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Examining the response of house prices to supply using a Markov regime switching approach: The case of the Irish housing market

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1. Introduction

Like many property markets across western economies, the Irish residential sector has experienced a pick-up in housing price inflation due to the impact of the Covid-19 pandemic. In 2021Q2, according to the Bank of International Settlements (2021)[1], global housing prices increased by 4.5 per cent on an annual basis; the highest rate since the start of the Great Financial Crisis (GFC). In real terms, global housing prices now exceed their immediate post-GFC average levels by 24.5 per cent. The demand side of the Irish residential market has been especially buoyant post 2013; between 2013 and 2021, Irish housing prices, in real terms, grew by 94 per cent. This increase in prices occurs at a time when a growing debate in housing markets internationally is focusing on whether increased housing supply can result in lower housing price inflation.

A large body of literature examines the relationship between housing prices and the level of housing supply. For example, there has recently been some debate concerning the relatively high level of housing prices in the UK market over the past 20 years. Miles and Monro (2019), Wren-Lewis (2020) and Mulheirn (2019) contend that the high level of prices is mainly due to the low interest rate environment observed internationally over this period. Low interest rates coupled with consistent growth in income levels results in a significant increase in affordability amongst prospective homebuyers, which in turn results in higher housing prices. However, a countervailing viewpoint is put forward by Cheshire and Buyuklieva (2019) who contend that higher housing prices can be explained by the relatively low levels of home building in the UK market over the same period. In terms of the US market, Anundsen and Heebøll (2016) in analyzing how the interaction between housing supply restrictions, mortgage credit constraints and a price-to-price feedback loop affect housing price volatility, conclude that tighter restrictions on supply lead to both larger housing price booms and busts.

While residential property markets in many countries experienced substantial swings in activity over the past 30 years, the Irish market was exceptionally volatile. A significant reason for this particular volatility in the Irish case was the emergence of a particularly strong period of economic growth, the "Celtic Tiger", in the mid-1990's and the presence of a credit bubble in the early to mid-2000's (see Cronin and McQuinn (2021), McCarthy and McQuinn (2017) and Honohan (2009)). The collapse of the credit bubble, owing in part to the emergence of the GFC of 2007/08, resulted in the subsequent downturn for the Irish housing market being especially acute by international standards. Housing prices fell in nominal terms by 50 per cent between 2008 and 2012, rendering Irish financial institutions, which had been particularly exposed to the residential sector, being especially vulnerable during the GFC in 2007/08. The difficulties experienced by the Irish banking sector was the main reason for the country entering an official programme of support in October 2010 with the EU

[1] Available at https://www.bis.org/statistics/pp*residential*111*pdf*

Commission, the ECB and the IMF (see Honohan (2009) for more). Although demand for housing eventually recovered in the Irish market post 2013, the level of supply has remained persistently lower than estimates of the structural demand for housing in the Irish economy (Bergin and Garcia-Rodriguez (2020)). Consequently, recent policy initiatives by the Irish Government have focused on significantly increasing the numbers of completions going forward. Therefore, accurately estimating the impact of additional housing supply on housing prices is imperative in assessing whether future increases in supply will temper periods of high housing price inflation.

The volatility in the Irish market, with pronounced movements in price levels and supply, has almost inevitably resulted in a number of structural changes in the residential and mortgage market. Consequently, any empirical approach seeking to quantify the impact of changes in supply on price inflation must allow for these potential alternative states. Despite the presence of large structural change in residential property markets, particularly owing to the GFC, the literature on asymmetry and non-linear dynamics in the residential property market is somewhat scarce. Dufrenot and Malik´ (2012), Azad Chowdhury and Maclennan (2014), Nneji, Brooks, and Ward (2013) and Fontana and Corradin (2013) have all examined housing price dynamics in a Markov switching framework. More recently, Pruser and Schmidt¨ (2021) use a panel Markov-switching model allowing for time-varying volatility to jointly analyze national and state-level housing price regimes for the US over the period 1976 to 2017. The authors find that a bubble in the housing market occurred in almost all states prior to the Great Recession and suggest this as one explanation for its severity.

In this paper, we quantify the impact of additional housing supply on Irish housing price inflation over time using a multiple breakpoint model and a Markov switching model, which can detect the presence of structural changes in the domestic residential market over the period 1981 to the present. Certain sub-periods since 1981 are clear and our empirical estimates distinctly reveal that not allowing for such change can lead to significantly different estimates of price sensitivities. Our estimation results suggest that credit has played a significant impact on Irish housing price inflation when prices have been high. The reaction of housing prices to changes in housing stock in a period when housing prices are elevated would appear to be negligible. On the other hand, the results also suggest that when Irish housing prices have been low or negative, a change in housing stock has had a significant impact on prices. The rest of the paper is structured as follows; in the next section we review developments in the Irish housing and mortgage market over the period in question, paying particular attention to the credit bubble which emerged in the mid-2000s, an empirical section then outlines the approach adopted in the paper, while a subsequent section summarises the results from our analysis. The final section offers some concluding comments.

2. The Irish housing and mortgage market

Over the period 1981 to 2019 the Irish housing and mortgage market experienced profound change. This is particularly evident from the mid-1990s onwards when the "Celtic tiger" emerged. Figures 1-5 plots relevant Irish macroeconomic series from 1981 to 2019. Large increases in disposable income, alongside an accommodative euro area monetary policy, led to sharp rises in housing affordability for a young, prospective home-owning population (Figure 1). As can be seen from Figure 2, housing prices began to rise sharply in this environment. The Irish property boom was the largest across OECD countries between 1995 and 2007, with average annual housing price increases of 9 per cent arising during that period. Figure 3 plots Irish housing construction over the same period; a similar trend is apparent with supply increasing consistently from the mid-1990s onwards. Over the period 2005 – 2007 an annual average of almost 85,000 units were built. However, after the GFC housing construction levels collapsed and by 2013 just over 8,000 units were being built. The Irish credit market also experienced considerable financial deregulation and liberalisation during this period. Table 1 summarises the main developments affecting credit supply from the late 1980s to 2007.[2]

Table 1: Taxonomy of Factors Influencing Irish Credit Supply

1988 - 1999	**1999 – 2007**
Major relaxation of exchange controls.	Adoption of euro and access to non-resident deposits.
Formal trigger mechanism for changes in retail interest rates suspended.	Introduction of 100 per cent loan to value ratio (LTV) mortgages.
Fixed rate mortgages introduced by some banks for first time.	Introduction of tracker mortgages into the Irish market.
Secondary liquidity requirement abolished	Mortgage securitisation.
Reduction in primary liquidity ratio from 8 to 2 percent.	Equity withdrawal and loan consolidation.

Central to developments in Irish credit markets post 1995 was Ireland's membership of the euro area. In general, across most euro area countries total lending and, in particular, lending of housing loans increased substantially from the mid-1990s onwards. While the gradual easing of regulatory controls within certain countries certainly facilitated this increase, the role of market innovations and, in

[2] An exact chronology of the control and subsequent liberalisation of the Irish credit market is discussed in detail in Kelly and Everett (2004). See, in particular, Box 1 on pp. 96-7, which illustrates the building and dismantling of controls over the period 1973 to 1999.

particular, the onset of cross-border lending between credit institutions was considerable. One of the most significant developments in this regard was the more widespread use of derivatives and repurchase (repo) agreements, which enabled financial institutions to better manage exchange rate, interest rate and credit risk. Lower risk resulted in greater use and a reduced cost of interbank lending, thereby, enabling institutions with a surplus of funds to lend to those in deficit. The importance of this development in increasing the depth of money markets is illustrated in ECB (2003) which finds that the volume of repo transactions (which reduce risk by collateralising loans) more than doubled in the EU between 2002 and 2003. Therefore, the most significant development in the provision of credit to the domestic housing market was the increased ability of Irish banks, following the adoption of the euro in 1999, to attract deposits from non-residents. Given the demand-side pressures in the Irish economy in the late 1990s, Irish financial institutions accessed the increased funding available within the euro area upon the adoption of the euro, raising the supply of credit in Ireland substantially.

Figure 4 highlights the difference between the actual level of property related credit[3] and the household deposit base in the domestic financial system. Up to the early 1990s the total level of credit extended was similar in magnitude to the total amount of household deposits, however, thereafter a substantial difference emerged with Irish financial institutions increasingly availing of international wholesale funding from abroad. The large gap between lending and retail deposits that had emerged by 2008 was critical to the vulnerability of the Irish banking sector to the severe distress that arose in wholesale funds markets during the financial crisis. The gap between credit and traditional, household deposits closed from 2015 onwards. Figure 5 highlights the increase in credit provision with respect to the overall economy, which in this case is proxied by total household disposable income given the well-established difficulties with using GDP in an Irish context (see Kostarakos, Varthalitis, and McQuinn (2022) for more on this). Even though the Irish economy experienced substantial growth during the period, the pace of credit expansion after 2003 exceeded that of the growth of the overall economy, causing a large increase in the credit-to-output ratio. A significant rise in this ratio above its long-run trend is an indicator of a period of excessive credit growth (Basel Committee on Banking Supervision, 2010).

The expansionary phase in mortgage credit provision in Ireland can be observed in Table 2. The total value of mortgages issued increased almost tenfold between 1995 and 2007. The total number of new mortgages in a year went from just under 50,000 in 1995, to 80,000 in 2000, and then to almost 90,000 mortgages by 2007. The average size of a mortgage also increased considerably over the period. In 1995, the average mortgage extended by an Irish credit institution was €54,094. This had climbed to €271,154 by 2007. Housing prices increased substantially over the period, almost doubling between 2000 and 2007. The peak in housing prices occurred in 2007 Q2.

[3] Credit here refers to residential mortgage credit and credit for construction and real estate.

The right-hand side column of Table 1 lists a number of other important factors that influenced mortgage developments and the sharp rise in housing prices and mortgage issue values in the 2000s. These included the introduction of 100 per cent LTV mortgages and the option of house owners realising equity. These products would have allowed households the opportunity to spend their savings and wealth gains on consumption expenditure. The introduction of tracker mortgages gave households an additional mortgage product option with which to organise their financial plans. The scale of the collapse in the Irish housing market from 2007 to 2012 in terms of both credit provision and housing prices is illustrated in Table 2. The total value and number of mortgages issued fell substantially, as did the overall amount of residential loans outstanding and the average new mortgage value. Since then, while the total value of new mortgages issued and their average value has risen, outstanding residential lending fell between 2012 and 2019 as domestic financial institutions deleveraged their loan books. The overall changes in credit provision in the economy after 2007 are also apparent in Figures 4 and 5. It can be seen in the former that the ratio between total private sector credit and domestic retail deposits has declined over time and was below 100 per cent by the late 2010s, while credit to households for house purchase declined up to 2011 Q4 and has remained broadly unchanged since. Figure 5 shows a steady fall in the ratio of private sector credit to total household disposable income since 2011Q4.

Table 2: Summary of Irish Residential Mortgage Market Statistics for Selected Years

Variable	**Unit**	**1995**	**2000**	**2007**	**2012**	**2019**
Outstanding level of residential lending	€m	11,938	32,546	123,002	84,973	75,857
Total value of mortgages issued	€m	2,666	9,004	24,064	3,412	11,088
Average mortgage issued	€	54,094	111,355	271,154	184,113	234,818
Total number of mortgages issued		49,288	80,856	88,747	18,532	11,660
Housing prices	€	77,994	169,191	322,634	227,376	281,947

The link between credit growth and housing price developments in Ireland's boom bust experience between 2002 and 2012 was especially acute. However, this relationship was not just particular to Ireland. Gueorguiev et al. (2017) provide an in-depth study and chronology of the relationship between credit growth and economic developments in Europe since the introduction of the euro. They subdivide the period 1999 to 2017 into three distinct phases: gradual acceleration and boom (1999–08), bust (2009–11), and a sluggish recovery (2012–17). They conclude that almost a decade after the Great Financial Crisis took hold in 2008, bank lending and economic activity in Europe had only partially recovered with restricted credit flows being the norm in 2017.

A growing literature has examined the Irish housing and mortgage market over this period. These include, but are not confined to, Cronin and McQuinn (2021), McCarthy and McQuinn (2017), Kelly and McQuinn (2014) and Lyons and Muellbauer (2013). For the purposes of the present study, the Cronin and McQuinn (2021) and Kelly and McQuinn (2014) studies are particularly relevant as they include estimates of housing supply in models of housing prices.

3. Methodology

a. Standard OLS Benchmark

The specification used in this paper attempts to explain real housing prices, hp_t, with real income inc_t, the real residential mortgage lending rate rmt_t and a measure of housing stock, $stock_t$. These variables have been included as standard in studies examining the determination of housing price movements both in Ireland and internationally (see for example Cronin and McQuinn (2021) for the Irish case and Caldera and Asa Johansson (2013) for OECD countries). In addition, this paper's specification contains a lag of the dependent variable, with positive estimated coefficients implying momentum or self-reinforcing effects. Finally, given the discussion in the preceding section, we include a measure of credit growth relating to the residential property market, $cred_t$[4]. The benchmark equation can be written therefore as follows:

$$hp_t = \alpha + \beta_1(L)hp_t + \beta_2 inc_{t-1} + \beta_3 stock_{t-1} + \beta_4 cred_{t-1} + \beta_5 rmt_{t-1} + \varepsilon_t \qquad (1)$$

where (L) is a polynomial in the lag operator and ε_t is error term. In the above equation, we would expect to see positive signs on the lag of housing prices, income and the credit variable while a negative relationship should exist between the housing stock variable and the interest rate. To account for the delayed impact of changes in the economy on the housing market and to prevent a potential endogeneity issue that

[4] A number of specifications were tested including different choices of deflator (CPI vs PCE). We also control for non-price credit conditions in a manner similar to Kelly and McQuinn (2014). In both cases, the results remain consistent across all estimations carried out.

could arise from feedback within the variables when the model is contemporaneous, all explanatory variables are lagged as in Nneji et al. (2013).

b. Multiple Breakpoint Model

The typical linear regression model assumes that the model's parameters do not change over time. Despite this assumption, structural change, or the changing of parameters at specific dates during the sample period, is empirically significant in applied time series analysis. As noted previously, Irish housing prices have been particularly volatile over the last number of decades. Given such a high degree of volatility, particularly owing to developments in the provision of credit, it is plausible that the relationship between housing prices and its fundamental drivers could have changed over time. In this case, a standard OLS equation may not appropriately capture the relationship between housing prices and its determinants. With this in mind, we also consider the methodology by Bai and Perron (2003). This methodology can be used to estimate multiple structural breaks in a linear model estimated by least squares. The methodology treats the number of breakpoints as well as the date at which they occur as unknown. Consider the below housing price model with *m* breaks:

$$hp_t = \alpha + \beta_{1,1}(L)hp_t + \beta_{2,1}inc_{t-1} + \beta_{3,1}stock_{t-1} + \beta_{4,1}cred_{t-1} + \beta_{5,1}rmt_{t-1} + \varepsilon_t \quad t = 1,\ldots,T_1 \tag{3}$$

$$hp_{t,m} = \alpha + \beta_{1,m}(L)hp_t + \beta_{2,m}inc_{t-1} + \beta_{3,m}stock_{t-1} + \beta_{4,m}cred_{t-1} + \beta_{5,m}rmt_{t-1} + \varepsilon_t \quad t = 1,\ldots,T_m \tag{4}$$

where the breakpoints $(T_1,\ldots\ldots T_{(m+1)})$ are treated as unknown. The Bai-Perron estimation is based upon least square estimates of $\beta_{1,i},\beta_{2,i},\beta_{3,i},\beta_{4,i},\beta_{5,i}$ which are obtained by minimizing the sum of squared of residuals $\sum_{i=1}^{m+1}\sum_{T_{i-1}+1}^{T_1} = \left(hp_{t,m} - \alpha + \beta_{1,m}(L)hp_t + \beta_{2,m}inc_{t-1} + \beta_{3,m}stock_{t-1} + \beta_{4,m}cred_{t-1} + \beta_{5,m}rmt_{t-1} + \varepsilon_t\right)^2$

To determine the number of breakpoints the "sequential process" suggested by Bai-Perron is used. The first step is to test the null hypothesis that there is $l = 0$ structural breaks using the $SupF$ test.[5] If the null hypothesis of *l* breaks is rejected in favour of the $l + 1$ breaks alternative, the test is applied to each sub-sample and so on, until rejection fails.

[5] This is a test for parameter stability at each of the different points of a time series. Pioneered by Quandt (1960) and developed by Andrews (1993) it tests for one or more structural break points in the sample of a specific regression equation.

c. Markov Switching Model

The multiple breakpoint regression described in Section 3.b allows us to examine how housing prices and its determinants have changed over different points in time between 1981-2019. However, many macroeconomic relationships do not just change over time, but may also display distinct patterns under different states or regimes. This non-linearity can provide a very different interpretation of shocks to macroeconomic variables depending on the state of the economy (Koop & Potter, 1999). Therefore, to fully capture non-linearity in the relationship between Irish housing prices and measures of housing stock, income, interest rates and credit we estimate the model presented in Section 3.a in a Markov switching (MS) framework. The MS model, developed by Hamilton (1989) is so called because the switching mechanism is controlled by an unobserved state variable, s_t, that follows a first order Markov chain process. Applying this to our housing price equation results in the following:

$$hp_t = \alpha_{st} + \beta_{1,st}(L)hp_t + \beta_{2,st}inc_{t-1} + \beta_{3,st}stock_{t-1} + \beta_{4,st}cred_{t-1} + \beta_{5,st}rmt_{t-1} + \varepsilon_t \quad (5)$$

where $\varepsilon_{s(j)} \sim N(0, \sigma^2(j))$. The setup of the MS model in Eq. (4) allows the possibility that the response of housing prices to all variables is dependent on s_t, an unobserved state variable which follows a first order Markov chain and has transition probability matrix of

$$P = \begin{pmatrix} P_{11} & P_{21} \\ P_{12} & P_{22} \end{pmatrix}$$

where $p_{ij} = P(S_t = j \,|S_{t-1} = i)$, with $\sum_{j=i}^{2} p_{ij} = 1$ for regime $i(i = 1,2)$.

The estimation of the model depends on maximum likelihood. The maximization of likelihood function of the model requires an iterative estimation technique to obtain estimates of the parameters of the model and the transition probabilities. With the parameters identified, it is then possible to estimate the probability that the variable of interest, in this case the growth rate of Irish housing prices, can be characterised by a particular regime or state. It is also possible to derive the smoothed and filtered state probabilities which indicate the probability of being in a particular regime or state.

4. Data and Empirical Results

a. Data Description

All models were estimated using quarterly data from 1981Q3 to 2019Q4. For the dependent variable, we use the year-on-year growth rate of the Residential Property Price Index from the Central Statistics Office (CSO)[6]. The level of income used is the average disposable household income. This is available from the CSO's Survey on Income and Living Conditions (SILC)[7]. The level of dwellings stock is calculated by accumulating the newly completed units on the depreciated housing stock from the previous period via a perpetual inventory equation (McQuinn (2004)). The completions data used in generating the housing stock are the official completions data from the Central Statistics Office (CSO)[8]. The interest rate is the residential mortgage interest rate provided by the Central Bank of Ireland. The credit variable is that advanced to Irish resident private-sector enterprises involved in construction and real estate and is also available from the Central Bank of Ireland's Credit and Banking Statistics. The housing price index, level of income, interest rate and credit variable are all expressed in real terms using the personal consumption expenditure (PCE) deflator. All variables used in the estimations are in the form of ($log_t - log_{t-4}$) representing year-on-year changes in the quarterly data. This is with the exception of the interest rate variable. Prior to estimation, unit root testing was carried out to specify the order of integration of the variables. All five variables are found to be I(0) at least at a 5 per cent significance level and results of this testing is available upon request.

b. Empirical Results

Table 3 presents a linear regression model (as in Eq. (1)) for a single regime using ordinary least squares estimation procedure. The analysis is performed on the whole sample between 1981Q3 and 2019Q4. The results show that the lag of housing prices is significant with a coefficient of 0.78 suggesting that housing price inflation is persistent and possess a degree of inertia. The coefficient on the income variable, inc_t, is also positive and significant, intuitively suggesting that higher incomes results in

[6] This data is available from 2005Q1 only, however. Therefore, for the pre-2005 we back cast this series with the housing price level provided by the Department of Housing, Local Government and Heritage.

[7] This data is available from 2005 – 2019 and is back-cast prior to this with data from aggregate disposable income.

[8] These data are backcast prior to 2010 using data on connections to the Electricity Supply Board (ESB) grid available from the Irish Department of Housing. These data served as the official data on housing supply in the Irish market until 2018. Information on the relationship between data on housing completions and housing connections is available from the CSO at https://www.cso.ie/en/methods/surveybackgroundnotes/newdwellingcompletions/

higher housing prices. The change in housing stock, $stock_t$, is correctly negatively signed and also significant at the five percent level. The change in credit, $cred_t$, is also correctly positively signed and significant. Finally, the residential mortgage rate, rmt_t, is found to be both incorrectly signed and insignificant. The parameter stability assumption is strongly rejected by Andrews (1993) *SupF* test, suggesting the possible existence of nonlinearities between housing prices and the explanatory variables. This type of parameter inconsistency in housing price models may result in an incorrect inference being drawn about the relationship between the variables.

Table 3: Standard OLS Estimation (1981Q2-2019Q4)

	(1)
β_1	0.781***
	(0.063)
β_2	0.112***
	(0.139)
β_3	-1.79**
	(0.766)
β_4	0.056**
	(0.026)
β_5	0.001
	(0.01)
$\bar{R}^2$	0.698
$SupF$	5.74***
	(2007Q3)

***, **, & * denotes significance at the 1, 5 and 10% levels respectively. Standard errors are in parenthesis.

Next, we examine the housing price equation in the context of Bai and Perron (2003) multiple breakpoint model. The breakpoint model in this paper allows for up to five breaks to occur over the estimation period. As shown in Table 4, the sequential process of selecting the number of breaks finds there to be two breakpoints located at 1994Q4 and 2007Q3. These dates roughly correspond to the beginning of the Celtic Tiger era and subsequent collapse of the Irish housing market, which were discussed in Section 2. The number of break points, l = 2, gives the model three separate estimation periods – Period 1 (1981Q3-1994Q3), Period 2 (1994Q4-2007Q2) and Period 3 (2007Q3-2019Q4).

In Period 1, the lag of housing prices, income and the residential mortgage rate, while all correctly signed, are not statistically significant[9] while the credit variable is neither significant nor correctly signed. The results instead suggest that the change in housing stock was the main drivers of housing price movements during this earlier estimation period. In terms of the reaction of housing prices to a change in the housing stock, the impact of the coefficient on $stock_t$ of -25.3 can be further assessed by estimating the standard deviation (S.D.) of variables[10]. The value of -0.93 indicates that an increase in the housing stock of one of its standard deviations (0.2 per cent) will result in an expected decrease in housing prices of 0.93 of its standard deviations (5.4 per cent). In other words, an increase of housing stock by 0.2 per cent will result in an expected housing price decrease of 5.1 per cent, or -0.93 x 5.4 per cent. In terms of actual stock, this result suggests that in the period between 1981Q3 and 1994Q3, an increase of 10,000 units would lead to a fall in housing prices of 15 per cent, based on the average stock number over the same period.

In Period 2, the coefficient on both the lag of housing prices and the interest rate are both incorrectly signed and insignificant while income is once again also insignificant. What is perhaps most interesting about the results in this period is that the model suggests that the growth rate of the housing stock no longer has a significant effect on housing price movement whereas the growth rate of credit becomes highly significant with the expected positive sign.

Finally, Period 3 examines the period post the collapse of the Irish housing market and subsequent recovery from 2007Q3 to 2019Q4. The results show that the lag of housing price inflation is correctly signed and significant with the coefficient of 0.59 indicating a moderate level of persistence. The growth rate of income is now significant with a strong coefficient of 0.59, suggesting an increase in the reaction of housing prices to changes in income over the estimation period. Once again, the interest rate is not significant. The growth rate of the housing stock is correctly signed and significant, although with a much lower sensitivity than in Period 1 with a coefficient on $stock_t$ of -4.96. Using the same method of calculating the standard deviation of variables results in a value of -0.33, indicating that an increase in the housing stock of one of its standard deviations (0.7 per cent) will result in an expected decrease in housing prices of 0.33 of its standard deviations (10.5 per cent). Using the average stock number over the period 2007Q3 to 2019Q4, this suggest that an increase of 10,000 units would lead to a fall in housing prices of 2.5 per cent. Finally, the growth rate of credit has gone from being highly significant in Period 2 to insignificant in Period 3.

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[9] As in Caldera and Asa Johansson˚ (2013) the effect of interest rates changes on housing prices is typically non-significant in almost all our estimations and sometimes yields a counter-intuitive positive sign. The authors put this down to the inability of the that the estimation framework to control for the potential simultaneity bias between interest rates and housing price

[10] The standard deviations (S.D.) of variables calculated by multiplying the coefficient given for a particular independent variable (in this case $stock_t$) by the S.D. of that variable divided by the S.D. of the dependent variable, hp_t. The calculation using $stock_t$ in Period 1 is -25.3 * (0.2 per cent/5.4 per cent) = -0.93.

Based on the overall results of the breakpoint model, we find some interesting dynamics between housing prices, housing stock and credit. First, the results suggest that housing prices were very sensitive to changes in the housing stock pre-1994. This relationship subsequently broke down during the 1995-2007 period but returned from 2007-2019, although it is not as strong as in the initial period.

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Table 4: Multiple Breakpoint Estimation (1981Q3-2019Q4)

Breaks 1994Q4, 2007Q3	1981Q3-1994Q3 Period 1	1994Q4-2007Q2 Period 2	2007Q3-2019Q4 Period 3
	53 obs	51 obs	50 obs
α	0.04	-0.03**	-0.01**
	(0.01)	(0.02)	(0.01)
β_1	0.20	-0.03	0.59***
	(0.14)	(0.14)	(0.12)
β_2	0.08	0.04	0.74***
	(0.26)	(0.14)	(0.36)
β_3	-25.31***	-0.82	-4.96***
	(6.08)	(1.51)	(0.95)
β_4	-0.02	0.34***	0.04
	(0.05)	(0.08)	(0.04)
β_5	-0.01	0.01	0.01
	(0.01)	(0.0)	(0.01)
Mean of hp_t	-1.0%	8.2%	-2.9%
S.D. of hp_t	5.4%	5.9%	10.5%

Breakpoint Specification

Break Test	*F-Statistic*	*Scaled F-Statistic*	*Critical Value*
0 vs. 1	5.74**	34.43	20.08
1 vs. 2	8.61**	51.71	22.11
2 vs. 3	3.77	22.61	23.04

***, **, & * denotes significance at the 1, 5 and 10% levels respectively. Standard errors are in parenthesis.

The final model we discuss is the Markov switching model as estimated by Equation 5. Before estimating the Markov regime switching model, the number of states or regimes to be included in the model must be chosen. As there are often relatively few transitions among states, it is difficult to estimate strictly exogenous explanatory variables accurately. For this reason, most applications assume only two or three states (Hamilton, 2010). In our preliminary estimations, tests for both a two-state and three state model were carried out with the three-state model being rejected in favour of the two-state model. Table 5 reports the results of the model while Figure 7 plots the estimated states along with a plot of the dependent variable hp_t. We estimate the Markov switching model over the full estimation period of 1981Q3-2019Q4 as well as over 1981Q3-2013Q4. The later estimation window was chosen as 2013 is generally accepted as the end of the housing crash in Ireland with prices returning to positive values in the preceding quarters. Both estimation periods produce very similar results. The MS model clearly identifies two separate states – State 1 and State 2. The summary statistics across both states provided in Table 5, as well as the outline of the states provided by Figure 7 would roughly suggest that State 1 and State 2 can be mostly characterised as the high (or rising) and low (or falling) housing price periods respectively. There are exceptions to this, for example, in the full estimation window, the MS defines housing prices between 2013-2018 by the 'low' state despite average growth of 6.7 percent in the period. This suggests that the model performed better using the shorter estimation period to 2013Q4.

The results, across both estimation windows, show that in State 1 (high state) there is no evidence of significant persistence in prices or changes in the level of income and interest rates having an impact on housing price growth. Interestingly, credit is highly significant and correctly positively signed while the growth of housing stock is not significant in this state. These results are consistent across both estimation windows. This finding suggests that when Irish housing prices have been high or rising, credit growth has been the significant driver whereas variables such as the interest rate, income and housing stock have had little or no impact. This result is consistent with that of Period 2 in the multiple breakpoint model. The growth rate of credit in State 1 of the MS model across both estimation windows is also high at 20.0 per cent (1981Q3-2019Q4 window) and 14.8 per cent (1981Q3-2013Q4 window) respectively. Moving to State 2, the interest rate, although correctly signed is once again insignificant reiterating the point made by Caldera and Asa Johansson˚ (2013). The level of persistence is moderate to high across both estimation windows and the growth rate of income is a highly significant driver of housing price growth in the longer estimation window (1981Q3 to 2019Q4). The change in housing stock goes from being insignificant in State 1 to highly significant in State 2 while the model suggests that credit no longer has a significant impact on housing price inflation.

Table 5: Markov Switching Estimation (1981Q3-2019Q4)

	1981Q3-2019Q4		**1981Q3-2013Q4**	
	State 1	**State 2**	**State 1**	**State 2**
α	-0.01	-0.01	-0.02	-0.03*
	(0.01)	(0.01)	(0.01)	(0.01)
β_1	0.20*	0.62***	0.16*	0.67***
	(0.11)	(0.10)	(0.10)	(0.10)
β_2	0.01	0.72***	-0.02	0.38
	(0.14)	(0.26)	(0.13)	(0.27)
β_3	-1.12	-3.77***	-1.17	-2.48***
	(1.04)	(1.25)	(0.87)	(1.09)
β_4	0.28***	-0.01	0.31***	0.01
	(0.05)	(0.03)	(0.05)	(0.04)
β_5	0.01	-0.01	0.01***	0.01
	(0.01)	(0.01)	(0.01)	(0.01)
p_{11}	0.95	-	0.96	
p_{12}	0.05		0.04	
p_{21}		0.05		0.04
p_{22}		0.95		0.96
Exp. Duration	18.8 Quarters	17.6 Quarters	23.5Quarters	14.7Quarters
Mean of hp_t	5.4%	-3.0%	5.6%	-7.5%
S.D. of hp_t	6.5%	9.1%	6.4%	7.1%%

***, **, & * denotes significance at the 1, 5 and 10% levels respectively. Standard errors are in parenthesis.

Overall, the results of both the breakpoint and MS model paint an interesting picture with regard to the dynamics between housing prices, credit and housing stock in the Irish residential property market over the last forty years. Firstly, the results suggest that credit has had a significant impact on Irish housing price movement in periods when prices are high. The reaction of housing prices to changes in housing stock in a high housing price period would appear to be negligible, however. On the other hand, the results also suggest that when Irish housing prices have been low or negative, a change in housing stock has had a significant impact on prices. Furthermore, the impact of supply on prices would appear to have been greatest in the 1980s, however, in the post financial crisis period, supply also have a contractionary impact on prices.

5. Conclusion

The widespread acknowledgement that actual housing completions in the Irish housing market are persistently below the structural level of housing demand has resulted in a number of initiatives by the Irish policymakers to stimulate the levels of housing supply. At the same time, concerns around affordability in the market has given rise to the question amongst policy makers and stakeholders generally in the Irish market whether a significant increase in house building (i.e. that aligns actual completions with the structural demand) will ultimately lead to a moderation in housing price inflation, if not an actual decline in prices. Therefore, the estimates presented in this paper are of particular importance. It is clear that estimating the responsiveness of prices to changes in supply is a complex challenge, given the degree of structural change observed in the Irish market over the sample period in question. This is particularly the case given the emergence of the Celtic Tiger in the mid 1990's and the distortionary role played by the substantial credit bubble observed in the Irish market from the early 2000's. This necessitates particular care being employed in choosing the appropriate sample period when addressing this empirical question.

Our results demonstrate that, in an Irish context, the estimates of the responsiveness of price to supply vary significantly according to the sample period used. Over the period 1994 to 2007, which corresponds to an economic boom and a credit bubble, there would appear to be very little relationship between supply and housing prices. However, this is not the case when estimates are based on a more steady-state period. Also, even in periods when quantity supplied does exert an impact on prices, the magnitude of the change can vary. From a policy-makers perspective, it is imperative therefore that in appraising the impact of further supply, estimates generated in a period absent of significant structural change are used. While the results based on a steady-state period indicate that increasing supply will temper housing price inflation, this is clearly in the absence of any other changes occurring in the market.

Appendix

Figure 1: Ireland's Gross Income Per Household (€)

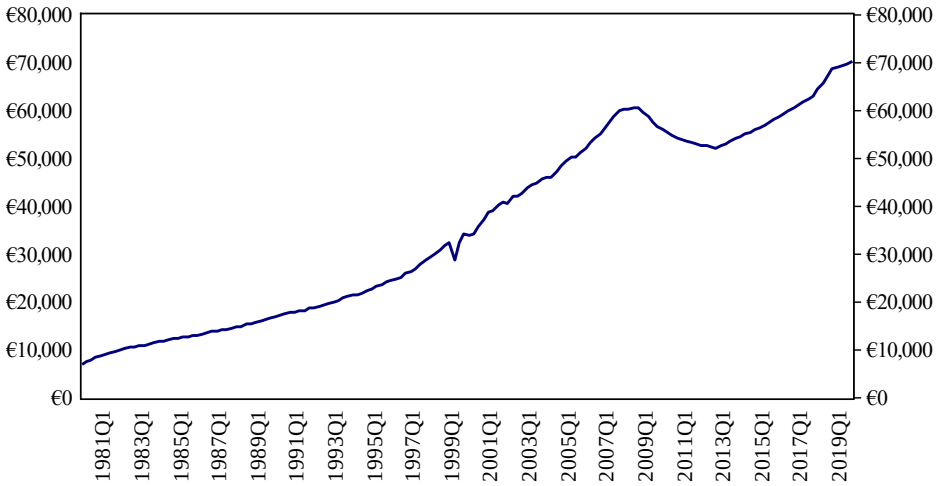


Figure 2: Ireland's Nominal housing Price Index (2002Q4 = 100)

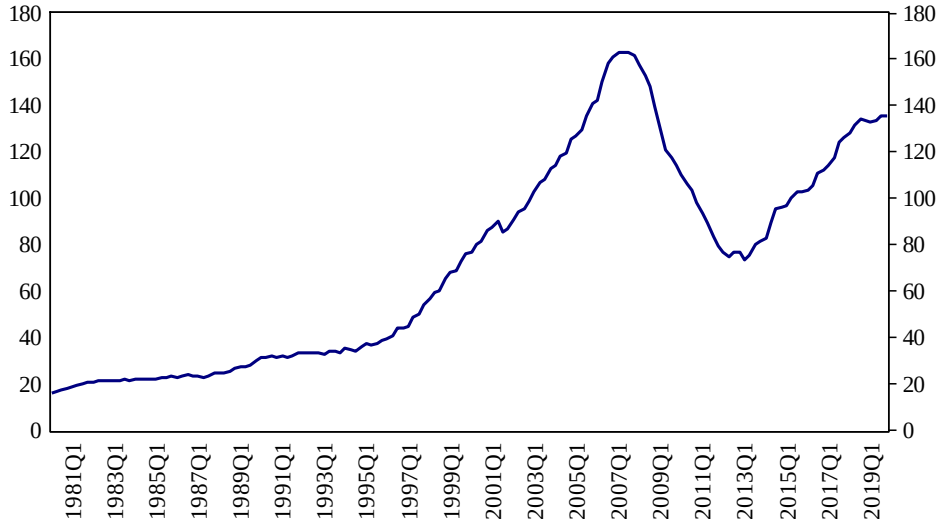


Figure 3: Ireland's Housing Supply: (units)

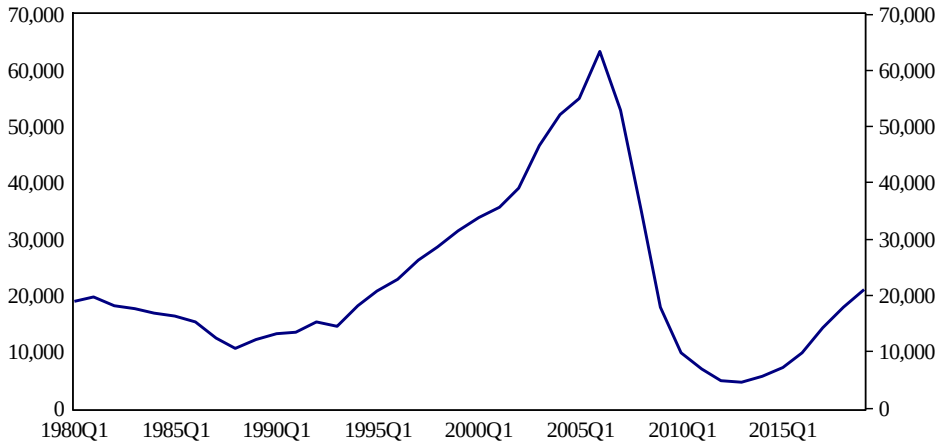


Figure 4: Ireland's Private Sector Credit and Total Household Deposits (€million)

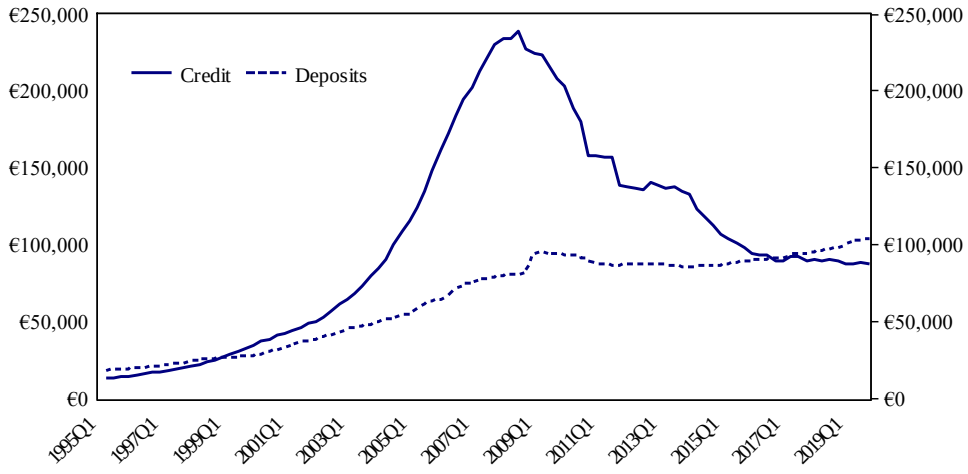


Figure 5: Ireland's Ratio of Private Sector Credit to Personal Disposable Income

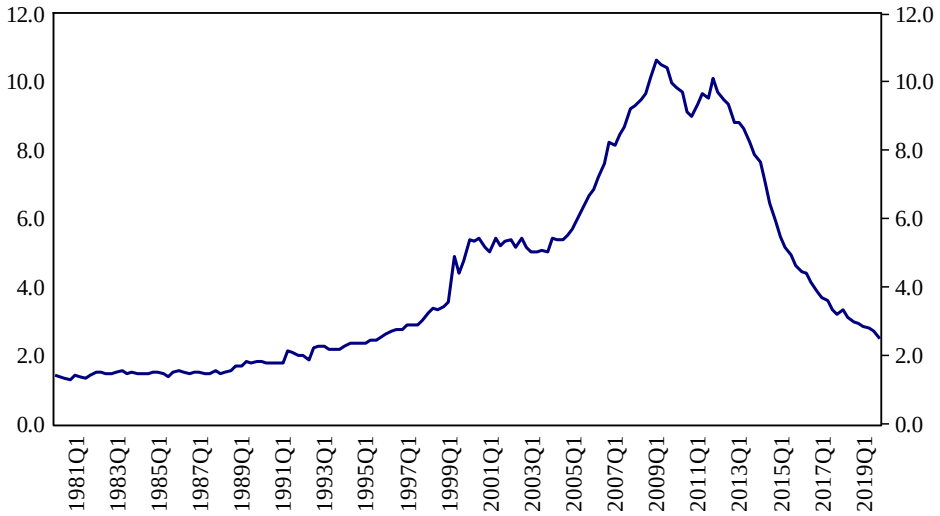


Figure 6: Growth Rate of Real Housing Prices and Breakpoints

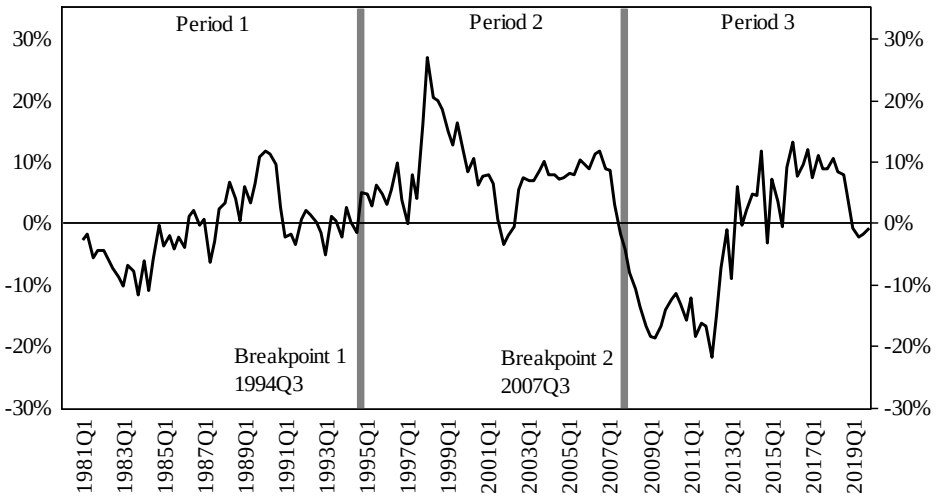
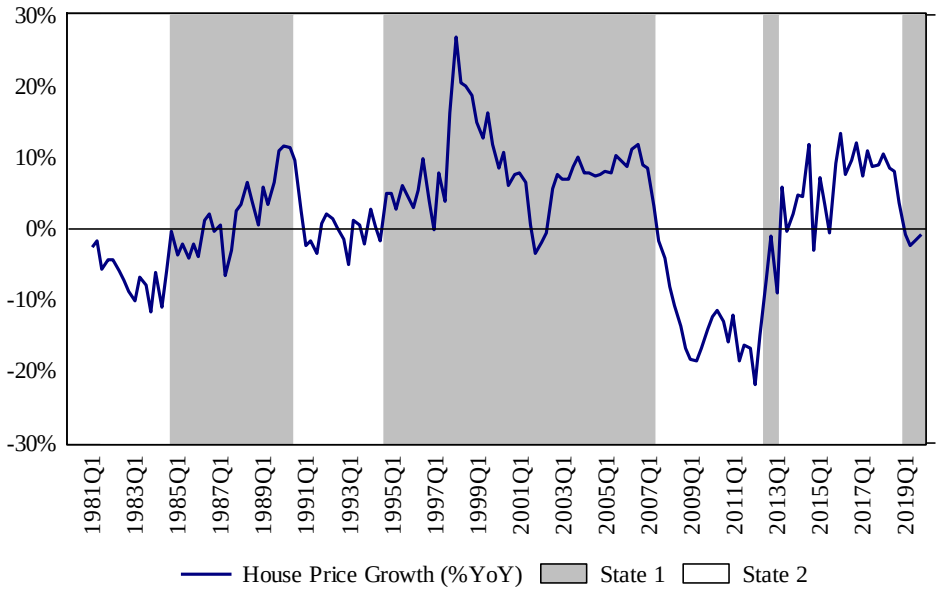


Figure 7 : Growth Rate of Real Housing Prices and Markov Switching States



References

Andrews, D. W. K. (1993). Exactly median-unbiased estimation of first order autoregressive/unit root models. *Econometrica*, *61*(1), 139–165. Retrieved from http://www.jstor.org/stable/2951781

Anundsen, A. K., & Heebøll, C. (2016). Supply restrictions, subprime lending and regional us house prices. *Journal of Housing Economics*, *31*, 5472. Retrieved from https://www.sciencedirect.com/science/article/ pii/S1051137716000048 doi: https://doi.org/10.1016/j.jhe.2016.02.001

Azad Chowdhury, R., & Maclennan, D. (2014). Regional house price cycles in the uk, 1978-2012: a markov switching var. *Journal of European Real Estate Research*, *29*(5), 345-366. Retrieved from https://doi.org/10.1108/ JERER-02-2014-0014 doi: https://doi.org/10.1108/JERER-02-2014-0014

Bai, J., & Perron, P. (2003). Computation and analysis of multiple structural change models. *Journal of Applied Econometrics*, *18*(1), 1-22. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1002/jae.659 doi: https://doi.org/10.1002/jae.659

Bergin, A., & Garcia-Rodriguez, A. (2020). *Regional demographics and structural housing demand at a county Level* (No. RS111). Economic and Social Research Institute (ESRI). Retrieved from https://ideas.repec.org/b/esr/ resser/rs111.html doi: /10.26504/rs111.pdf

Caldera, A., & Asa Johansson.˚ (2013). The price responsiveness of housing supply in oecd countries. *Journal of Housing Economics*, *22*(3), 231-249. Retrieved from https://www.sciencedirect.com/science/article/pii/ S105113771300020X doi: https://doi.org/10.1016/j.jhe.2013.05.002

Cheshire, P., & Buyuklieva, B. (2019). Homes on the right tracks: greening the green belt to solve the housing crisis. *London School of Economics and Political Science, LSE Library*.

Cronin, D., & McQuinn, K. (2021). House Prices and the Credit-Driven Household Demand Channel: The Case of the Irish Economy. *Credit and Capital Markets*, *54*(2), 199-221. Retrieved from https://ideas.repec.org/a/kuk/ journl/v54y2021i2p199-221.html doi: 10.3790/ccm.54.2.199

Dufrenot, G., & Malik, S.´ (2012). The changing role of house price dynamics over the business cycle. *Economic Modelling*, *7*(3), 1960-1967. Retrieved from https://www.sciencedirect.com/science/article/pii/ S0264999312001642 doi: https://doi.org/10.1016/j.econmod.2012.05.029

Fontana, A., & Corradin, S. (2013). House price cycles in europe. *European Central Bank, Working Paper Series*, *1613*.

Gueorguiev, N., Yehoue, E. B., Arena, M., Antoshin, S., Ralyea, J., & Lybek, T. (2017, November). *Credit Growth and Economic Recovery in Europe After the Global Financial Crisis* (IMF Working Papers No. 2017/256). International Monetary Fund. Retrieved from https://ideas.repec.org/p/imf/ imfwpa/2017-256.html

Hamilton, J. D. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica*, *57*(2), 357–384. Retrieved from http://www.jstor.org/stable/1912559

Hamilton, J. D. (2010). Regime switching models. In B. L. Durlauf S.N. (Ed.), *Macroeconometrics and time series analysis, the new palgrave economics collection.* London: Palgrave Macmillan.

Honohan, P. (2009). Policy paper: Resolving ireland's banking crisis. *Economic and Social Review*, *40*, 207-231.

Kelly, & McQuinn, K. (2014, September). On the Hook for Impaired Bank Lending: Do Sovereign-Bank Interlinkages Affect the Net Cost of a Fiscal Stimulus? *International Journal of Central Banking*, *10*(3), 95-128. Retrieved from https://ideas.repec.org/a/ijc/ijcjou/y2014q3a3.html

Kelly, J., & Everett, M. (2004). Financial liberalisation and economic growth in ireland. *Central Bank Quarterly Bulletin*, *4*.

Koop, G., & Potter, S. M. (1999). Bayes factors and nonlinearity: Evidence from economic time series. *Journal of Econometrics*, *88*(2), 251-281. doi: 10.1016/ S0304-4076(98)00031-1

Kostarakos, I., Varthalitis, P., & McQuinn, K. (2022). The role of intangible investment in ireland: A growth accounting perspective. volume = 719, journal = Economic and Social Research Institute (ESRI) Working Paper Series.

Lyons, R., & Muellbauer, J. (2013). *Explaining the bubble: House prices, user-cost and credit conditions in Ireland, 1975-2012* . Retrieved from http://www.ronanlyons.com/wp-content/uploads/2014/ 12/Lyons-Muellbauer-House-Prices-and-Credit-Conditions-in -Ireland-DRAFT.pdf doi: f

McCarthy, Y., & McQuinn, K. (2017). Credit conditions in a boom and bust property market: Insights for macro-prudential policy. *The Quarterly Review of Economics and Finance*, *64*(C), 171-182. Retrieved from https://ideas .repec.org/a/eee/quaeco/v64y2017icp171-182.html doi: 10.1016/ j.qref.2016.08.00

McQuinn, K. (2004). A model of the irish housing sector. *Research Technical Papers*, *1/RT/04*.

Miles, D., & Monro, V. (2019). Uk house prices and three decades of decline in the risk free real interest rate. *Bank of England working papers*, *837*.

Mulheirn, I. (2019, August). *Tackling the UK housing crisis: is supply the answer?* (Report). UK Collaborative Centre for Housing Evidence. Retrieved from https://housingevidence.ac.uk/wp-content/uploads/ 2019/08/20190820b-CaCHE-Housing-Supply-FINAL.pdf

Nneji, O., Brooks, C., & Ward, C. W. (2013). House price dynamics and their reaction to macroeconomic changes. *Economic Modelling*, *32*, 172-178. Retrieved from https://www.sciencedirect.com/science/article/pii/ S0264999313000576 doi: https://doi.org/10.1016/j.econmod.2013.02.007

Pruser, J., & Schmidt, T.¨ (2021). Regional composition of national house price cycles in the us. *Regional Science and Urban Economics*, *87*, 103645. Retrieved from https://www.sciencedirect.com/science/article/pii/ S0166046221000053 doi: https://doi.org/10.1016/j.regsciurbeco.2021
.103645

Quandt, R. E. (1960). Tests of the hypothesis that a linear regression system obeys two separate regimes. *Journal of the American Statistical Association*, *55*(290), 324–330. Retrieved from http://www.jstor.org/stable/2281745

Wren-Lewis, S. (2020). *Evidence and the persistence of mistaken ideas: the case of house prices.* Retrieved from https://mainlymacro.blogspot.com/2020/
01/evidence-and-persistence-of-mistaken.html