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Nordic house price bubbles?

André K. Anundsen

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André K. Anundsen†

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Abstract

This article estimates fundamental house prices for Denmark, Finland, Norway, and Sweden over the past 20 years. Fundamental house prices are determined by per capita income, the housing stock per capita, and the real after-tax interest rate. The trajectory of fundamental prices are compared to actual house price developments for the period 2000q1–2019q4. My results suggest that house prices were overvalued in all countries in the years preceding the global financial crisis, but that prices quickly returned to equilibrium following the ensuing housing market bust. Results suggest that house prices were undervalued in Denmark and Finland towards the end of 2019, and that they were overvalued in Norway and Sweden. There are no signs of explosive house price developments in Finland, Norway, or Sweden over the sample period. There are, however, signs of explosive house price dynamics in Denmark before the crash in 2007. My results suggest that interest rate changes have a major impact on fundamental house prices in all countries, and that interest rate developments have been important drivers of fundamental house prices over the past 10 years.

Keywords: *Cointegration; Explosive Roots; Housing Bubbles.*

JEL classification: *C22; C32; C51; C52; C53; G01; R21*

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†Housing Lab – Oslo Metropolitan University, andre-kallak.anundsen@oslomet.no

1 Introduction

House prices have grown substantially in most industrialized countries since the 1990s, with a substantial drop in the aftermath of the 2008 financial crisis. The Danish, Finnish, Norwegian, and Swedish housing markets are no exceptions. Developments after the financial crisis have, however, been somewhat different in the Nordic countries. Looking at the past 20 years, real house prices have been growing markedly in Norway and Sweden, with cumulative real growth rates of 109 percent and 147 percent, respectively. House price developments have been more moderate in Finland, where real house prices are up by 27 percent over the same period, while they have increased by 45 percent in Denmark between 2000 and 2019.

An important question is whether these price increases can be explained by underlying economic fundamentals, or whether there are signs of imbalances in the Nordic housing markets. A presence of imbalances in the housing market is important to detect, given the large effects a collapse in house prices may have on financial stability and real economic activity. The real economic consequences of a house price bust were clearly shown during the Great Recession (see e.g., Ferreira et al. (2010), Mian et al. (2013), Mian and Sufi (2014),Brown and Matsa (2020), and also Duca et al. (2020) for an excellent review). The literature has documented both consumption wealth effects (Aron et al., 2012; Mian et al., 2013) and self-reinforcing effects between the housing market and the credit market (Hofmann, 2003; Fitzpatrick and McQuinn, 2007; Gimeno and Martinez-Carrascal, 2010; Anundsen and Jansen, 2013). In addition, Leamer (2007) and Leamer (2015) have shown that large drops in housing investments are a strong indicator of future recessions in the US economy – a result that has gained international support in a recent study by Aastveit et al. (2019). Against this backdrop, I ask one main question: Have there been signs of bubble-like dynamics in Nordic housing markets over the period 2000q1–2019q4?

In the first part of my analysis, I test for house price bubbles by applying the methodology of testing for exuberance suggested by Phillips et al. (2015b,a) (PSY), which – as also discussed in Phillips and Shi (2020) – increasingly has been used by central banks as a real-time monitoring device of exuberance (Yiu and Jin, 2013; Amador-Torres et al., 2018; Gomez-Gonzalez et al., 2018; Caspi, 2016). The PSY-procedure also serves as an early warning device for future financial market meltdowns and crises, as shown in Anundsen et al. (2016) and Phillips and Shi (2019). Using the PSY-approach, I find no evidence of explosive developments in real house prices in Finland, Norway, or Sweden at any point during the past 20 years. For Denmark, this approach shows that house prices had an explosive development in the years preceding the global financial crisis.

Independent of the presence of exuberance or not, house prices may be overvalued or undervalued for periods of time. I therefore take another approach to determine whether house prices have evolved in line with the trajectory predicted by developments in underlying economic fundamentals. In particular, I follow Anundsen (2019) and calculate a fundamental house price path for the period 2000q1-2019q4 using the system-based cointegration approach of Johansen (1988). This fundamental path is calculated based on information and estimates that would have been available in 1999q4. Having constructed the trajectory of fundamental house prices, I investigate how actual house prices developed relative to the model-implied fundamental prices in the period thereafter. As noted in

Anundsen (2019), this approach relies on the bubble definition provided by Stiglitz (1990, p.13), which states that a bubble exists "if the reason why the price is high today is *only* that investors believe that the selling price will be high tomorrow – when 'fundamental' factors do not seem to justify such a price".

My results indicate an overvaluation of house prices in all countries in the years leading up to the global financial crisis. In 2007, the estimated overvaluation was 57 percent in Denmark. My estimates suggest that the estimate is 13 percent and 17 percent for Finland and Norway, respectively, whereas Swedish real house prices were overvalued by only 4 percent. The correction in real house prices following the Great Recession brought prices back to equilibrium within two years. After this, the countries have seen different developments in actual house prices relative to the value implied by economic fundamentals. Danish house prices have fluctuated around the fundamental path, but have remained mostly undervalued. At the end of 2019, my estimates suggest that Danish house prices were undervalued by 9 percent. In Finland, actual prices stagnated and have fluctuated around their equilibrium value. At the end of 2019, my estimates suggest that Finnish house prices were undervalued by 3 percent. In Norway, estimates suggest that prices were undervalued until 2016. After this, prices have remained overvalued – at most by 13 percent in 2018. At the end of 2019, I find that Norwegian house prices were overvalued by 9 percent. For Sweden, my estimates suggest that house prices have been systematically overvalued since 2014. Towards the end of the sample, the gap between actual and fundamental prices was 7 percent in Sweden. The only country were my results point in the direction of a systematic overvaluation is Sweden, but the gap between actual and fundamental prices has remained relatively small.

Although national imbalances are particularly important to detect from a financial stability point of view, it is well known that there are large regional differences in house price developments (Ferreira and Gyourko, 2012) and that national developments may be driven by certain local markets (Glaeser et al., 2008; Capozza et al., 2004; Malpezzi and Wachter, 2005). The Nordic countries are no exceptions in this regard. To explore whether there are signs of bubble-like developments in house prices in the capital cities, I perform separate tests for exuberance using the approach in Phillips et al. (2015b,a). My results show that there were signs of exuberance in the Oslo market for a short period between 2012m9 and 2013m1, but there is no systematic pattern of exuberance and there are no signs of exuberance in recent years. For Stockholm, my results show exuberance for a short period between 2016m11 and 2017m2, but – similar to Oslo – there are no signs of systematic exuberance. There are no signs of exuberance towards the end of the sample for Stockholm. For Helsinki, there are no signs of exuberance at any point in this period. In Copenhagen, the test suggests that there have been exuberance between 2018m8 and 2019m9.

As a final contribution of this paper, I discuss the main drivers of the developments in fundamental house prices over the past 20 years. As an implication, I estimate semi-elasticities of real after-tax interest rates on house prices. I also discuss what factors may contribute to imbalances in the housing market, and tools that may be used to prevent imbalances from building up. I conclude that the Nordic markets are particularly vulnerable to interest rate hikes. Further, the low supply elasticities in Nordic countries (Caldera and Johansson, 2013) make them more sensitive to demand shocks and also to greater house price volatility over the course of a boom-bust cycle (Huang and Tang (2012); Glaeser et al. (2008); Anundsen and Heebøll (2016)).

Related work:

House price developments in Norway, Sweden, and Denmark in the 2000s resemble those in many other countries, and are consistent with an increased synchronization of global house price developments (Duca, 2020). The developments in Finland has been somewhat different – particularly the past 10 years. There are several other studies that have asked the question of whether house price developments in the Nordic countries have been developing along a sustainable trajectory. The European Commission (Commission (2013)) estimated that Finnish house prices were consistently overvalued over the period 2003-2011 and that the overvaluation reached 15 percent in 2006-2008 and 2010-2011. For the case of Norway, Moodys, 2017 estimates that Norwegian house prices have been consistently overvalued since 2010. The IMF has warned about developments in house prices in both Norway, Sweden, and Finland over the years. Geng (2018) presents a panel data analysis of 20 countries over the period 1990q1-2016q4, in which both Denmark, Finland, Norway, and Sweden are included in the sample. House prices are estimated to have been overvalued in all four countries in the period preceding the financial crisis. Towards the end of the sample, in 2016q4, the author concludes that Norwegian and Swedish house prices are overvalued, whereas Danish and Finnish house prices are undervalued. This is consistent with the findings in this paper. The underlying model that is developed in Geng (2018) is maintained and used by the IMF. Recent updates in the 2019 Article IV consultations (IMF (2019a,b,c)) conclude that Norwegian and Swedish house prices are still overvalued, but far less so. For Finland, they find little evidence of overvaluation.

Another study in which both Denmark, Finland, Norway, and Sweden are analyzed is Dermani et al. (2016), who use a panel data approach for the 1995-

2015 period. They find no evidence of overvaluation in any of the countries once indebtedness is included in the model. When indebtedness is not included, there are signs of overvaluation in Norway and Denmark, but not in Sweden or Finland. They conclude that this finding may be suggestive of imbalances in the Norwegian and Danish housing markets. Bergman and Sørensen (2018), on the other hand, find that there is a high probability that Swedish house prices have been overvalued for quite some time, which is consistent with the findings in this paper. Consistent with my findings, Dam et al. (2011) find that Danish house prices were overvalued in the period before the financial crisis.

The rest of the paper proceeds as follows. In the next section, I present the data that are used throughout the paper, and I discuss house price developments in Denmark, Finland, Norway, and Sweden over the past 20 years. I also look at the capital cities of Copenhagen, Helsinki, Oslo, and Stockholm. Finally, I briefly discuss the methodologies employed throughout the paper in the same section. In Section 3, I start by presenting results from tests for exuberance at the national level. After this, I estimate the degree of over- or undervaluation of house prices over the past 20 years. The section also presents results from tests for exuberance in the capital cities. In Section 4, I discuss what the main drivers of fundamental house prices have been, and what sort of policies may reduce the probability of a bubble to emerge. The final section concludes.

2 Data, house price developments, and methodology

2.1 Data

I have collected data at both the national level and for the capital cities; Copenhagen, Helsinki, Oslo, and Stockholm. This section briefly describes the data.

National data

The aggregate data used in the analysis are collected with a quarterly frequency. House prices developments are measured through national indices and are deflated by CPI in order to obtain real house price developments. Income is measured by disposable household income, whereas the housing stock is measured by the real housing stock in fixed prices for Denmark and Norway.[1]. Due to data availability, the housing stock is measured through the number of dwellings for Finland and Sweden.[2] Both income and the housing stock are divided by the total population to obtain per capita measures.[3]

Interest rates are measured through the mortgage interest rate. In all countries, I consider the after-tax interest rate by adjusting the nominal rates for tax deductions.[4] The real after-tax interest rate is constructed by subtracting overall CPI-inflation. Details on data sources are given in Table A.1 in Appendix A.

[1] The total stock of housing is calculated according to the perpetual inventory method

[2] Data on number of dwellings in only available at the annual frequency, and have been interpolated to the quarterly frequency using linear interpolation.

[3] For Denmark and Finland, I was only able to collect population data at the annual frequency. Quarterly time series where constructed using linear interpolation.

[4] For Denmark, I have followed Dam et al. (2011) and constructed the after-tax interest rate using a combination of the interest rate on 30-year bonds and 1-year bonds, controlling for the minimum amortization rate and property taxes.

The analysis ends in 2019q4 for all countries. The sample's starting point is 1990q1 for Sweden,[5] Danish, Finnish, and Norwegian data start in 1985q1.

Regional data

Although income and housing stock data are not readily available at the local level, I do test for the presence of bubbles using the Phillips test for the capital cities. The data are measured with a monthly frequency. To obtain measures of real house prices, I deflate the series with the national CPI index. The sample ends in 2019m12 for all cities, and the sample start is set to 2006m1.[6] Details on data sources for the local house price indices are given in Table A.1 in Appendix A.

2.2 Developments

National developments

Figure 1 shows real house price developments in Denmark, Finland, Norway, and Sweden over the past 20 years, while Table 1 shows cumulative growth rates in real house prices for 5-year periods. I have also added the cumulative growth rates from 2000q1 to the peak in prices before the financial crisis (boom)[7], the drop in prices from peak to trough (bust),[8] as well as the cumulative growth over the full

[5] I was not able to collect data on the housing stock dating further back.

[6] For Oslo, data with a monthly frequency are available from 2003m1. For Stockholm they start in 2005m1, while data for Copenhagen start in 2006m1. For Helsinki, monthly data are only available from 2015m1, so I have linearly interpolated quarterly data for Helsinki.

[7] The peak in real house prices for the different countries are: Denmark (2007q1), Finland (2007q3), Norway (2007q2), and Sweden (2007q3).

[8] The troughs for the different countries are: Denmark (2009q2), Finland (2009q1), Norway (2008q4), and Sweden (2009q1). Note that Danish house prices had a new drop later on, but I use the trough around the financial crisis in calculating the fall in prices during the bust.

sample period (2000q1–2019q4).

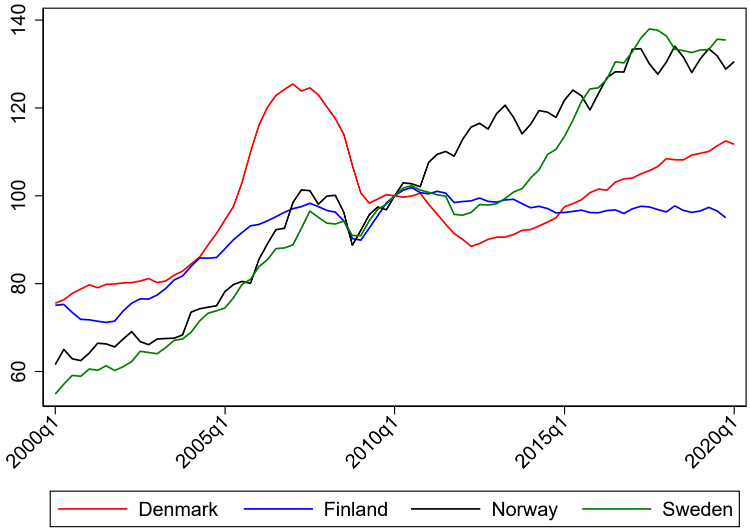


Figure 1: Real house price developments in Denmark, Finland, Norway, and Sweden. 2000q1–2019q4. Real house prices are constructed by deflating nominal price indices with CPI. I have normalized each series, so that the real house price index equals 100 in 2010q1 for all countries.

All countries experienced increasing house prices in the period leading up to the 2008 financial crisis. The cumulative growth rate was highest in Sweden, and lowest in Finland. The drop in house prices during the bust was largest in Denmark, with a drop of 22 percent. In Finland and Norway, real house prices dropped by 9 and 12 percent. In Sweden, house prices dropped by 6 percent. Real house prices exceeded pre-crisis levels already in early 2010 in Finland, Norway, and Sweden. In Denmark, real house prices were still below the previous peak at the end of 2019. After 2010, the countries have followed quite different paths.

In Finland, house prices have stagnated, and were 5 percent lower in 2019 than in 2010. In Norway, prices had increased by 29 percent over the same period, whereas Sweden had the highest real house price growth with 35 percent cumulative

Period	*Denmark*	*Finland*	*Norway*	*Sweden*
5-year cumulative growth rates:				
2000q1-2004q4	20.99	14.50	21.77	34.54
2005q1-2009q4	6.02	11.81	23.77	31.68
2010q1-2014q4	-4.99	-3.89	17.84	10.57
2015q1-2019q4	12.49	-1.23	5.80	19.34
10-year cumulative growth rates:				
2000q1-2009q4	32.65	31.00	57.26	78.76
2010q1-2019q4	9.68	-4.99	28.85	35.46
Cumulative growth rates over the boom-bust:				
Boom	65.99	30.95	64.61	75.90
Bust	-21.62	-8.54	-12.43	-5.79
Cumulative growth rates over full sample:				
Full sample	45.13	26.56	109.28	146.88

Table 1: Cumulative real house price growth for 5-year periods, 10-year periods, and the boom-bust cycle for Denmark, Finland, Norway, and Sweden. The boom is defined as the period from 2000q1 to the peak before the financial crisis, which for the different countries was: Denmark (2007q1), Finland (2007q3), Norway (2007q2), and Sweden (2007q3). The bust is defined as the period from the peak to the trough. The troughs for the different countries are: Denmark (2009q2), Finland (2009q1), Norway (2008q4), and Sweden (2009q1). Note that Danish house prices had a new drop later on, but I use the trough around the financial crisis in calculating the fall in prices during the bust. The final row shows the cumulative growth rates for the full sample period, 2000q1-2019q4. Real house prices are calculated by dividing the national indices by the national consumer price index.

growth between 2010 and 2019. In Denmark, prices were almost 10 percent higher in 2019 than they were in 2010.

Developments in Copenhagen, Helsinki, Oslo, and Stockholm

Figure 2 plots developments in real house prices for Copenhagen, Helsinki, Oslo, and Stockholm for the period from 2006m1 to 2019m12. In Table 2, I show cumulative growth rates for 5-year and 10-year intervals. The table also summarizes the cumulative growth in house prices from 2006m1-2019m12.

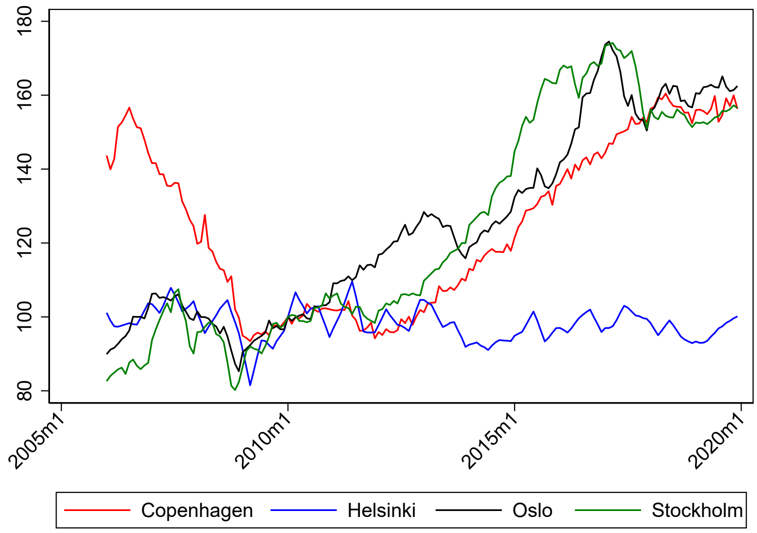


Figure 2: Real house price developments in Copenhagen, Helsinki, Oslo, and Stockholm. 2006m1–2019m12. Real house prices are obtained by deflating nominal price indices for the three cities with the national CPI. For Helsinki, monthly data are only available from 2015m1, so I have linearly interpolated quarterly data for Helsinki. Real house prices are normalized to be 100 in 2010m1.

Compared to the national house price growth, house prices have grown substantially more in the capital cities over the past ten years. In Oslo and Stockholm, real house prices have increased by 62 and 57 percent over this period, which is about twice of the national house price growth. In Helsinki, real house prices have remained flat, with a cumulative growth just around zero percent. At the national level, prices fell by 5 percent. In Copenhagen, prices have increased by 56 percent, whereas the national average is just below 10 percent.

Period	*Copenhagen*	*Helsinki*	*Oslo*	*Stockholm*
		5-year cumulative growth rates:		
2006m1-2009m12	-31.42	-4.76	7.48	18.49
2010m1-2014m12	17.86	-6.55	28.48	38.14
2015m1-2019m12	28.74	5.52	22.73	8.06
		10-year cumulative growth rates:		
2010m1-2019m12	56.31	0.14	62.49	56.54
		Cumulative growth rates over full sample:		
Full sample	8.79	-0.96	80.73	89.50

Table 2: Cumulative real house price growth for 5-year periods and 10-year periods for Copenhagen, Helsinki, Oslo, and Stockholm over the period 2006m1–2019m12. The final row shows the cumulative growth rates for the full sample period, 2006m1–2019m12. Real house prices are obtained by deflating nominal price indices for the three cities with the national CPI. For Helsinki, monthly data are only available from 2015m1, so I have linearly interpolated quarterly data for Helsinki.

2.3 Methodology

My approach to investigate whether there have been bubbles in the Nordic countries over the past 20 years relies on two different econometric methodologies. The first method I use is to test for exuberance using the framework developed by Phillips et al. (2015b) and Phillips et al. (2015a), while the second approach compares developments in actual and fundamental prices in a similar way as in Anundsen (2019). This section briefly describes the two methodological approaches.

Testing for explosivity

My first approach is to apply the recursive ADF-based framework suggested by Phillips et al. (2015b) and Phillips et al. (2015a) to explore whether there are signs of explosive developments in real house process.[9] The procedure uses a recursive algorithm to estimate a Dickey-Fuller (Dickey and Fuller, 1979) regression to detect possible explosiveness in a time series for certain periods. With reference to the econometric framework of Phillips et al. (2015b) and Phillips et al. (2015a), I test whether house prices follow an I(1) process (no bubble), or whether they have explosive roots (bubble). I apply this test to real house prices, both at the national level and for the capital cities.

I use information from 1990q1–2019q4 when looking at national data, and I set the minimum window size to 41 quarters, so that the first test is done for 2000q1. I use 4 lags in the ADF-regressions, and include a deterministic linear trend. For the analysis of the capital cities, I use data from 2006m1–2019m12. I set the minimum window size to 49 months, so that the first test is done for 2010m1. A deterministic trend is included and the lag length is set to 12. Critical values depend both on the sample size, nuisance parameters, lag length, and the minimum window size. To calculate the sequence of finite sample critical values, I use the Matlab program accompanying Phillips et al. (2015b), using M = 5,000 Monte Carlo replications.[10]

Estimating fundamental house prices

A commonly used theory for the drivers of house prices is the life-cycle model of housing (see e.g. Meen (1990, 2001, 2002)). This theoretical framework takes as a

[9] This approach has a clear link to asset pricing theory, in which the current value of the asset (the house) should be equal to the expected discounted stream of pay-offs in the next period. This framework is similar to a standard present value model (see e.g., Gordon and Shapiro (1956) and Blanchard and Watson (1982)), and Clayton (1996), who argue that it may equally well be considered for housing.

[10] Further details on this econometric approach are provided in Appendix B.

starting point a standard representative-agent model, in which an agent maximizes her lifetime utility with respect to consumption of housing goods and "other" goods. One can show that this implies an inverted demand equation for housing, which has been used in numerous studies that investigate house price determination (Buckley and Ermisch, 1983; Hendry, 1984; Meen, 1990; Holly and Jones, 1997; Meen and Andrew, 1998; Meen, 2001; Duca et al., 2011a,b; Anundsen, 2015). This inverted demand equation implies that house prices are determined by income, the user cost of housing, and the housing stock.

In my econometric operationalization, I start by applying the system-based test for cointegration in Johansen (1988) to analyze the long-run relationship between real house prices, real per capita income, the housing stock per capita, and the real direct user cost (operationalized by considering real after-tax interest rates). My estimation sample is 1985q1–1999q4 for Denmark, Norway, and Finland, while the sample starts in 1990q1 for Sweden.[11] The sample ends in 1999q4, so that the parameters are determined before the evaluation period (2000q1–2019q4). To save degrees of freedom, I impose the restriction that the coefficient on income and housing stock are the same, but with opposite signs. This implies an income elasticity of demand equal to one, which is in accordance with what Meen (2001); Duca et al. (2011b); Anundsen (2015) find on US data, and it is one of the central estimates put out in Meen (2001).[12] Detailed results from the cointegration analysis are tabulated in Table B.1 in Appendix B.

Having obtained the parameters in the long-run relationships, I estimate the implied fundamental house price path during the period 2000q1-2019q4. I as-

[11]For all countries, I consider a VAR(2)-model, which is also supported by Schwarz information criterion.

[12]A similar restriction is used in Anundsen (2019).

sume that house prices were in equilibrium in 2000q1, and I calculate the implied fundamental trajectory of house prices in the ensuing period. Developments in fundamental prices are then compared to actual house prices.[13]

3 Results

I start this section by looking at aggregate results for the Nordic countries. First, I present my results from testing for exuberance, before I discuss the evolution of house prices relative to what is implied by economic fundamentals. In the second part, I test for periods of exuberance in the capital cities.

3.1 National results

Testing for explosive roots

The test statistics for all three countries are plotted together with critical values for a 10% significance level in Figure 3. The line for the critical values is plotted in black, while the test statistic is shown in red. If the test statistic crosses the black line, the test indicates that there are signs of exuberance.

It is evident that there are no points in time where the test statistic is higher than the critical value for Finland, Norway, or Sweden. For Denmark, the test indicates a bubble in the period before the sharp price drop starting in the first quarter for 2007q1. There are no signs of bubble-behavior in Denmark in the period thereafter.

[13]Further details on this econometric approach are provided in Appendix B.

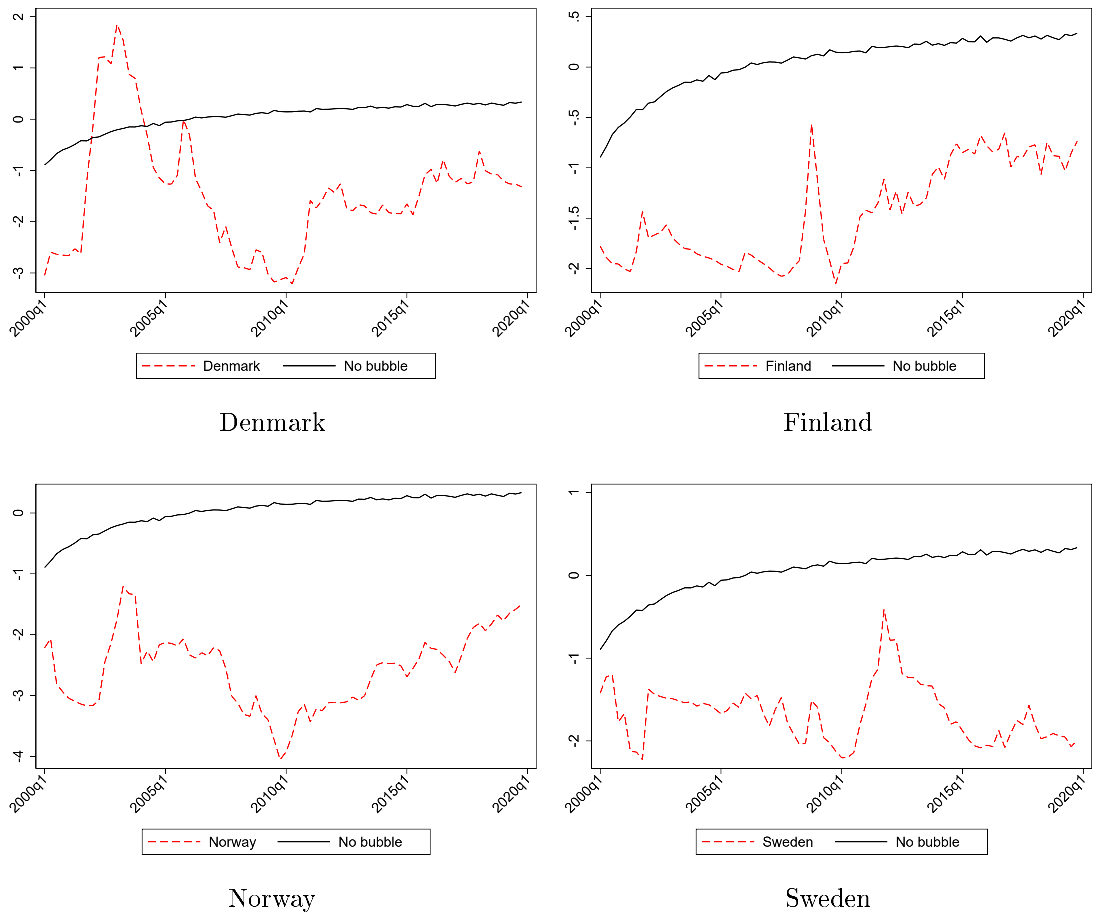


Figure 3: Test for exuberance in Denmark, Finland, Norway, and Sweden. 2000q1–2019q4. The figure shows the test statistic for Denmark (upper left panel), Finland (upper right panel), Norway (lower left panel), and Sweden (lower right panel) based on the PSY-approach. The tests are performed on real house prices, which are obtained by deflating the national house price indices by the national CPI. The test statistic is plotted in red, while the sequence of 10 percent critical values are shown in black. The interpretation of the figures is that if the test statistic crosses the black line, there are signs of exuberance. The sample covers the period 2000q1–2019q4 for all countries. The estimation sample starts in 1990q1. I use a minimum window size of 41 quarters, and include 4 lags and a deterministic linear trend in the ADF-regressions. The critical values are simulated using 5000 Monte Carlo replications. Details on the econometric approach are provided in Appendix B.

House prices and fundamentals

An important finding from the cointegration analysis is that house prices are highly sensitive to interest rate changes in all countries. This is particularly so in Denmark and Norway, where my results suggest that an interest rate increase of one percentage point will lower long-run house prices by 13 and 11 percent, respectively. The estimates for Norway resemble those in Anundsen (2019) and the estimates for Denmark are close to Dam et al. (2011), in which similar type of models are estimated. These estimates may be considered semi-elasticities of interest rates on (equilibrium) house prices, and may have additional usage elsewhere for policy makers.

The implied fundamental prices (orange) are plotted together with actual house prices (black) in Figure 4, and average percentage deviations between actual and fundamental prices are shown in Table 3.

Comparing actual to fundamental prices, it is evident that house prices were overvalued in all four countries in the years leading up to the 2008 financial crisis. The overvaluation was particularly prominent in Denmark, which also saw the largest drop in actual house prices from peak-to-trough. This finding is consistent with the results from testing for exuberance, which points towards a bubble in the Danish housing market in the years preceding the global financial crisis.

The correction in house prices around 2008, brought house prices back to the value implied by fundamentals in all countries by 2010.

After 2010, Norwegian house prices remained undervalued, until 2016, in which the model suggests that Norwegian house prices were overvalued. At the most, prices were overvalued by 13 percent in 2018. Recently, prices have converged

Period	*Denmark*	*Finland*	*Norway*	*Sweden*
2000q1-2004q4	-2.82	6.57	1.62	-5.91
2005q1-2009q4	38.44	12.85	0.10	3.60
2010q1-2014q4	5.53	2.03	-4.58	-2.30
2015q1-2019q4	-5.34	3.72	2.15	7.39

Table 3: Average deviation from estimated fundamentals at the national level for 5-year periods from 2000q1 for Denmark, Finland, Norway, and Sweden. Real house prices are calculated by dividing the national indices by the national consumer price index. Fundamental prices are determined by income per capita, the housing stock per capita, and real after tax interest rates. Detailed results on estimated coefficients are given in Table B.1 in Appendix B.

back to their fundamental value, and at the end of 2019, prices were overvalued by 9 percent.[14] For Sweden, the estimates suggest that house prices have been overvalued – although relatively modestly – since 2014. At the end of 2019, the model suggests that Swedish house prices were overvalued by 7 percent.

In Finland, house prices have had a flat development since 2010, and prices have been at, or even below, equilibrium in recent years. At the end of 2019, the model suggests that Finnish house prices were undervalued by 3 percent. Following the drop in house prices in the aftermath of the global financial crisis, Danish house prices have remained mostly undervalued, and towards the end of the sample, my estimates suggest that Danish house prices were undervalued by 9 percent.

Based on these results, I conclude that Danish and Finnish house prices were undervalued at the end of 2019, whereas Norwegian and Swedish house prices were overvalued. The only country where there are signs of systematic overvaluation is Sweden, in which prices have remained elevated since 2014.

[14] Housing Lab – National center for housing market research updates this indicator for Norway on a quarterly basis. Recent estimates suggest that the interest rate reduction accompanying the lock-down in relation to the spreading of Covid-19 has closed the gap between actual and fundamental prices – at the end of 2020q2, actual prices were a little less than one percent above fundamentals, according to Housing Lab.

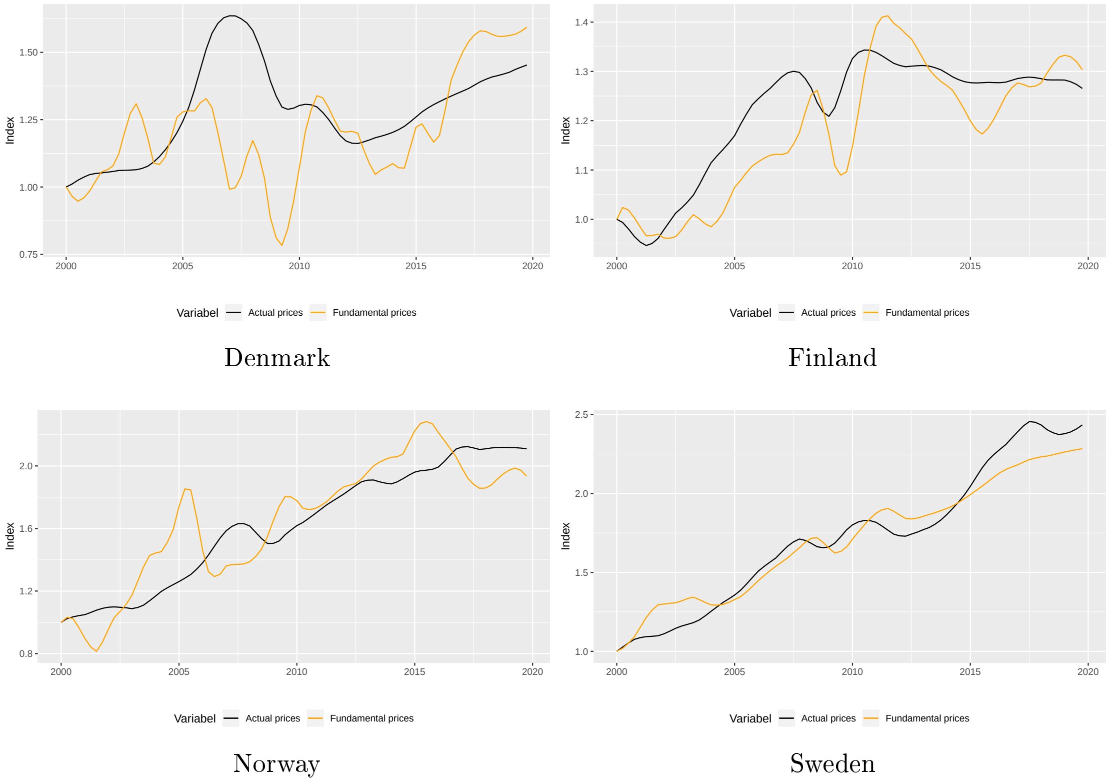
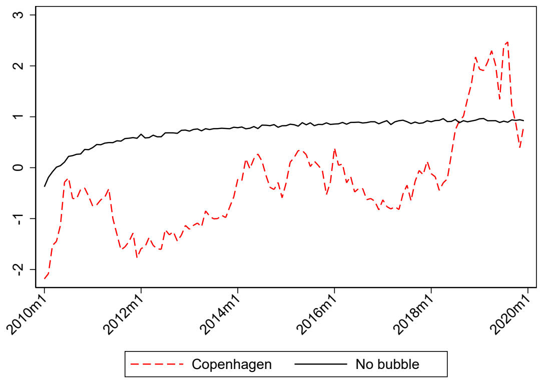


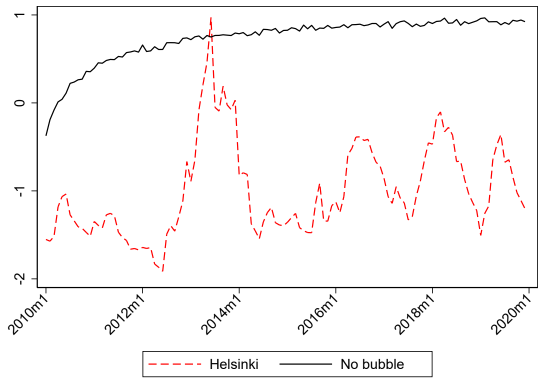
Figure 4: Actual versus fundamental house prices in Denmark, Finland, Norway, and Sweden. 2000q1–2019q4. The figure shows fundamental house prices (orange line) and actual house prices (black line) over the period 2000q1–2019q4 for Denmark (upper left panel), Finland (upper right panel), Norway (lower left panel), and Sweden (lower right panel). Fundamental prices are determined by income per capita, the housing stock per capita, and real after tax interest rates. Both fundamental and actual prices are normalized to one in 2000q1. Detailed results on estimated coefficients are given in Table B.1 in Appendix B.

3.2 Results for Copenhagen, Helsinki, Oslo, and Stockholm

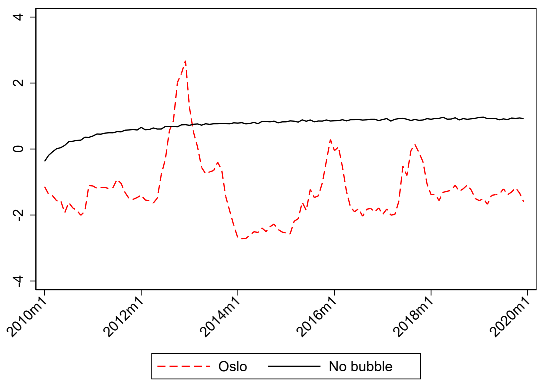
Test statistics from the PSY-approach for Copenhagen, Helsinki, Oslo, and Stockholm are plotted together with critical values for a 10% significance level in Figure 5. The line for the critical values is plotted in black. If the test statistic crosses the black line, the test indicates that there are signs of exuberance. There are no signs of exuberance in Helsinki over the sample period. There are some signs of exuberance in Stockholm and Oslo, but this is very short-lived, so it is hard to conclude that there has been bubble-like dynamics in these cities. For Copenhagen, there have been signs of exuberance between August 2018 and September 2019, but that there are no signs of exuberance towards the end of the sample.



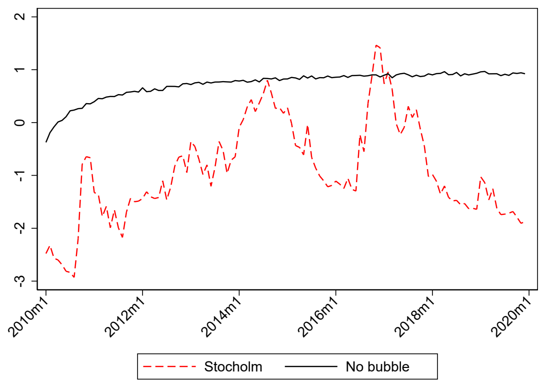
Copenhagen



Helsinki



Oslo



Stockholm

Figure 5: Test for exuberance in Copenhagen, Helsinki, Oslo, and Stockholm. 2006m1–2019m12. The figure shows test statistics for Copenhagen (upper left panel), Helsinki (upper right panel), Oslo (lower left panel), and Stockholm (lower right panel) from the PSY-approach. The tests are done on real house prices, which are obtained by deflating the city-level house price indices by the national CPI. The test statistic is plotted in red, while the sequence of 10 percent critical values are shown in black. The interpretation of the figures is that if the test statistic crosses the black line, there are signs of exuberance. The sample covers the period 2010m1–2019m12 for all cities. The estimation sample starts in 2006m1. I use a minimum window size of 49 months, and include 12 lags and a deterministic linear trend in the ADF-regressions. The critical values are simulated using 5000 Monte Carlo replications. Details on the econometric approach are provided in Appendix B.

4 What factors contribute to overvaluation?

My results indicate that the Nordic housing markets are sensitive to interest rate changes. In order to probe deeper into this finding, I have estimated quasi-counterfactual developments for fundamental prices, by holding the real after-tax interest rate fixed since 2000q1. This is not a fully-fledged counterfactual analysis, however, since that would require a model taking general equilibrium effects into account. The main motivation for this analysis is simply to illustrate the importance of developments in the real after-tax interest rate for the evolution of fundamental house prices.

In Figure 6, I plot actual house prices (solid black), fundamental house prices (orange), and fundamental house prices when holding the real after-tax interest rate constant from 2000q1 (blue). It is evident that the real after-tax interest rate matters a great deal to fundamental prices. At face value, this exercise suggest that house prices would have been greatly overvalued in all countries over large parts of the sample period had it not been for the secular decline in the real after-tax interest rate. Of course, this is a simplification, since another development in the real after-tax interest rate also would have affected the other fundamentals in the model, and it would have resulted in another development in actual house prices.

That interest rate developments are important to house price dynamics finds support in the literature, see e.g., Williams (2015) for an excellent summary of some international studies. For US metro areas, Aastveit and Anundsen (2017) show that monetary policy shocks exercise a great impact on house price developments. They also show that whether expansionary or contractionary shocks have

Figure 6: Fundamental house prices, actual house prices, and fundamental house prices without interest rate changes. Denmark, Finland, Norway, and Sweden. 2000q1–2019q4. The figure shows fundamental house prices (orange line), actual house prices (black line) and fundamental prices when the interest rate is kept unchanged from 2000q1 for Finland (upper left panel), Denmark (upper right panel), Norway (lower left panel), and Sweden (lower right panel). The sample covers the period 2000q1–2019q4. Fundamental prices are determined by income per capita, the housing stock per capita, and real interest rates after taxes. All series are normalized to one in 2000q1. Detailed results on estimated coefficients are given in Table B.1 in Appendix B.

the greatest impact on house prices depends on the elasticity of housing supply. In particular, they show that expansionary shocks have a greater impact on house prices in areas with low housing supply elasticities, whereas the opposite is true for areas with high housing supply elasticities. At the median, they find that expansionary shocks hit harder than contractionary shocks.

The average housing supply elasticity in the US is calculated to be around 2 (Caldera and Johansson, 2013).[15] The estimated elasticities in Caldera and Johansson (2013) for Denmark (1.2), Finland (less than 1), Norway (0.5), and Sweden (1.4) are all estimated to be lower than in the US. To the extent that the results in Aastveit and Anundsen (2017) are generalizable outside the US, contractionary monetary policy may have a relatively weaker impact in slowing down house price increases than expansionary shocks have in fuelling price increases. This can create a trade-off for financial stability purposes, as expansionary shocks fuels house price increases, whereas the reduction in house prices is more modest following a corresponding increase in the interest rate.

House prices are autocorrelated (Case and Shiller (1989); Cutler et al. (1991); Røed Larsen and Weum (2008); Head et al. (2014)), and momentum effects are seen as a key feature of the housing market (Glaeser et al., 2014). Aastveit and Anundsen (2017) suggest that one potential reason for why expansionary monetary policy shocks have a greater impact on house prices than contractionary shocks is that momentum effects are asymmetric. For instance, if an interest rate reduction increases house prices, a momentum effect may lead to an additional increase in demand. This increases house prices further. Such a momentum effect is more important in supply inelastic markets, since the initial price increase is greater. On the other hand, an interest rate increase typically leads to lower house prices. If the momentum effect is less prominent when prices are falling, the additional demand increase will also be smaller. Aastveit and Anundsen (2017) show that the coefficients on lagged house prices in a simple AR(4)-model for a panel of 263

[15] This estimate is close to the average estimate in Saiz (2010), who construct estimates of supply elasticities for US metro areas. It is the elasticities in Saiz (2010) that are used by Aastveit and Anundsen (2017).

MSAs are twice as large when house prices are increasing.

To explore the relevance of asymmetric momentum effects in the Nordic housing markets, I have estimated simple AR(4)-models for house price growth, where I follow Aastveit and Anundsen (2017) and let the AR-coefficients be different in periods when the four-quarter growth in real house prices is positive versus periods when the four-quarter growth is negative. I have estimated these models for each country separately, and pooled as a panel using a fixed-effects estimator. Results are listed in Table 4. Results are consistent with Aastveit and Anundsen (2017) and suggest that the momentum effect is more pronounced when prices are increasing. In sum, the results from the simple AR-models and the low supply elasticities estimated for Nordic countries (Caldera and Johansson, 2013) are consistent with the idea that expansionary shocks have a greater impact on house prices than contractionary shocks.

Low supply elasticities are also shown to increase house price volatility in booms and busts Huang and Tang (2012); Glaeser et al. (2008); Anundsen and Heebøll (2016)), and – with the low supply elasticities in the Nordic countries – one may be worried that prices may take a hit in the future. From a policy point of view, fewer restrictions on construction activity would make builders more responsive to house price increases, thereby dampening the effects of demand shocks and lowering house price volatility over the course of a boom-bust cycle. Policy actions that could reduce the bureaucratic hurdle in the building process could therefore lower the chances of bubbles building up. If there is a supply side problem, it is easier to solve it on the supply side, not by manipulation of the demand side.

Several papers have also shown that relaxation of lending standards matters to regional house price developments in the US (e.g., Mian and Sufi (2009); Favara

Country	*Pos. Coeff*	*Pos. SE*	*Neg. Coeff.*	*Neg. SE*
Denmark	0.84	0.12	0.79	0.14
Finland	0.92	0.20	-0.14	0.33
Norway	0.64	0.22	0.33	0.41
Sweden	0.84	0.20	-0.47	0.48
Panel	0.79	0.10	0.47	0.14

Table 4: Momentum effects. The table reports the sum of coefficients on lagged house price appreciation based on estimating an AR(4)-model for house price growth, where the coefficients on lagged house prices are allowed to be different when the four-quarter growth is positive versus negative. Results are shown for each individual country, and when the countries are pooled as a panel (final row). I include country-fixed effects in the panel estimation.

and Imbs (2015); Anundsen and Heebøll (2016)), and a strand of the literature attributes the bubble-like dynamics in the US housing market in the 2000s to the subprime explosion (see Duca et al. (2011a,b); Pavlov and Wachter (2011); Anundsen (2015)). In this context, it may be tempting for authorities to impose limits to credit expansion through macroprudential policies. As a policy to cool down credit growth and to lower the risk of financial imbalances, this may be a sound tool, but it is not necesarrily the best way to deal with housing market developments. If the reason why prices are increasing is that not enough houses are built in high-demand areas, it is a supply-side problem that requires supply-side policies. Tightening of credit standards can lower credit growth and thereby lower demand for housing. This pushes house prices down, but at the same time results in less construction activity – thus magnifying the initial structural deficiency. Given the low elasticities that are estimated for the Nordic countries, together with the high interest rate sensitivity, it seems to be of acute importance that one commissions a thorough investigation of political hurdles in the building process, which also studies housing needs in different part of the countries, and in particular whether new construction activity meets the actual needs in terms of type of housing, size, and not least location.

5 Conclusion

In this paper, I have investigated whether there are signs of bubbles in the Danish, Finnish, Norwegian, and Swedish housing markets. First, I tested for explosive developments in real house prices. My results suggest that Danish house prices had an explosive development in the years preceding the global financial crisis. There is no evidence of explosiveness for the other Nordic countries. I also estimated the trajectory of fundamental house prices for the period 2000q1-2019q4, as implied by developments in per capita income, the housing stock per capita, and the real after-tax interest rate. My results show that there were signs of overvaluation in all countries before the housing busts towards the end of the previous decade. In 2019, I find that Norwegian and Swedish house prices were overvalued, and that they have been so in Sweden since 2014. My results show that Danish and Finnish house prices were undervalued at the end of 2019.

My estimation results imply that the Nordic housing markets are highly sensitive to interest rate changes, and that the secular decline in real after-tax interest rates over the past 20 years has been a major contributor to developments in fundamental house prices. A quasi-counterfactual exercise suggest that house prices would have been grossly overvalued for most part of the sample in all counties if the real after-tax interest rate had been kept constant since 2000. I argue that the high sensitivity of house prices with respect to interest rate changes in Denmark, Finland, Norway, and Sweden must be seen in conjunction with the low housing supply elasticities that have been estimated for the Nordic countries. The low elasticities contribute to increased house price volatility over the boom-bust cycle and implies a stronger effect of demand shocks on house prices. In conclusion, I think it is of key importance that policy makers in the Nordic countries gets a thorough overview of housing needs in terms of geographical preferences, as well as latent demand for size and type of units, so that new construction meets these needs. Removing bureaucratic hurdles in the building process can also lower house prices in the long run, make them less sensitive to demand shocks and reduce house price volatility.

References

Aastveit, K. A. and A. K. Anundsen (2017). Asymmetric effects of monetary policy in regional housing markets. Working Paper 25, Norges Bank.

Aastveit, K. A., A. K. Anundsen, and E. I. Herstad (2019). Residential investment and recession predictability. *International Journal of Forecasting 35*(4), 1790–1799.

Amador-Torres, J. S., J. E. Gomez-Gonzalez, and S. Sanin-Restrepo (2018). Determinants of housing bubbles' duration in OECD countries. *International Finance 21*(2), 140–157.

Anundsen, A. K. (2015). Econometric regime shifts and the US subprime bubble. *Journal of Applied Econometrics 30*(1), 145–169.

Anundsen, A. K. (2019). Detecting imbalances in house prices: What goes up must come down? *Scandinavian Journal of Economics 121*(4), 1587–1619.

Anundsen, A. K., K. Gerdrup, F. Hansen, and K. Kragh-Sørensen (2016). Bubbles and crises: The role of house prices and credit. *Journal of Applied Econometrics 31*(7), 1291–1311.

Anundsen, A. K. and C. Heebøll (2016). Supply restrictions, subprime lending and regional US housing prices. *Journal of Housing Economics 31*, 54–72.

Anundsen, A. K. and E. S. Jansen (2013). Self-reinforcing effects between housing prices and credit. *Journal of Housing Economics 22*(3), 192–212.

Aron, J., J. V. Duca, J. Muellbauer, K. Murata, and A. Murphy (2012). Credit, housing collateral and consumption: Evidence from the UK, Japan and the US. *Review of Income and Wealth 58*(3), 397–423.

Bergman, U. M. and P. B. Sørensen (2018). The interaction of actual and fundamental house prices: A general model with an application to Sweden. Unpublished manuscript.

Blanchard, O. and M. Watson (1982). *Crisis in the Economics Financial Structure*. Lexington Books, Lexington.

Brown, J. and D. A. Matsa (2020). Locked in by leverage: Job search during the housing crisis. *Journal of Financial Economics 136*(3), 623–648.

Buckley, R. and J. Ermisch (1983). Theory and empiricism in the econometric modelling of house prices. *Urban Studies 20*(1), 83–90.

Caldera, A. and Å. Johansson (2013). The price responsiveness of housing supply in OECD countries. *Journal of Housing Economics 22*(3), 231–249.

Capozza, D. R., P. H. Hendershott, and C. Mack (2004). An anatomy of price dynamics in illiquid markets: analysis and evidence from local markets. *Real Estate Economics 32*(1), 1–32.

Case, K. E. and R. J. Shiller (1989). The efficiency of the market for single-family homes. *American Economic Review 79*(1), 125–137.

Caspi, I. (2016). Testing for a housing bubble at the national and regional level: The case of Israel. *Empirical Economics 51*, 483–516.

Clayton, J. (1996). Rational expectations, market fundamentals and housing price volatility. *Real Estate Economics 24*(4), 441–470.

Commission, E. (2013). Finland's high house prices and household debt: A source of concern. Country Focus 6, European Commission.

Cutler, D. M., J. M. Poterba, and L. H. Summers (1991). Speculative dynamics. *Review of Economic Studies 58*(3), 529–546.

Dam, N. A., T. S. Hvolbøl, E. H. Pedersen, P. B. Sørensen, and S. H. Thamsborg (2011). Udviklingen på ejerboligmarkedet i de senere år - Kan boligpriserne forklares? (Developments in the housing market in recent years - Can the price developments be explained?). Kvartalsoversigt 2011-2, Nationalbanken.

Dermani, E., J. Lindé, and K. Walentin (2016). Is there an evident housing bubble in Sweden? Economic review, Sveriges Riksbank.

Dickey, D. A. and W. A. Fuller (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association 74*(366), 427–431.

Duca, J., Muellbauer, J., and A. Murphy (2020). What drives house price cycles? international experience and policy issues. *Journal of Economic Literature*. Forthcoming.

Duca, J., J. Muellbauer, and A. Murphy (2011a). House prices and credit constraints: Making sense of the US experience. *Economic Journal 121*, 533–551.

Duca, J., J. Muellbauer, and A. Murphy (2011b). Shifting credit standards and the boom and bust in US home prices. Technical Report 1104, Federal Reserve Bank of Dallas.

Duca, J. V. (2020). Making sense of increased synchronization in global house prices. *Journal of European Real Estate Research.*

Favara, G. and J. Imbs (2015, March). Credit Supply and the Price of Housing. *American Economic Review 105*(3), 958–92.

Ferreira, F. and J. Gyourko (2012). Heterogeneity in neighborhood-level price growth in the United States, 1993-2009. *American Economic Review 102*(3), 134–140.

Ferreira, F., J. Gyourko, and J. Tracy (2010). Housing burst and household mobility. *Journal of Urban Economics 68*, 34–45.

Fitzpatrick, T. and K. McQuinn (2007). House prices and mortgage credit: Empirical evidence for Ireland. *The Manchester School 75*, 82–103.

Geng, N. (2018). Fundamental drivers of house prices in advanced economies. IMF Working Paper 18/164, IMF.

Gimeno, R. and C. Martinez-Carrascal (2010). The relationship between house prices and house purchase loans: The Spanish case. *Journal of Banking and Finance 34*, 1849–1855.

Glaeser, E., J. Gyourko, E. Morales, and C. G. Nathanson (2014). Housing dynamics: An urban approach. *Journal of Urban Economics 81*, 45–56.

Glaeser, E., J. Gyourko, and A. Saiz (2008). Housing supply and housing bubbles. *Journal of Urban Economics 64*(2), 198–217.

Gomez-Gonzalez, J., J. Gamboa-Arbelàez, J. Hirs-Garzòn, and A. Pinchao Rosero (2018). When bubble meets bubble: Contagion in oecd countries. *Journal of Real Estate Finanance and Econonmics 56*, 546–566.

Gordon, M. J. and E. Shapiro (1956). Capital equipment analysis: The required rate of profit. *Management Science 3*(1), 102–110.

Head, A., H. Lloyd-Ellis, and S. Hongfei (2014). Search, liquidity, and the dynamics of house prices and construction. *American Economic Review 104*(4), 1172–1210.

Hendry, D. F. (1984). Econometric modelling of house prices in the United Kingdom. In D. F. Hendry and K. F. Wallis (Eds.), *Econometrics and Quantitative Econometrics*, Chapter 8, pp. 211–252. Blackwell.

Hofmann, B. (2003). Bank lending and property prices: Some international evidence. Working paper 22, The Hong Kong Institute for Monetary Research.

Holly, S. and N. Jones (1997). House prices since the 1940s: Cointegration, demography and asymmetries. *Economic Modelling 14*(4), 549–565.

Huang, H. and Y. Tang (2012). Residential land use regulation and the US housing price cycle between 2000 and 2009. *Journal of Urban Economics 71*(1), 93–99.

IMF (2019a). Finland. Country Report 5, International Monetary Fund.

IMF (2019b). Norway. Country Report 159, International Monetary Fund.

IMF (2019c). Sweden. Country Report 88, International Monetary Fund.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control 12*, 231–254.

Leamer, E. E. (2007). Housing IS the business cycle. In *Housing, Housing Finance, and Monetary Policy*, pp. 149–233. Federal Reserve Bank of Kansas City.

Leamer, E. E. (2015). Housing really is the business cycle: What survives the lessons of 2008-09? *Journal of Money, Credit and Banking 47*(1), 43–50.

Malpezzi, S. and S. Wachter (2005). The role of speculation in real estate cycles. *Journal of Real Estate Literature 13*(2), 143–164.

Meen, G. (1990). The removal of mortgage market constraints and the implications for econometric modelling of UK house prices. *Oxford Bulletin of Economics and Statistics 52*(1), 1–23.

Meen, G. (2001). *Modelling Spatial Housing Markets: Theory, Analysis and Policy.* Kluwer Academic Publishers, Boston.

Meen, G. (2002). The time-series behavior of house prices: A transatlantic divide? *Journal of Housing Economics 11*(1), 1–23.

Meen, G. and M. Andrew (1998). On the aggregate housing market implications of labour market change. *Scottish Journal of Political Economy 45*(4), 393–419.

Mian, A., K. Rao, and A. Sufi (2013). Household balance sheets, consumption, and the economic slump. *Quarterly Journal of Economics 128*(4), 1687–1726.

Mian, A. and A. Sufi (2009). The consequences of mortgage credit expansion: Evidence from the U.S. mortgage default crisis. *Quarterly Journal of Economics 124*(4), 1449–1496.

Mian, A. and A. Sufi (2014). What explains the 2007-2009 drop in employment? *Econometrica 82*(6), 2197–2223.

Moodys (2017). High house prices pose persistent risk where slow to adjust to homeownership costs. Sector in-depth December, Moody's.

Pavlov, A. and S. Wachter (2011). Subprime lending and real estate prices. *Real Estate Economics 39*(1), 1–17.

Phillips, P. C. B. and S. Shi (2019). Detecting financial collapse and ballooning sovereign risk. *Oxford Bulletin of Economics and Statistics 81*(6), 1336–1361.

Phillips, P. C. B. and S. Shi (2020). Chapter 2 - real time monitoring of asset markets: Bubbles and crises. In D. V. Hrishikesh and C. Rao (Eds.), *Financial, Macro and Micro Econometrics Using R*, Volume 42 of *Handbook of Statistics*, pp. 61–80. Elsevier.

Phillips, P. C. B., S. P. Shi, and J. Yu (2015a). Testing for multiple bubbles: Historical episodes of exuberance and collapse in the S&P 500. *International Economic Review 56*(4), 1043–1078.

Phillips, P. C. B., S. P. Shi, and J. Yu (2015b). Testing for multiple bubbles: Limit theory and real time detectors. *International Economic Review 56*(4), 1079–1134.

Røed Larsen, E. and S. Weum (2008). Testing the efficiency of the Norwegian housing market. *Journal of Urban Economics 64*(2), 510–517.

Saiz, A. (2010). The geographic determinants of housing supply. *Quarterly Journal of Economics 125*(3), 1253–1296.

Stiglitz, J. E. (1990). Symposium on bubbles. *Journal of Economic Perspectives 4*(2), 13–18.

Williams, J. C. (2015). Measuring monetary policy's effect on house prices. *FRBSF Economic Letter* (28).

Yiu, M. and L. Jin (2013). Detecting bubbles in the hong kong residential property market: An explosive-pattern approach. *Journal of Asian Economics 28*, 115–124.

A Data definitions

Series	Description	Denmark	Finland	Norway	Sweden
PH	House price index	DS/DN	SF/BoF	SSB/NB/EV	SS/RB/VG
P	Consumer Price Index	DS	SF/BoF	SSB/NB	SS/RB
H	Housing stock	DS/DN	SF/BoF	SSB/NB	SS/RB
Y	Households' disposable income	DS/DN	SF/BoF	SSB/NB	SS/RB
i	Mortgage interest rate	RKR/DN/Dam et al. (2011)	BoF	NB	RB
τ_y	Capital gains tax rate	DS	BoF	SSB/NB	RB
POP	Population	DS/DN	SF/BoF	SSB/NB	SS/RB

Table A.1: Variable definitions and data sources. The data period runs from 1985q1 to 2019q4 for Denmark, Finland, and Norway. For Sweden, the sample covers the the period 1909q1–2019q4. The abbreviations are the following: SD = Danmarks Statistikk, DN = Danmarks Nationalbank, RKR = Realkredittrådet, SF = Statistics Finland, BoF = Bank of Finland, SSB = Statistisk Sentralbyrå, NB = Norges Bank, EV = Eiendomsverdi, SCB = Statistiska Centralbyrån, RB = Riksbanken, and VG = Valueguard. For Denmark, I follow Dam et al. (2011) and construct the real after-tax interest rate using a combination of the interest rate on 30-year bonds and 1-year bonds, controlling for the minimum amortization rate and property taxes.

B Methodology

Exuberance

Below is a brief explanation of the recursive ADF-based framework of Phillips et al. (2015b,a). Consider the following generalized ADF-regression model:

$$\Delta X_t = \mu_{r_1,r_2} + \rho_{r_1,r_2} X_{t-1} + \sum_{j=1}^{p} \gamma_{r_1,r_2} \Delta X_{t-j} + \varepsilon_t,\ \varepsilon_t \sim IIN(0, \sigma^2_{r_1,r_2})$$

where $r_1 = \frac{T_1}{T}$ and $r_2 = \frac{T_2}{T}$, with T_1, T_2 and T denoting the sample starting point, end point and the total number of observations, respectively. When $T_1 = 0$ and $T_2 = T$, the model is similar to a standard ADF-regression model. The null hypothesis of interest is that $\rho_{r_1,r_2} = 0$, i.e., that $X_t \sim I(1)$ versus the alternative hypothesis that $\rho_{r_1,r_2} > 0$, i.e., that X_t is explosive. The test statistic is computed as $ADF_{r_1}^{r_2} = \frac{\hat{\rho}_{i,r_1,r_2}}{se(\hat{\rho}_{i,r_1,r_2})}$. Like standard ADF test statistics, this test statistic has a non-standard limiting distribution under the null hypothesis. Moreover, the distribution depends on both r_2 and nuisance parameters. Finite sample critical values may be simulated using a Monte Carlo simulation.

My aim is to identify whether there are signs of explosive house price developments at different points in time. I test this by applying the Backward Sup ADF (BSADF) test of Phillips et al. (2015b,a). Consider the case where we keep the sample end point fixed at $\bar{T}_2$. The BSADF-statistic then becomes:

$$BADF(r_2 = \bar{r}_2) = \sup_{r_1 \in [0, \bar{r}_2 - \tilde{r}]} ADF_{r_1}^{r_2 = \bar{r}_2}$$

where $\tilde{r} = \frac{\tilde{T}}{T}$, in which $\tilde{T}$ is the minimum sample used for the test. By recursively changing $\bar{T}_2$, we obtain a sequence of BSADF statistics. These test statistics are compared to the relevant critical values, $CV(\alpha)_{r_1}^{r_2}$, to determine if and when there have been evidence of explosive behavior.

The starting point of a bubble is defined as the first period at which the BSADF statistic exceeds its critical value:

$$r_{start} = \inf_{r_2 \in [\tilde{r}, 1]} r_2 : BSADF_{r_2} > CV(\alpha)_{r_2}^{r_1}$$

Having determined the start of the bubble (as a fraction of the number of observations), r_{start}, the end of the bubble (as a fraction of the sample), r_{end}, is defined as the first period at which the BSADF statistic is again below its critical value:

$$r_{end} = \inf_{r_2 \in [r_{start}, 1]} r_2 : BSADF_{r_2} < CV(\alpha)_{r_2}^{r_1}$$

Fundamental house prices

To estimate how fundamental house prices in Nordic countries respond to changes in income per capita, the housing stock per capita, and real after tax interest rates, I consider a VAR(2) model, which is supported by Schwarz information criterion. The VECM representation of the underlying VAR(2) model takes the following form:

$$\Delta \boldsymbol{y}_t = \boldsymbol{\Pi} \boldsymbol{y}_{t-1} + \boldsymbol{\Gamma} \Delta \boldsymbol{y}_{t-1} + \boldsymbol{\Phi} \boldsymbol{D}_t + \boldsymbol{\varepsilon}_t$$

where the vector $\boldsymbol{y}_t$ contains real house prices, ph, real disposable income per capita, y, the housing stock per capita, h, and the real after-tax interest rate,

r. The vector $\boldsymbol{D}$ collects a constant, and a deterministic trend. I impose the restriction that the coefficient on income and housing stock are the same, but with opposite signs, so that the vector $\boldsymbol{y}_t$ is 3×1. This restriction implies an income elasticity of demand equal to one, which is in accordance with what Meen (2001); Duca et al. (2011b); Anundsen (2015) find on US data, and it is one of the central estimates put out in Meen (2001).[16] The disturbances are assumed to follow a multivariate normal distribution, $\boldsymbol{\varepsilon}_t \sim MVN\left(\mathbf{0}, \boldsymbol{\Sigma}\right)$.

Testing for cointegration amounts to testing the rank of the matrix $\boldsymbol{\Pi}$, which corresponds to the number of independent linear combinations of the variables in $\boldsymbol{y}_t$ that are stationary. I test this using the trace test and impose $Rank\left(\boldsymbol{\Pi}\right) = 1$. The reduced rank representation implies that $\boldsymbol{\Pi} = \boldsymbol{\alpha}\boldsymbol{\beta}'$, where $\boldsymbol{\alpha}$ is a 3×1 matrix, whereas $\boldsymbol{\beta}$ is a 4×1 matrix (since a deterministic trend is also restricted to enter the space spanned by $\boldsymbol{\alpha}$). Having imposed a rank of one, I follow Anundsen (2019) and impose the restrictions that the series in $\boldsymbol{y}_t$ are co-trending, and that disposable per capita income relative to the existing housing stock per capita and the real after-tax interest rate are weakly exogenous with respect to the long-run parameters. Table B.1 summarizes the estimated long-run coefficients, $\boldsymbol{\beta}$, and the adjustment parameter, α_{ph}, for each of the countries.

It is evident that there is a substantial interest rate effect in all countries, and that the income effect is larger in Norway and Denmark than in Sweden and Finland. There is also evidence suggesting that equilibrium deviations are restored more slowly in Norway and Denmark than in the other two countries.

Having determined the parameters in the long-run relationship, I construct the

[16] A similar restriction is used in Anundsen (2019).

Variable	*Denmark*	*Finland*	*Norway*	*Sweden*
Real interest rate	-12.548	-7.902	-11.001	-5.842
	(6.389)	(0.986)	(5.106)	(1.495)
Disp. income	4.775	0.959	5.362	2.153
	(1.667)	(0.481)	(1.327)	(1.360)
Housing stock	-4.775	-0.959	-5.362	-2.153
	(-)	(-)	(-)	(-)
Adjustment parameter	-0.045	-0.191	-0.029	-0.146
	(0.016)	(0.058)	(0.006)	(0.043)

Table B.1: Results from cointegration analysis. This table reports a summary of the main results when the system based approach of Johansen (1988) is implemented. The estimation period runs from 1985q1 to 1999q4 for Denmark, Finland, and Norway. For Sweden, it covers the period 1990q1–1999q4. The dependent variable is real house prices, while the independent variables are real per capita disposable income, the housing stock per capita, and the real after tax interest rate. The VAR models are of order two.

fundamental house price path in the following way:

$$ph_t^* = ph_{t-1}^* + \hat{\beta}_y^{1999q4}\Delta y_t + \hat{\beta}_h^{1999q4}\Delta h_t + \hat{\beta}_r^{1999q4}\Delta r_t \ \ ; t > 1999q4$$

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Authors:
André K. Anundsen, Housing Lab, Oslo Metropolitan University, Norway;
email: *andrekal@oslomet.no*

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