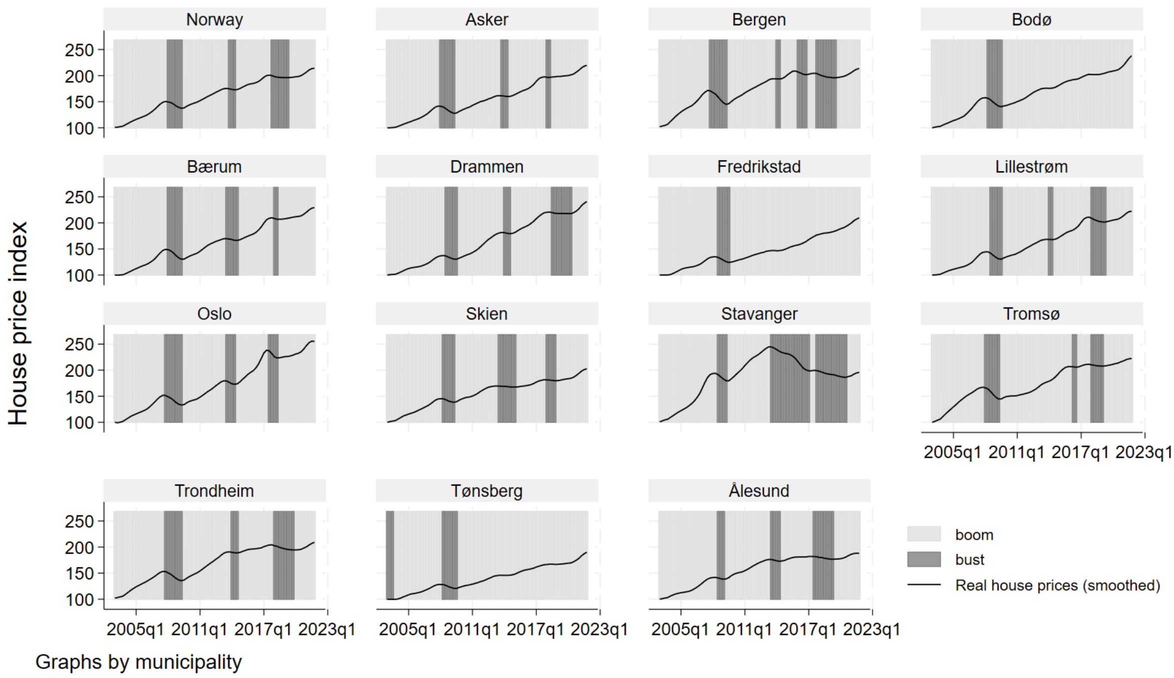
## 2 Historical booms and busts

We start by dating historical booms and busts, at the national level and for the 14 municipalities, over the period 2003q1-2021q4. We apply the approach of Harding and Pagan (2002) for detecting turning points, which is a quarterly version of the Bry and Boschan (1971) algorithm. The aim of their algorithm is to identify turning points between phases of growth (booms) and decline (busts) in real economic variables based on predefined censoring rules. The censoring rules include (*i*) the window; in what time span the algorithm searches for local minima and maxima, (*ii*) the phase; the minimum time of growth or contraction to be considered a boom or bust, and (*iii*) the cycle length; a minimum time of a complete cycle, from peak-to-peak or trough-to-trough. Originally, the window was set to 6 months, the phase to 6 months and the cycle to 15 months by Bry and Boschan (1971). We settle on a window of 2 quarters, phase of 2 quarters and cycle of 6 quarters, which gives a reasonable number of booms and busts and is in line with Bry and Boschan (1971).

Figure 1 shows real house prices with shaded areas for housing booms and busts for Norway and the 14 municipalities over the sample period. The municipalities have experienced between 1 and 4 busts, and for all areas, except Stavanger, busts are considerably shorter than booms. In addition, we see that house prices typically decline less in busts than they increase in booms, hence real house prices increase over the cycle. Real house prices follow a similar pattern across most municipalities, but there is heterogeneity both in the timing and the duration of the phases across areas. Particularly, Stavanger and Bergen, municipalities that are highly exposed to the petroleum sector, have experienced a weaker trend and a longer bust period after 2014, when oil prices plummeted.

For national house prices, the first peak is detected in the fourth quarter of 2007. The ensuing decline in house prices, related to the global financial crisis, lasted until the second

**Figure 1** Housing cycles, real house prices




**Notes**: This figure shows a quarterly index for real house prices in each municipality from 2003q1-2021q4. The nominal, quarterly, house price indices from Eiendomsverdi/Eiendom Norge are deflated by the consumer price index (CPI) to obtain a series for real house prices. The series are smoothed with a four-quarter moving average. To assess turning points, the following censoring rules are applied: window=2, phase=2, cycle=6 (quarters). **Data sources:** Eiendomsverdi/Eiendom Norge, Statistics Norway.

quarter of 2009. All municipalities experienced a peak in real house prices at the end of 2007, or beginning of 2008, and an ensuing downturn, although with slightly different timing, duration and price drop. The country as a whole, and roughly half of the municipalities, experienced a new bust in 2013. This decline may have been a response to the capital buffer requirements that were introduced in 2013. The 2013-bust lasted between 2 and 3 quarters, except in Stavanger, in which the decline in real house prices lasted until 2017, followed by a short boom and a new bust lasting until the third quarter of 2020. Again, house price developments in Stavanger must be seen in context with the oil price drop in 2014. The most recent bust at the national level was in 2017, after a period of rapid price growth. This bust in prices was particularly sharp in the capital, Oslo, but also apparent in several other municipalities.

**Table 1** Summary statistics. Peaks and troughs, 2003-2021.

| Average | Ålesund | Bodø | Tromsø | Skien | Tønsberg | Asker | Bærum | Drammen |
|---|---|---|---|---|---|---|---|---|
| No. peaks | 3.0 | 1.0 | 3.0 | 3.0 | 1.0 | 3.0 | 3.0 | 3.0 |
| No. troughs | 3.0 | 1.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 |
| Bust (qtrs.) | 5.0 | 6.0 | 4.3 | 5.3 | 6.0 | 3.7 | 4.3 | 5.3 |
| Boom (qtrs.) | 14.5 | | 16.0 | 13.5 | | 15.5 | 14.5 | 16.0 |
| P-to-P (qtrs.) | 18.0 | | 20.0 | 19.5 | | 20.0 | 20.0 | 20.0 |
| T-to-T (qtrs.) | 20.5 | | 19.5 | 19.0 | 24.0 | 18.0 | 18.0 | 21.5 |
| Bust (% growth) | -0.5 | -2.3 | -1.1 | -0.5 | -1.3 | -0.8 | -1.1 | -0.5 |
| Boom (% growth) | 2.9 | | 3.8 | 2.9 | | 4.5 | 5.0 | 5.4 |
| P-to-P (% growth) | 2.5 | | 2.3 | 2.2 | | 3.3 | 3.4 | 4.7 |
| T-to-T (% growth) | 2.5 | | 3.6 | 2.6 | 4.1 | 4.3 | 4.6 | 5.2 |

| Average | Fredrikstad | Lillestrøm | Oslo | Bergen | Stavanger | Trondheim | Norway |
|---|---|---|---|---|---|---|---|
| No. peaks | 1.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 |
| No. troughs | 1.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 |
| Bust (qtrs.) | 5.0 | 4.3 | 5.0 | 5.2 | 10.3 | 6.0 | 5.3 |
| Boom (qtrs.) | 15.5 | 14.0 | 9.0 | 9.0 | 15.5 | 15.0 | |
| P-to-P (qtrs.) | | 19.0 | 19.5 | 13.3 | 18.5 | 20.5 | 19.5 |
| T-to-T (qtrs.) | | 19.5 | 18.0 | 13.7 | 22.5 | 21.0 | 20.0 |
| Bust (% growth) | -1.7 | -1.0 | -1.5 | -1.2 | -2.2 | -1.2 | -0.8 |
| Boom (% growth) | | 4.8 | 6.2 | 2.5 | 3.0 | 4.2 | 3.9 |
| P-to-P (% growth) | | 3.7 | 4.4 | 1.1 | 0.4 | 2.8 | 2.9 |
| T-to-T (% growth) | | 4.4 | 5.2 | 2.0 | 0.4 | 3.7 | 3.6 |

**Notes:** This table shows summary statistics for the real house price cycles shown in Figure 1 for Norway and 14 Norwegian municipalities. To assess turning points, the following censoring rules are applied: window=2, phase=2, cycle=6. N=15. **Data sources:** Eiendomsverdi/Eiendom Norge, Statistics Norway.

Table 1 summarizes the number of peaks and troughs in each municipality, as well as the duration of the boom and bust phases and the complete cycle, between 2003-2021. Price developments in each phase, and over the cycle, are also shown.[2] We see that the average length of a bust varied between 3.7 quarters for Asker and 10.3 quarters for Stavanger. Booms varied between an average duration of 9 quarters in Bergen and Oslo and 16 quarters in Tromsø and Drammen. Price developments also varied between the municipalities, and we find that the average growth in real prices during a boom was 2.5 per cent in Bergen, while

[2] In Appendix B, summary statistics of peaks and troughs in 81 geographical areas in Norway is presented, illustrating the heterogeneity across an even larger set of areas.

it was 6.2 per cent in Oslo. For busts, the decline varied between 1 per cent in Lillestrøm and 2.3 per cent in Bodø.

# 3 A long-run model for regional prices

## 3.1 Methodological framework

A theoretical framework for modelling house prices that is commonly used in the literature, is based on the life-cycle model of housing and is often referred to as the inverted demand approach, (see for example Meen (1990) and Meen (1999)). In this framework, a representative agent maximizes life-time utility with respect to a housing good and other consumption goods. There also exists a rental sector and, in an efficient market, the rent equals the user cost of housing. Since the imputed rent is unobserved, we assume that it develops proportionally with income and the housing stock and use them as proxies for rental prices. In equilibrium, house prices will depend on the user cost of housing, household disposable income and housing supply.

As a point of departure for an empirical analysis of regional house prices in Norway, we follow Anundsen (2019) and use a semi-logarithmic specification.

$$ph = \beta_y y + \beta_h h + \beta_{UC} UC \tag{1}$$

In Equation 1, $ph$ is the logarithm of real house prices, $y$ is the logarithm of real disposable income, $h$ is the logarithm of the housing stock[3] and $UC$ is the user cost, which is defined as $UC = (1 - \theta)i - \pi + \delta - \Delta ph$, where $\theta$ is the tax rate for which interest rate expenses are deductible, $i$ denotes the nominal interest rate, $\pi$ inflation rate, $\delta$ depreciation rate and $\Delta ph$ expected house price growth. In the econometric analysis, the depreciation rate

[3]The housing stock and disposable income are usually measured relative to the population. Since we use a measure for disposable income relative to the housing stock in the econometric analysis, the population variable cancels out.

(which is assumed to be constant over time) is discarded and expected house price growth is assumed to be captured by lagged house prices which are included in the econometric model. According to theory, we would, *ex ante*, expect that $\beta_y > 0$ and $\beta_h, \beta_{UC} < 0$. Further, in the econometric specification, disposable income is measured relative to the housing stock, so that Equation (1) is re-written to Equation 2, in which $\tilde{Y} = Y/H$ or $\tilde{y} = y - h$ in logs. The reason for this choice is that we estimate the model over a relatively short time-period, which makes precise estimates of a large number of coefficients challenging. By combining the measure for disposable income and the housing stock, we reduce the number of coefficients that need to be estimated.

$$ph = \tilde{\beta}_{\tilde{y}}\tilde{y} + \tilde{\beta}_{UC}UC \tag{2}$$

In a well-specified fundamental value model of house prices, one should expect house prices to revert to equilibrium over time. An assumption for this to hold is that the linear combination of $ph - \tilde{\beta}_{\tilde{y}}\tilde{y} - \tilde{\beta}_{UC}UC$ is stationary, or that house prices cointegrate with the user cost and disposable income relative to the housing stock. We follow Anundsen (2019) and use the system-based test for cointegration developed by Johansen (1988), meaning that we test whether there exists an equilibrium relationship between the variables in Equation 2. Consider the following VAR(p) model:

$$\Delta\mathbf{x}_t = \Pi\mathbf{x}_{t-1} + \sum_{i=1}^{p-1}\Gamma_{\mathbf{x},i}\Delta\mathbf{x}_{t-i} + \Phi\mathbf{D}_t + \epsilon_t \tag{3}$$

The vector $\mathbf{x}_t$ consists of the endogenous variables $ph$, $UC$ and $\tilde{y}$. In $\mathbf{D}$, three centered seasonal dummies, a deterministic trend and a constant term is included. A lag length of $p = 5$ is used for all regions, a selection that is based on AIC. By assuming that there exists one cointegrating relationship between the variables in $\mathbf{x}_t$, an assumption that we test in the econometric analysis, the matrix $\mathbf{\Pi}$ will have rank one and has the following Vector Error Correction Model (VECM) representation:

$$\begin{pmatrix} \Delta ph_t \\ \Delta \tilde{y}_t \\ \Delta UC_t \end{pmatrix} = \begin{pmatrix} \alpha_{ph} \\ \alpha_{\tilde{y}} \\ \alpha_{UC} \end{pmatrix} (ph - \beta_{\tilde{y}}\tilde{y} - \beta_{UC}UC - \beta_T T)_{t-1} + \sum_{i=1}^{p-1} \Gamma_{\mathbf{x},i} \Delta \mathbf{x}_{t-i} + \tilde{\mathbf{\Phi}}\tilde{\mathbf{D}}_t + \epsilon_t \tag{4}$$

The $\alpha's$ are the adjustment parameters, indicating the speed at which the endogenous variables revert to equilibrium, while the $\beta's$ express the long-run relationships between the cointegrating variables. The cointegration vector is normalized with respect to house prices so that $\beta_{ph} = 1$ and the user cost is assumed to be weakly exogenous, so that $\alpha_{UC} = 0$, see Johansen (1992) for details. $\tilde{\mathbf{D}}_t$ only contains the constant and the seasonal dummies, since the deterministic trend term is restricted to enter the cointegration space.

After estimating the long-run coefficients $\hat{\beta}_{\tilde{y}}$ and $\hat{\beta}_{UC}$, a fundamental house price path, or an equilibrium path for house prices, $ph_t^*$ is constructed by Equation 5. $ph_t^*$ can be compared to actual house prices, $ph_t$, to investigate whether there exists a gap between the two ie, whether house prices are overvalued or undervalued. Given the existence of a cointegrating relationship and a well specified econometric model, actual prices are expected to revert to the model-implied path over time. A large and persistent gap signals imbalances, or a structural break in the underlying econometric model.

$$ph_t^* = ph_{t-1}^* + \hat{\beta}_{\tilde{y}}\Delta\tilde{y} + \hat{\beta}_{UC}\Delta UC \tag{5}$$

Ideally, we would estimate the model in an in-sample time-period, and estimate the equilibrium path out-of-sample. However, due to a relatively short time-period with quality data at the regional level, we have chosen to estimate the model from 2003q1-2019q4 and estimate the equilibrium path quasi out-of-sample, from 2014q1-2021q4. The equilibrium price is hence estimated on parts of this period, 2003Q1-2019Q4, which means there is overlap for the period 2014q1-2019q4. We assume that house prices are in equilibrium in 2014q1, so that $ph^*_{2014q1} = ph_{2014q1}$. The starting point for the equilibrium path is made with basis in an assessed neutral business cycle at this time, see for example Norges Bank (2015).

## 3.2 Data

We have access to data on house prices, disposable income, unemployment rates and number of dwellings at the municipality level, while mortgage rates, tax deduction rates for mortgages and the consumer price index, CPI, are on a national level. Table 2 gives an overview of the data.

**Table 2** Summary of data and sources. 2003-2021

| Variable | Geographic level | Frequency | Source |
|---|---|---|---|
| House prices | Municipality | Quarterly | Eiendom Norge |
| Disposable income | Municipality | Annual | microdata.no |
| Disposable income | National | Quarterly | Statistics Norway |
| Unemployment rate | Municipality | Quarterly | NAV |
| Dwellings | Municipality | Annual | Ambita |
| Building works completed | Municipality | Quarterly | Statistics Norway |
| Mortgage rates | National | Quarterly | Statistics Norway |
| Tax deduction | National | Annual | TNTA |
| Consumer price index | National | Quarterly | Statistics Norway |

**Notes:** This table shows an overview of the data used in the analysis. TNTA is The Norwegian Tax Administration. Nav is the Norwegian abbreviation for the Labour and Welfare Administration.

The house price indices are collected from Eiendom Norge. The price indices produced is a collaboration between Eiendom Norge, Eiendomsverdi and Finn.no. They are based on all transactions passed through the online advertisement platform Finn.no, which accounts for around 70 percent of all transactions. They produce price indices for 81 geographical areas in Norway, spanning from municipalities to more remote areas. The index for Norway is computed based on seven main regions covering the whole country, in which the total index for the country is computed using transaction-based weights from the last 24 months.

The indexes are computed using a version of the SPAR-method (Sales Price Appraisal Ratio).[4] The appraisal value they apply is based on an hedonic model and they compute a ratio between the predicted price from the hedonic model and the observed sales price. They use the median ratio to assess the price change since the last period. Lastly, to uncover the

[4]An explanation of the methodological approach that is used to compute the indices can also be found at www.eiendomnorge.no/about/category967.html.

underlying price growth they do a smoothing process over two steps. First, they compute a moving average for a smaller area. Second, they apply a non-adjusted series for a more aggregate area and estimate a ratio between the moving average in the smaller area and the un-smoothed index for the aggregate area. They use this ratio to adjust the moving average for potential over-smoothing in the fist step.

Data on disposable income are downloaded from Statistics Norway's platform microdata.no[5] and based on annual tax records at the individual- and household level. The tax records are combined with residential information, to construct a series at the municipality level. Quarterly growth rates of disposable income at the national level from National Accounts are used to interpolate the annual data to a quarterly frequency at the municipality level.

Data on total number of dwellings in each municipality per year is obtained from Ambita.[6] A quarterly series for dwellings is constructed by adding the quarterly share of new housing completions through the year. For this, the quarterly statistics on building works completed from Statistics Norway is used.

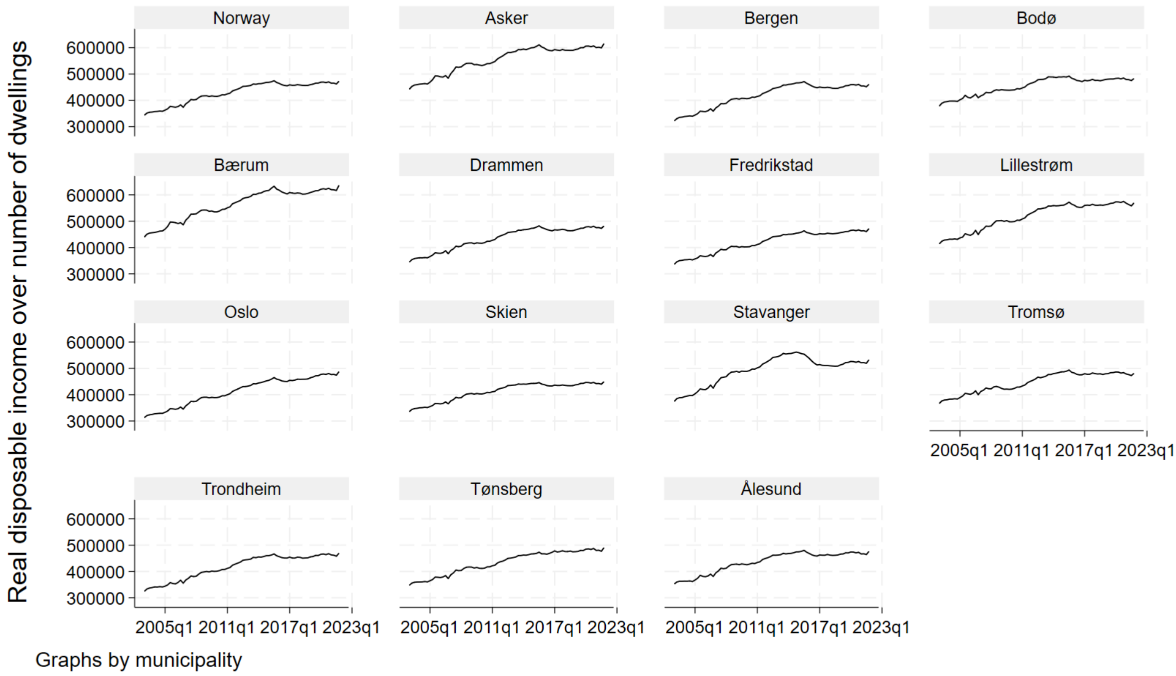
We create a series for real disposable income relative to the number of dwellings which is used in the fundamental value model for real house prices. This series is shown for each municipality in Figure 2. We can see that this variable, in general, increases somewhat over time, but that the upward trend has abated somewhat over time and there is some heterogeneity across municipalities. Stavanger is the only municipality in which we detect a substantial decline over the last years, while other municipalities have experienced a more flat trend.

Data on mortgage rates and the consumer price index are downloaded from Statistics Norway, while the unemployment rate is published by NAV (the Norwegian abbreviation for

[5]Microdata.no is an online platform serviced by Statistics Norway which provides instant, online access to large amounts of detailed and mergeable Norwegian microdata. The service is open to employees and students at universities and colleges, approved research institutions, ministries and directorates. Link: https://www.microdata.no/en/

[6]Ambita is a technology firm, which services a database from The Land Registry, which has information on all properties and housing cooperatives in Norway. Link: https://www.ambita.com/

**Figure 2** Real disposable income over number of dwellings




**Notes**: This figure shows a quarterly series for real disposable income in NOK relative to the housing stock in each municipality from 2003q1-2021q4. **Data sources**: Statistics Norway and Ambita.

the Labour and Welfare Administration) and tax deduction from TNTA (The Norwegian Tax Administration).

### 3.3 Results cointegrated VAR-model

The cointegrated VAR-model, as presented in Equation 4, is estimated using both national aggregate data and data for the 14 municipalities. The main estimation period is 2003q1-2019q4. The Jarque-Bera test indicates that residuals are normally distributed in all regions and we find little evidence of auto-correlation. The AIC (Akaike information criterion) indicates an optimal lag-length of five quarters for Norway as a whole and all municipalities, except Oslo, in which it indicates two. We use five lags for all areas in the main estimation. The trace test for cointegration, see Johansen (1988), indicates one cointegrating relationship in Norway as a whole and in eight municipalities, while it indicates two cointegrating relationships in six municipalities. The results from the trace test are reported in Appendix C. We continue under the modelling assumption of one cointegrating relationship in all municipalities in the main estimation, to be able to construct one equilibrium path for real house prices. This is also consistent with the underlying theoretical model. In addition, the restriction of weak exogeneity of the user cost ($\alpha_{UC} = 0$) is imposed.

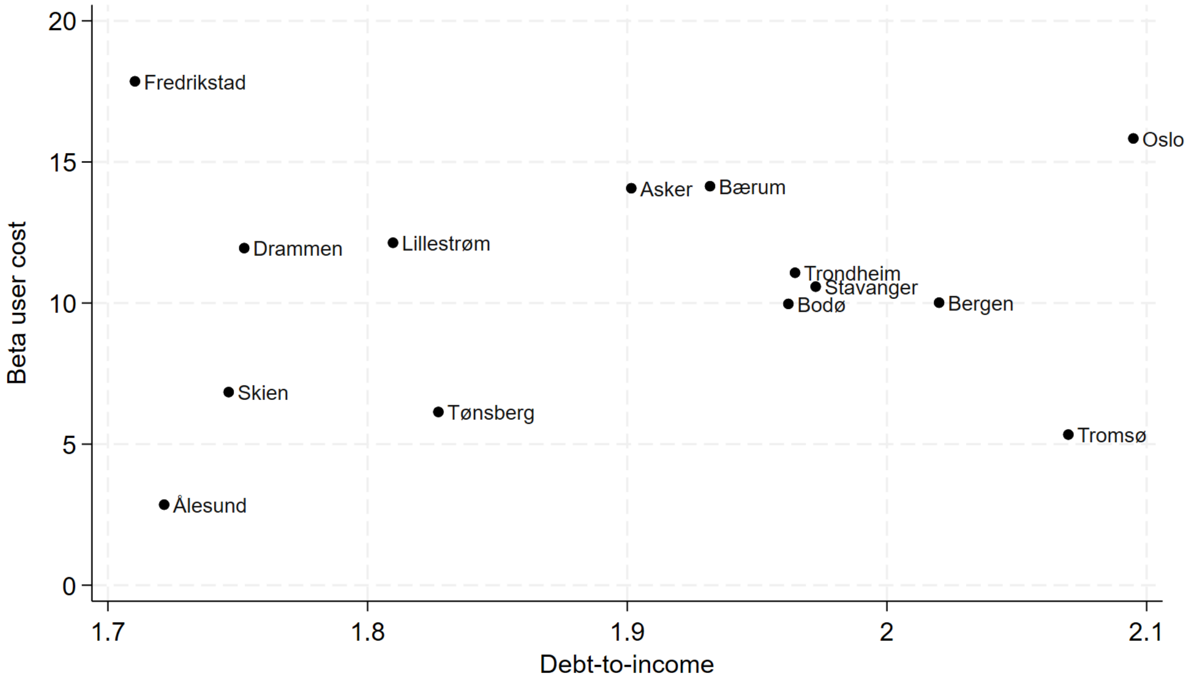
Table 3 shows the long-run coefficients for the real direct user cost and real disposable income per housing unit from the CVAR-analysis for Norway as a whole and for the 14 municipalities separately. Also, the estimated adjustment parameter, $\hat{\alpha}_{ph}$, of real house prices and the p-value from the likelihood ratio test for over identifying restrictions is displayed in the table. The test does not reject the null hypothesis that the restrictions imposed are valid for 11 out of the 14 municipalities, as well as for the national model. We see that the coefficients on the user cost are all negative. There is, however, substantial heterogeneity in the size of the coefficient across space, as well as the precision of the estimates. For Norway as a whole, the results indicate that a 1 percentage point increase in the real user cost is associated with a long-run decline in real house prices of approximately 10 percent. This

**Table 3** Results long-run coefficients from cointegrated VAR analysis of house prices

| Variable | Oslo | Stavanger[1] | Bergen | Trondheim | Tromsø |
|---|---|---|---|---|---|
| User Cost | -15.833*** | -10.581* | -10.014*** | -11.073*** | -5.338*** |
| Disposable income/Housing stock | 1.469*** | 2.059 | 1.378*** | 1.484*** | 1.494*** |
| Adjustment parameter | -0.098*** | -0.009 | -0.154*** | -0.097*** | -0.137*** |
| P-value O.R. | 0.231 | 0.000 | 0.104 | 0.070 | 0.268 |
| Variable | Bærum | Asker | Drammen | Lillestrøm | Fredrikstad |
| User Cost | -14.141*** | -14.068*** | -6.225* | -12.136*** | -17.858*** |
| Disposable income/Housing stock | 1.469*** | 1.592*** | 1.916*** | 1.712*** | 1.139*** |
| Adjustment parameter | -0.067*** | -0.067** | -0.111*** | -0.083*** | -0.047** |
| P-value O.R. | 0.428 | 0.427 | 0.014 | 0.073 | 0.044 |
| Variable | Ålesund | Bodø | Skien | Tønsberg | Norway |
| User Cost | -2.854*** | -9.970* | -6.844*** | -6.139*** | -9.895*** |
| Disposable income/Housing stock | 1.53*** | 1.910 | 1.842*** | 1.272*** | 1.618*** |
| Adjustment parameter | -0.207*** | -0.134*** | -0.088** | -0.116** | -0.106*** |
| P-value O.R. | 0.140 | 0.457 | 0.888 | 0.393 | 0.489 |

**Notes:** This table reports the long-run coefficients ($\beta$) in Equation 4. The estimation period is 2003q1-2019q4. The dependent variable is real house prices (nominal house prices deflated by cpi), the real user cost is measured as the nominal, tax-adjusted, mortgage rate subtracted cpi, real disposable income is disposable income deflated by cpi and measured relative to housing supply. [1] In the estimation for Stavanger, a quarterly series for oil investments is included for establishment of a cointegrating relationship, meaning Equation 2 is substituted with $ph = \beta_{\tilde{y}}\tilde{y} + \beta_{UC}UC + \beta_{o}oil$ for Stavanger. *p<0.1; **p<0.05; ***p<0.01.

**Figure 3** Debt-to-income and the long-run coefficient for the real user cost, $\hat{\beta}_{UC}$ (2003-2019)




**Notes**: This figure shows the long-run coefficient from the CVAR for the user cost of housing, $\hat{\beta}_{UC}$, and the mean debt-to-income (DTI) over the period of estimation (2003-2019) for each municipality. **Data sources**: Microdata/Statistics Norway

result corroborates the findings of Anundsen (2019), which found that a 1 percentage point increase in real user cost is associated with a long-run decline in real house prices of 13.8 percent. For the capital, Oslo, the effect is larger than for the country as a whole. An increase in the real user cost of 1 percentage point indicates a decline in real house prices of approximately 16 percent.

In Figure 3, the long-run coefficients for the real direct user cost, $\hat{\beta}_{UC}$, for each municipality are plotted together with average debt-to-income (DTI) per household in each municipality over the estimation period. House price sensitivity to the user cost seems to be positively associated with DTI. This is in line with the recent literature on cash-flow effects amplifying the effect from the user cost.[7] There are, however, also some outliers, such as the

[7] Almgren et al. (2022), Cloyne et al. (2020) and Holm et al. (2021).

municipalities Fredrikstad and Tromsø.

An increase in disposable income per housing unit of 1 per cent implies an increase in real house prices of about 1.6 per cent in Norway as a whole. The heterogeneity at the municipality level is less visible than for the real user cost. On municipality level, the coefficient for disposable income over housing stock varies between 1.1 in Fredrikstad and 2.1 in Stavanger. However, there is also heterogeneity in the disposable income over households across the municipalities over time as shown in Figure 2, which means it is still important for heterogeneity in the house price cycles across regions.

The adjustment parameters for real house prices are negative in all regions, indicating that when real house prices are not in equilibrium as defined by this model, they will revert to equilibrium over time. This is additional evidence of cointegration, since the Engle and Granger (1987) representation theorem says that cointegration implies equilibrium correction, and vice versa. The adjustments parameters vary between - 0.21 in Ålesund to -0.05 in Fredrikstad[8]. This implies that actual prices will revert back to equilibrium in 5 quarters in Ålesund and 5 years (20 quarters) in Fredrikstad.

### 3.4 Equilibrium paths for real house prices

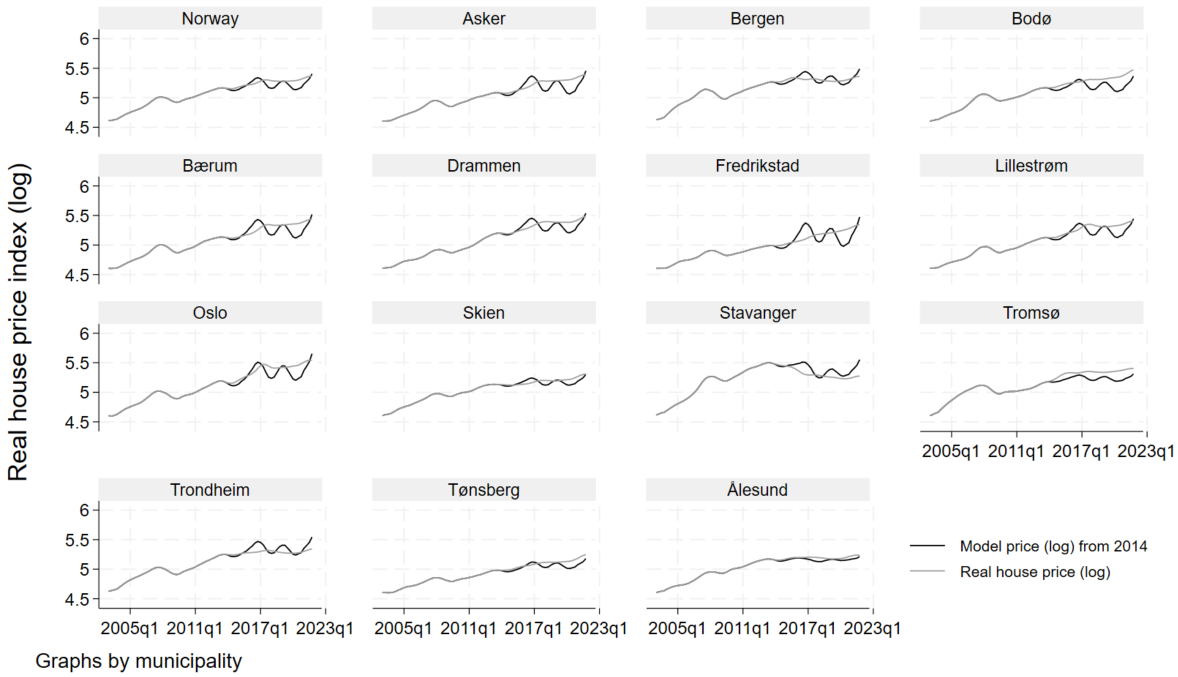
Based on the results from the cointegration analysis and Equation 5, an equilibrium path for real house prices can be constructed for each municipality. This path is shown in Figure 4, for Norway and the 14 municipalities. The equilibrium path is constructed from 2014q1-2021q4, which is quasi out-of-sample, and with the assumption that real house prices were in equilibrium in 2014q1. This assumption seems to fit reasonably well with the output gap published by Norges Bank, which was estimated to be close to zero at this point in time, Norges Bank (2015).

Figure 4 shows smoothed actual real house prices for the full sample period and the equilibrium price path constructed from 2014q1-2021q4[9]. The equilibrium path fluctuates around

[8]The adjustment parameter is reported to be -0.01 in Stavanger. However, this is not statistically significant.

[9]Both series are smoothed with a four-quarter moving average.

**Figure 4** Equilibrium paths for real house prices (2014-2021) vs. actual real house prices (2003-2021)




**Notes**: This figure shows the equilibrium path for real house prices (blue line) from 2014q1-2021q4, when applying the long-run coefficients from the VEC- model, presented in Table 3, and actual real house prices (red line) for the full sample period, 2003q1-2021q4. Both series are smoothed with four-quarter moving averages. House prices are assumed to be in equilibrium in 2014q1 and after that the equilibrium path for real house price is constructed using Equation 5: $ph_t^* = ph_{t-1}^* + \hat{\beta y}\Delta\tilde{y} + \hat{\beta_{UC}}\Delta UC$. For Stavanger the equilibrium path is constructed including the parameter for oil investments:
$ph_t^* = ph_{t-1}^* + \hat{\beta}_{\tilde{y}}\Delta\tilde{y} + \hat{\beta}_{UC}\Delta UC + \hat{\beta}_o\Delta oil$. **Data sources**: Eiendomsverdi/Eiendom Norge, Statistics Norway.

actual prices in most areas, which indicates that actual prices have been well in line with fundamentals over this period, although sometimes above (overvalued) and sometimes below (undervalued). At the end of the period (2021q4), house prices are in line with fundamentals in most of the municipalities and the country as a whole. In some areas, like Stavanger and Trondheim, equilibrium prices are mostly above actual prices, which is indication of undervalued house prices, while in others, such as Bodø, Tromsø and Tønsberg, equilibrium prices are mostly below actual prices, which is a sign of overvalued prices according to this model and the development in the fundamentals.

There is a sharp increase in the model-implied price towards the end of the period in most areas. This is related to an increase in disposable income in 2021, as well as a sharp decrease in the mortgage rate in 2020. Both drivers are related to the Covid-19 pandemic. One could argue that this period was special in a historical context and that this might have led to a break in the cointegrating relationship at this point, making the end point of the figures challenging to interpret. Nevertheless, it is interesting to see that over the two periods when actual real house prices increased rapidly, 2016 and 2020, the model implied even higher fundamental real house prices due to the strong effect that the mortgage rate exercise on fundamental house prices.

Table 4 shows summary statistics for the real house price gap; the difference between actual house prices and the predicted equilibrium house prices from the VEC-model, at the national level and for each municipality, calculated from 2014q1 to 2021q4. At the national level, the mean value of this gap is 4 percent, which means that, on average, actual real house prices have been above fundamental prices, hence house prices have been overvalued on average. However, the house price gap has varied between almost 16 per cent overvaluation and 8 per cent undervaluation over this period. The largest overvaluation among the municipalities was in Fredrikstad (27 percent) in the second quarter of 2020, while the largest undervaluation was in Stavanger (-28 percent) in the fourth quarter of 2021.

**Table 4** Summary real house price gap in percent, 2014-2021

| Variable | Oslo | Stavanger | Bergen | Trondheim | Tromsø |
|---|---|---|---|---|---|
| Minimum | -11.69 | -27.70 | -13.70 | -20.27 | 0.83 |
| Mean | 5.94 | -7.82 | -0.87 | -4.74 | 10.05 |
| Maximum | 24.42 | 4.22 | 7.05 | 4.32 | 17.36 |
| Standard deviation | 10.21 | 8.05 | 6.40 | 7.26 | 4.51 |
| Variable | Bærum | Asker | Drammen | Lillestrøm | Fredrikstad |
| Minimum | -17.53 | -16.00 | -14.04 | -9.95 | -27.19 |
| Mean | 3.83 | 4.96 | 3.21 | 5.51 | 1.63 |
| Maximum | 24.04 | 24.19 | 17.77 | 20.31 | 27.21 |
| Standard deviation | 11.53 | 10.92 | 9.19 | 8.49 | 14.08 |
| Variable | Ålesund | Bodø | Skien | Tønsberg | Norway |
| Minimum | 0.41 | -4.48 | -8.20 | -4.79 | -8.22 |
| Mean | 3.10 | 9.78 | 1.81 | 4.57 | 4.27 |
| Maximum | 6.92 | 24.30 | 9.93 | 12.54 | 15.57 |
| Standard deviation | 1.99 | 8.20 | 5.31 | 4.95 | 6.73 |

**Notes:** This table shows minimum, mean, maximum and standard deviation of the real house price gap; the difference between actual house prices and the predicted equilibrium house prices from the VEC-model, in per cent for each municipality.

# 4 From boom to bust: Predicting turning points

## 4.1 Methodological framework

We test if the gap between actual prices and equilibrium prices have predictive power on turning points in real house prices. We pool the data from the 14 municipalities in our sample to a panel. The specification is shown in Equation 6, in which the variables vary over time, $t$, and with municipality, $m$.

$$peak_{m,t} = \alpha^p_m + \beta^p(ph_{m,t} - ph^*_{m,t}) + \mu^p \mathbf{X}_{m,t} + \epsilon^p_{m,t} \tag{6}$$

The dependent variable, $peak_{mt}$, is a dummy-variable equal to 1 when there is a peak in real house prices, and 0 otherwise. The explanatory variable $ph_{m,t} - ph^*_{m,t}$ is the real house price gap; approximately the percentage difference[10] between actual house prices and the equilibrium house price path predicted by the VEC-model, as specified in Equation 5. We include municipality fixed effects, $\alpha^p_m$ in all estimations. $\mathbf{X}_{m,t}$ is a vector of municipality specific control variables that vary over time. These control variables are the duration of the house price gap and the registered unemployment rate, which serves as a proxy for the local business cycle, as well as polynomials of the price gap to capture potential non-linearities.

The coefficient of main interest is $\beta^p$, which measures the increase in the probability of a peak when the real house price gap increases by 1 percentage point. The expected sign of the coefficient $\beta^p$ is positive, as one would expect that an increase in the real house price gap increases the probability of turning from a boom to a bust.

## 4.2 Results panel regression: Quasi out-of-sample

We start with the quasi out-of-sample estimation based on the VEC-model from Section 3, which we estimated on the sample 2003q1-2019q4. The predicted equilibrium house price

[10] Log point difference.

**Table 5** Results panel regression quasi out-of-sample

| | Peak | | | | Trough | | | |
|---|---|---|---|---|---|---|---|---|
| Model | LPM | LPM 2 | LPM 3 | 4.Poly. | LPM | LPM 2 | LPM 3 | 4.Poly. |
| Price-gap | 0.002*** | 0.004** | 0.005*** | 0.007*** | 0.000 | 0.000 | 0.001 | 0.002 |
| Duration gap | | -0.007*** | -0.006** | -0.007** | | 0.002 | 0.003 | 0.005 |
| Unemployment rate | | | -0.025*** | -0.021** | | | -0.006 | -0.004 |
| $Pricegap^2$ | | | | 0.000 | | | | -0.000 |
| $Pricegap^3$ | | | | -0.000*** | | | | -0.000 |
| $Pricegap^4$ | | | | -0.000 | | | | 0.000 |
| Municipality fixed effects | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations | 448 | 301 | 277 | 277 | 448 | 448 | 416 | 416 |
| Municipalities | 14 | 12 | 11 | 11 | 14 | 14 | 13 | 13 |

**Notes:** The table reports estimates of $\beta$; how the probability of a turning point is affected by an increase in the house-price-gap, see Equation 6 and Equation 7: $peak_{m,t} = \alpha_m + \beta(ph_{m,t} - ph^*_{m,t}) + \mu\mathbf{X}_{m,t} + \epsilon_{m,t}$. $\beta$ is estimated by OLS with municipality-fixed effects. The estimation period is 2014q1-2021q4 and 14 municipalities are included. $^*$p<0.1; $^{**}$p<0.05; $^{***}$p<0.01.

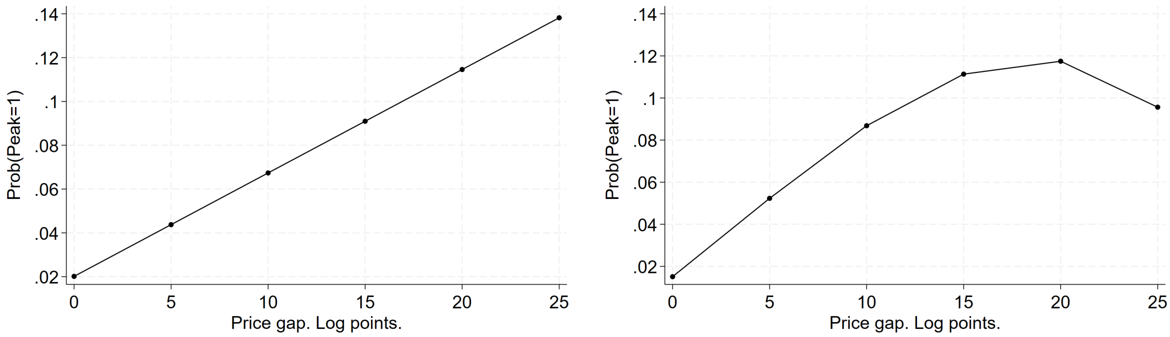
path was constructed from 2014q1-2021q4, which overlaps parts of the estimation period. The quasi out-of-sample panel-regression is estimated on quarterly data from 2014q1-2021q4 for 14 municipalities, leaving us with 448 observations.

In the first four columns of Table 5, results from the estimation of $\beta^p$ in Equation 6 are reported. Since we use a specification with municipality fixed effects, we choose to use a linear probability model, due to the strict assumptions and inability to report partial effects in the logit model with fixed effects, see Wooldridge (2010).[11] The first column shows results on the probability of a peak dependent on the price gap. We find that an increase in the price gap of 1 percentage point, indicates an increase in the probability of 0.22 percentage points. We also test whether the duration of the price gap has an effect on the probability of a peak and we include registered unemployment at the municipality level, as a proxy for the local business cycle (column 2 and 3). The effect of the price gap becomes even

[11] Log odds ratios from a logit estimation with fixed effects are however included in Appendix D, giving coefficients with the same sign and significance as in the linear model reported here.

larger and statistical significance is maintained when adding control variables. In the linear model, the effect increases to 0.47 percentage points when control variables are included in the regression. In the fourth column, we add a fourth degree polynomial of the price gap to the model to be able to assess non-linearity within the linear probability model framework.

**Figure 5** Predicted probability of peak and the real price gap




**(a)** Linear **(b)** Polynomial

**Notes**: This figure shows the predicted probability of a peak from the linear probability estimation of Equation 6: $peak_{m,t} = \alpha^p_m + \beta^p(ph_{m,t} - ph^*_{m,t}) + \mu^p \mathbf{X}_{m,t} + \epsilon^p_{m,t}$ with predictions made quasi out-of-sample. The left chart shows the linear model with control variables, as shown in Column 3 of Table 5, while the right chart shows the fourth degree polynomial, as shown in Column 4 of Table 5.

Figure 5 illustrates the predicted probability of a peak from the linear probability model for different levels of the real house price gap. In panel a, the linear model with control variables, as shown in Column 3 in Table 5 is depicted. When the price gap increases from 0 to 15 percent, the probability of a peak increases by 7 percentage points to 9 percent. Panel b shows the results reported in Column 4, with a fourth degree polynomial of the house price gap is included in the estimation. The results are similar to the ones from the linear model and the probability of a peak increases by 9 percentage points to 11 percent when the price gap increases from 0 to 15 percent. In the latter model, the effect is largest for small values of the price gap and diminishes when the price gap becomes very large. One could, instead, have expected that the effect of the house price gap was increasing in the size of the gap, since highly overvalued prices could be associated with a high probability of a turning point and a downturn in prices. However, the diminishing effect might indicate that a very large price gap is caused by factors outside the model, or a structural break.

One can also investigate the effect of an increase in the house price gap on the probability of a through, see Equation 7. In this case, the expected sign of $\beta^t$ is negative.

$$trough_{m,t} = \alpha_m^t + \beta_(^t ph_{m,t} - ph_{m,t}^*) + \mu^t \mathbf{X}_{m,t} + \epsilon_{m,t}^t \tag{7}$$

The results from this estimation are provided in Column 5-8 in Table 5. We see that the house price gap does not have a significant impact on the probability of a trough and the sign is, somewhat surprising, positive. Our results indicate that a higher house price gap (more overvalued prices) increases the probability of a peak (and an ensuing downturn), while it does not decrease the probability of a trough (and an ensuing upturn).

### 4.3 Results panel regression: Out-of-sample

For the price gap to be applicable as a predictor of turning points in house prices, it should also have an effect out-of-sample. Due to the limited time period with quality data at the municipality level, it is challenging to establish a cointegrating relationship using a shorter time period than 2003q1-2019q4. As a sensitivity check, we perform an out-of-sample exercise, in which we estimate equilibrium prices between 2014q1 and 2021q4, based on a VEC-model estimated from 2003q1-2013q4. The VEC-estimation from 2003q1-2013q4 provides long-run coefficients with the same sign as in the baseline estimation, but with slightly lower coefficients for the real user cost. The adjustment parameters are all negative and significant, which is reassuring for the assumption of cointegration. The long-run coefficients and adjustment parameters are reported in Appendix E.

The panel regression is performed on quarterly data from 2014q1-2021q4 for the same 14 municipalities, again leaving us with 448 observations. The results are provided in Table 6. The results indicate an even larger effect on the probability of a peak (see Column 1-3) when predictions are made out-of-sample. Without control variables, the effect of an increase in the price gap of 1 percentage point is estimated to 0.3 percentage points, while the effect is

**Table 6** Results panel regression: Out-of-sample

| | Peak | | | | Trough | | | |
|---|---|---|---|---|---|---|---|---|
| Model | LPM | LPM 2 | LPM 3 | 4.Poly. | LPM | LPM 2 | LPM 3 | 4.Poly. |
| Price-gap | 0.003*** | 0.007*** | 0.007** | 0.006** | -0.002** | -0.002** | -0.002 | -0.004 |
| Duration gap | | -0.006*** | -0.005*** | -0.006** | | 0.001 | 0.001 | 0.000 |
| Unemployment rate | | | -0.015** | -0.017*** | | | -0.000 | -0.002 |
| $Pricegap^2$ | | | | 0.000 | | | | 0.000 |
| $Pricegap^3$ | | | | -0.000 | | | | 0.000 |
| $Pricegap^4$ | | | | -0.000 | | | | -0.000 |
| Municipality fixed effects | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations | 448 | 448 | 416 | 416 | 448 | 448 | 416 | 416 |
| Municipalities | 14 | 14 | 13 | 13 | 14 | 14 | 13 | 13 |

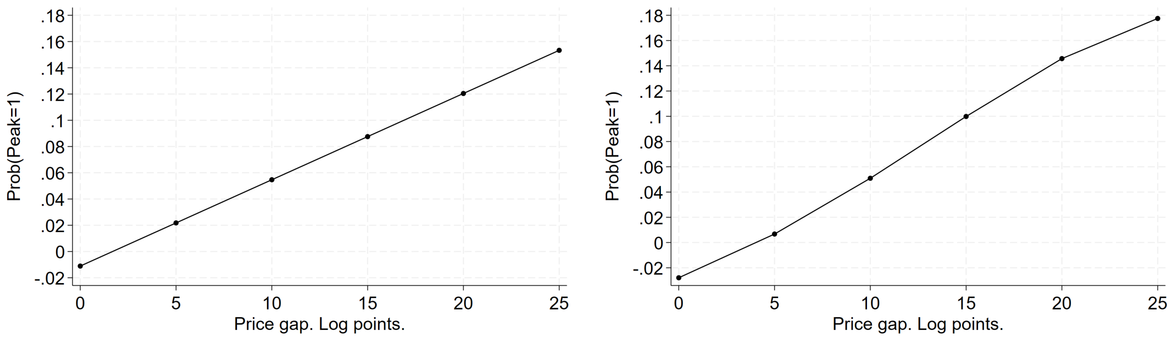
**Notes:** The table reports estimates of $\beta$; how the probability of a turning point is affected by an increase in the house-price-gap, see Equation 6 and Equation 7: $peak_{m,t} = \alpha_m + \beta(ph_{m,t} - ph^*_{m,t}) + \mu\mathbf{X}_{m,t} + \epsilon_{m,t}$. $\beta$ is estimated by OLS with municipality-fixed effects. The estimation period is 2014q1-2021q4 and 14 municipalities are included. $^*$p<0.1; $^{**}$p<0.05; $^{***}$p<0.01.

estimated to 0.7 percentage points when control variables are included. The out-of-sample exercise therefore increases our confidence in the model as a useful tool for predicting house price peaks.

In the out-of-sample exercise, the house price gap also has a statistically significant effect on the probability of a trough, in contrast to the ”quasi-out-of-sample” results. However, the effect is no longer significant when control variables are added to the model.

Once again, we illustrate the magnitude of the effect for different magnitudes of the house-price-gap, see Figure 6. We recognize that the size of the effect is slightly larger than in the previous subsection, and we see that the polynomials of the price gap are slightly less important. In summary, we see that when the price gap is around 15 percent, the predicted probability of a peak - and a ensuing downturn in prices, is around 10 percent in all estimations.

**Figure 6** Predicted probability of peak and the real price gap




**(a)** Linear

**(b)** Polynomial

**Notes**: This figure shows the predicted probability of a peak from the linear probability estimation of Equation 6: $peak_{m,t} = \alpha_m^p + \beta^p(ph_{m,t} - ph_{m,t}^*) + \mu^p \mathbf{X}_{m,t} + \epsilon_{m,t}^p$ with predictions made out-of-sample. The left chart shows the linear model with control variables, as shown in Column 3 of Table 6, while the right chart shows the fourth degree polynomial, as shown in Column 4 of Table 6.

# 5 Conclusion

House price cycles are closely related to real business cycles. High and persistent growth in house prices and credit can amplify economic downturns. In addition, house prices are closely linked to housing investments, which has been shown to act as a leading indicator for economic downturns. Further, house price cycles are regional. In this paper, we seek to increase our understanding of house price cycles at the regional level, by describing and explaining the fundamental drivers of these cycles. We also apply our model and the real house price gap as a tool in assessing the probability of a turning point in house prices.

We document the timing and duration of booms and busts in real house prices for Norway as a whole, and for 14 of the largest municipalities, between 2003 and 2021. We find that although house price cycles are similar across municipalities in many instances, there is also considerable heterogeneity in the timing and duration, as well as the amplitude, of booms and busts in real house prices across these areas.

Further, we use a CVAR-model to establish a long-run relationship between real house prices and fundamental drivers, defined as real disposable income, the housing stock and the real user cost of housing, at the municipality level. By this, we seek to explain the drivers of local house price cycles. We find that the effect of the user cost on real house prices varies across the municipalities, with the strongest effect found in the capital, Oslo. We find that the effect is larger in areas with high debt-to-income ratios. The effect of disposable income relative to the housing stock is more similar across municipalities with an elasticity of between 1 and 2.

Finally, the fundamental house price path from the CVAR-model is applied to investigate whether the real house price gap; the difference between actual and fundamental prices, as implied from the model, can help predict turning points in house prices. We find that an increase in the house price gap from 0 to 15 percent increases the probability of a peak (a downturn) by about 7 percentage points to 9 percent. The effect is statistically significant and of a similar size both when fundamental prices are calculated quasi and completely out-of-sample.

This paper finds that the housing cycle and its fundamental drivers varies across Norwegian municipalities. A framework for analysing house price cycles at the regional level can thus be a useful supplement to national house price models. Although monetary- and macroprudential policy makers are mainly concerned with the national cycle, regional models increase the understanding of heterogeneous regional cycles.

Further analysis of regional heterogeneity in house price cycles in other countries would shed more light on the importance of the regional component of house price cycles more generally. Future research on this topic could also benefit from longer time-series, which could allow for a more in depth out-of-sample analysis, as well as a more fine-tuned estimation of long-run coefficients, for example separate coefficients for disposable income and the housing stock.

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# Appendix A: Overview of changes in municipalities

**Table A.1** Overview changes in municipalities

| Municipality | Year | Merged with |
|---:|---:|---:|
| Oslo | | |
| Bergen | | |
| Trondheim | 2020 | Klæbu |
| Stavanger | 2020 | Finnøy, Rennesøy |
| Bærum | | |
| Drammen | 2020 | Nedre Eiker, Svelvik |
| Asker | 2020 | Røyken, Hurum |
| Lillestrøm | 2020 (established) | Sørum, Fet, Skedsmo |
| Fredrikstad | | |
| Tromsø | | |
| Ålesund | 2020 | Ørskog, Skodje, Haram, Sandøy |
| Tønsberg | 2020 | Re |
| Skien | | |
| Bodø | | |

The 14 municipalities include the most populated areas in Norway in which most of the housing transactions take place. Some of the municipalities have merged over the period analyzed. Data for these municipalities are merged over the complete sample to avoid any breaks in the series. See details in Table A.1.

## Appendix B: Summary statistics, peaks and troughs

**Table B.1.** Summary statistics. Peaks and troughs. Norway.

| | p10 | p25 | p50 | p75 | p90 |
|---|---|---|---|---|---|
| No. peaks | 2 | 3 | 3 | 3 | 4 |
| No. troughs | 2 | 3 | 3 | 3 | 4 |
| Bust (qtrs.) | 3.5 | 4.0 | 5.0 | 6.0 | 7.3 |
| Boom (qtrs.) | 7.5 | 9.0 | 14.5 | 16.0 | 18.0 |
| P-to-P (qtrs.) | 12.3 | 15.0 | 19.0 | 20.0 | 23.0 |
| T-to-T (qtrs.) | 13.0 | 14.7 | 19.5 | 21.5 | 24.0 |
| Bust (% growth) | -1.4 | -1.0 | -0.8 | -0.6 | -0.5 |
| Boom (% growth) | 1.4 | 2.0 | 3.0 | 4.6 | 6.0 |
| P-to-P (% growth) | 0.3 | 1.1 | 2.2 | 3.7 | 4.7 |
| T-to-T (% growth) | 0.4 | 1.2 | 2.7 | 4.2 | 5.1 |

**Notes:** This table shows summary statistics for real house price cycles for 81 Norwegian regions. To assess turning points, the following censoring rules are applied: window=2, phase=2, cycle=6. N=81. **Data sources**: Eiendomsverdi/Eiendom Norge, Statistics Norway.

Table B.1 shows summary statistics for peaks and troughs in real house prices for all areas in Norway in which price indices are calculated by Eiendom Norge, a total of 81 areas. These areas include municipalities and larger geographical, but less densely populated, districts. We see that the number of peaks and troughs vary between 2 for the 10 percent of areas with lowest number of peaks and troughs, to 4 for the areas with 90 percent highest number of peaks and troughs. The duration of booms varies between 8 and 18 quarters, while the same figures for busts are 4 and 7. There is also heterogeneity in the price development over the phases, in which busts involve a decline in real prices of 0.5 to 1.4 per cent for the first and last decile, respectively. For booms, real prices increase between 1.4 and 6 per cent for the first and tenth decile, respectively.

# Appendix C: Results from trace test

**Table C.1.** Results trace test

| Trace stat. | Oslo | Stavanger' | Bergen | Trondheim | Tromsø | Crit.value |
|---|---|---|---|---|---|---|
| 0 | 39.32 | 80.75 | 53.94 | 52.15 | 46.88 | 34.55 |
| 1 | 12.56* | 33.90* | 18.44 | 17.72* | 23.38 | 18.17 |
| 2 | 0.94 | 15.23 | 0.71* | 0.18 | 2.64* | 3.74 |
| Trace stat. | Bærum | Asker | Drammen | Lillestrøm | Fredrikstad | Crit.value |
| 0 | 49.43 | 49.57 | 41.30 | 43.05 | 42.07 | 34.55 |
| 1 | 22.46 | 18.31 | 14.11* | 12.57* | 19.32 | 18.17 |
| 2 | 0.35* | 0.35* | 1.14 | 0.95 | 0.22* | 3.74 |
| Trace stat. | Ålesund | Bodø | Skien | Tønsberg | Norway | Crit.value |
| 0 | 50.69 | 60.75 | 55.97 | 39.63 | 47.560 | 34.55 |
| 1 | 15.89* | 17.18* | 21.57 | 13.13* | 17.87* | 18.17 |
| 2 | 0.20 | 1.13 | 0.96* | 0.31 | 0.24 | 3.74 |

**Notes:** This table reports the trace statistic from the cointegration test of Johansen (1988). The estimation period is 2003q1-2019q4. *Indicates test statistic below critical value and thereby the number of cointegrating relationships reported from the test. 'In the estimation for Stavanger, a series for oil investments is included in the model and the critical values are 54.64, 34.55 and 18.17.

# Appendix D: Panel regression: Logit-estimation

**Table D.1.** Results panel regression quasi out-of-sample. Logit estimation

| | Peak | | | Trough | | |
|---|---|---|---|---|---|---|
| Model | Logit | Logit 2 | Logit 3 | Logit | Logit 2 | Logit 3 |
| Price gap | 0.108** | 0.313*** | 0.315** | 0.002 | 0.009 | 0.028 |
| Duration gap | | -1.154** | -1.013* | | 0.040 | 0.069 |
| Unemployment rate | | | -0.970 | | | -0.118 |
| Municipality fixed effects | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations | 352 | 231 | 207 | 352 | 352 | 320 |
| Municipalities | 11 | 9 | 8 | 11 | 11 | 10 |

**Notes:** This table reports estimates of $\beta$ in Equation 6 and Equation 7. The estimation period is 2014q1-2021q4 and 14 municipalities are included. *p<0.1; **p<0.05; ***p<0.01.

# Appendix E: VECM 2003q1-2013q4

**Table E.1.** Results long-run coefficients from cointegrated VAR analysis of house prices

| Variable | Oslo | Stavanger | Bergen | Trondheim | Tromsø |
|---|---|---|---|---|---|
| User Cost | -6.555*** | -8.802*** | -10.682*** | -8.244*** | -2.476 |
| Disposable income/housing stockk | 1.362*** | 2.139*** | 1.378*** | 1.334*** | 1.232*** |
| Adjustment parameter | -0.228*** | -0.152*** | -0.164*** | -0.131*** | -0.116*** |
| Variable | Bærum | Asker | Drammen | Lillestrøm | Fredrikstad |
| User Cost | -5.494** | -4.036*** | -6.225* | -4.357** | -4.096** |
| Disposable income/housing stock | 1.613*** | 1.627*** | 1.916*** | 1.561*** | 1.047*** |
| Adjustment parameter | -0.149*** | -0.213*** | -0.111** | -0.202*** | -0.166*** |
| Variable | Ålesund | Bodø | Skien | Tønsberg | Norway |
| User Cost | -3.567*** | -13.199*** | -4.624*** | -2.781** | -5.646*** |
| Disposable income/housing stock | 1.892*** | 1.827*** | 1.778*** | 1.223*** | 1.618*** |
| Adjustment parameter | -0.200*** | -0.120*** | -0.181*** | -0.273*** | -0.185*** |

**Notes:** This table reports the long-run coefficients ($\beta$) in Equation (4). The estimation period is 2003q1-2013q4. The dependent variable is real house prices (nominal house prices deflated by cpi), the real user cost is measured as the nominal, tax-adjusted, mortgage rate subtracted cpi, real disposable income is disposable income deflated by cpi and measured relative to housing supply. *p<0.1; **p<0.05; ***p<0.01.

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**Authors:**
Nini Barth, Housing Lab, Oslo Metropolitan University, Norway;
email: *ninibart@oslomet.no*

Jeanette Fjære-Lindkjenn, Housing Lab, Oslo Metropolitan University, Norway;
email: *jeasf@oslomet.no*

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