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Untangling the nonlinear 'knots' of UK's housing prices

Structured Abstract

Purpose: Housing prices in the UK offer an inspiring, yet a complex and under-explored research area. We investigate the critical factors that affect UK's housing prices.

Design/methodology/approach: We utilize the recently developed nonlinear ARDL approach of Shin et al. (2014) over the period 1969 to 2016.

Findings: We find that both the long-run and short-run impact of the price-to-rent ratio and credit-to-GDP ratio on house prices is asymmetric whilst ambiguous results are established for mortgage rates, industrial production and equities. Apart from the novel framework of analysis, this study also establishes a positive association between house prices and the price-to-rent ratio which suggests a speculative behaviour and could imply the formation of a housing bubble.

Originality/value: It is the first study for the UK housing market that explores the underlying fundamental relationships by looking at nonlinearities hence, allowing house prices to be tied by asymmetric relationships in the long as well as in the short-run. Modelling the inherent nonlinearities enhances significantly our understanding of UK housing market which can prove useful for policymaking and forecasting purposes.

Keywords: Housing Prices, UK, Nonlinear Autoregressive Distributed Lag.

JEL: *C22, R21, R31.*

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1. Introduction

In economic terms, a market is in equilibrium when there is a balance between supply and demand. In the event, however, where supply fails to respond to higher prices, or when prices are affected by factors other than the need to buy as well as the ability to pay or service debt, then house prices become unaffordable or overvalued.

The UK housing market has experienced upward trending prices in real terms along with wide fluctuations of upturns and downturns for more than four decades. As a result, the housing choices and risk patterns associated with such volatile cycles have affected mortgage arrears and gave rise to the buy-to-let phenomenon, hence, leading to increased intergenerational inequality. The complexity and persistence of the housing problem restricts policy-making in providing a sustainable and effective solution for the younger generations.

Undoubtedly, the UK presents a stimulating setting for exploring the factors affecting housing prices in an uncertain, due to Brexit, environment, where house affordability is stretched to the limits. At the same time, the low levels of unemployment in conjunction with the historically low-interest rates and shortages of housing supply have caused house prices to reach unprecedented high levels (Fitch, 2018). Ostensibly, the introduction of government schemes to support first-time buyers as well as the longer time repayment periods for mortgages have allegedly contributed to this upward trend. The median price-to-income ratio remains at its highest level for five years indicating amplified leverage of house-buyers and vulnerability to interest rate increases. It is worth noting that the UK ranks among the OECD countries with the highest price-to-income and price-to-rent ratios. More specifically, the country's price-to-rent is overvalued by around 50% higher than its long-term average, suggesting that the prices have risen faster than rents. Roughly 15% of mortgage debt is on buy-to-let properties while more than ten percentage points of the 150% rise in real house prices between 1996 to 2007 was caused by increased lending to landlords (Economist, 2017).

Recent evidence emphasizes the need for factoring in nonlinearities in the data generating process of real housing prices (André et al., 2017). In view of the scarcity of empirical evidence in the existing literature to account for nonlinearities in UK's housing market, we focus on the critical factors that affect the British housing prices using the recently developed NARDL approach to cointegration vis-à-vis the standard ARDL approach to cointegration (see Pesaran et al. 2001) where a linear path is assumed. To the best of our knowledge, it is the first study for the UK housing market that explores the underlying fundamental relationships by looking at nonlinearities hence, allowing house prices to be tied by asymmetric relationships in the long as well as in the short-run. Apart from the novel framework of analysis, an interesting finding that merits mentioning is the positive association between house prices and the price-to-rent ratio which as a proxy for housing affordability may signal irrational landlords-investors' behaviour or the formation of a housing bubble.

The rest of the paper is organized as follows: Section 2 provides a brief review of the literature whilst section 3 presents the data and methodology. Section 4 discusses the results and finally, section 5 provides some concluding remarks.

2. Literature Review

Identifying interregional differences in UK's house prices has received considerable currency over the last decades. This growing interest in the area has been further motivated by the emerging cyclical patterns observed in the UK housing market. Inevitably, the majority of the studies have been focused on the research hypotheses relating to convergence, divergence, or cyclical behaviour.

On the empirical front, research studies on the existence of a long-run equilibrium relationship across all regional house prices have produced inconclusive evidence (see Rosenthal, 1986; Giussani and Hadjimatheou, 1990; MacDonald and Taylor, 1993; Alexander and Barrow, 1994; Drake, 1995; Ashworth and Parker, 1997; Meen, 1999; Petersen et al., 2002; Cook, 2003 and 2005; Holmes, 2007; Holmes and Grimes, 2008; Abbott and De Vita, 2009; Cook and Watson, 2016).

Regionally, the investigation of the behaviour of house prices in the UK has focused on two propositions: a) regional house prices convergence towards a constant vector for all regional pairs and b) UK regional house prices originate in London and then these are propagated to other UK regions i.e. a ripple effect.

According to Holmes and Grimes (2008) "If the first proposition holds, the ratio between each regional and the national house price will be stationary. If both propositions hold, the process of convergence will occur most rapidly in regions close to London (for example, through migration, spatial arbitrage and equity transfer), with the speed of convergence diminishing with distance from London" (p.1531). In this context, a number of studies have explored the existence of a ripple effect in UK's housing. More specifically, Guissani and Hadjimatheou, (1991) and Alexander and Barrow, 1994) by adopting Granger causality methodology found that there is directional causality that runs from the South East to the North, whereas in a similar vein, Guissani and Hadjimatheou (1991) and Petersen et al. (2002) provide evidence supporting the ripple effect hypothesis by looking at the correlation between house prices.

Furthermore, Holmes and Grimes (2008) using mix-adjusted quarterly data for the UK over the period 1973–2006, found that all UK regional house prices are driven by a single common stochastic trend. They also concluded that the regional speeds of adjustment towards long-run equilibrium are inversely related to distance in the case of all regions within England and Wales whereas in the case of Scotland, the speed of adjustment is considerably slower compared to other regions. In a similar study, Abbot and De Vita (2013), using a mix of adjusted house price data for the UK covering the period 1973:Q4 to 2008:Q4, failed to provide any evidence of long-run convergence among regional house prices.

House purchases are typically financed by a combination of personal income and mortgage loans. In the existing literature, several variables have been put forward in an attempt to explain the observed variability in house prices. According to Arceluz and Meltzer (1973) relative prices, interest rates, income and real wealth are *inter alia* the principal determinants of housing equations whilst for Reichart (1990) regional housing prices react uniformly to national as well as local factors such as population, employment, and income trends.

On the empirical front, the evidence on the relationship between the business cycle and housing prices has been rather controversial. In this context, Davis and Heathcote (2005), in a study on the US market find that house prices and real gross domestic product (GDP) are highly correlated. Further evidence points to a direct association between GDP cycles with housing bubble busts, especially, during downturns (Reinhart and Rogoff, 2008). In the event where real estate has been used as collateral for start-up business loans, Black et al. (1996) provide evidence on the basis of which an increase in real housing equity (a proxy for collateral values) causes a significant number of new businesses to increase. In contrast, Kan et al. (2004) find that the average correlation between residential property prices and real output growth is rather weak, suggesting that the focal point should be the relationship between the real side of the housing market and business cycles. In a different context, Leamer (2007) suggests that the main cause of recessions is the dwindling volume of housing investment rather than house prices whilst Strauss (2013) and Ghent and Owyang (2010) argue that not only housing permits are potentially an effective leading indicator of employment in cities but also outperform traditional indicators such as house prices and wealth, in forecasting state-level job creation and income growth.

Moreover, Iacoviello and Neri (2008) in a study investigating the impact of GDP on the housing market found that the fluctuation of housing investment has a direct impact on GDP whilst Mikhed and Zemčík (2009) noted that in the USA the fall in house prices could negatively affect both consumption and GDP. Tsatsaronis and Zhu (2004) when explored the long-term contribution of GDP through the decomposition of its fluctuation, concluded that it did not exceed 10% of the overall fluctuation in house prices. In Madsen (2012) however, the existing short-term relationship between GDP and the housing market fades away in the longer term.

Recent literature looking at housing price and stock market returns suggests that stock prices of local firms (i.e., headquartered in said city) can be influenced by local pricing patterns for housing, alluding to the likelihood that localized shocks in housing wealth influence investor decisions (Anderson and Beracha, 2010). Furthermore, Louis and Sun (2013) by studying the connection between local housing price growth and long-term abnormal growth of local firms established a negative relationship between past increases in housing prices and abnormal stock returns.

The fluctuations in stock prices since the mid-1990s have rekindled the interest in the impact of asset prices on consumer spending. Despite the fact that over long periods, equity and house prices tend to move together, property prices in a number of countries have acted as a cushion in so far as they absorb negative wealth effects due to equity losses. In this context, Sutton (2002) in a study for six counties provides evidence indicating that stock prices explain a significant proportion of house price fluctuations. Further supporting evidence of equity and house prices is provided by Kakes and Van den End (2004) in a study of the Dutch housing market. In the same spirit, a study by the Bank for International Settlements (2003) finds that house prices follow the stock market with a 2 to 3-year lag. Given that the correlation between equity and house prices reflects a causal relationship, it makes sense to perceive equity prices as a reliable leading indicator in the context of the stock market's forward-looking nature.

Furthermore, several research papers have explored the relationship between rent to house-price movements. More specifically, Gallin (2008) by looking into the capability of the rent-to-price ratio in predicting real rents and prices found that the rent-to-price ratio has some predictive power for real prices but failed to predict changes in real rent.

The interest rate according to Assenmacher-Wesche and Gerlach (2008) is one of the most important macroeconomic determinants of the housing market. They argued that monetary policy not only significantly affects house prices but also real economic activity. In a different spirit, Iacoviello and Pavan (2011) stressed that it is not clear whether monetary policy is strong enough to stabilize house prices without causing fluctuations in other macroeconomic indicators. In this context, Yang and Wang (2012) posit that there is a significant housing price reaction stemming from interest rate fluctuation while Arslan (2010) argued that the intensity of the impact of interest rates on house prices depends on the housing stock.

Empirical studies exploring the behavior of house prices have been conducted for different countries/cities across the globe have produced mixed evidence (for a detailed review see Malpezzi (1999). So far, the dominant empirical frameworks of analysis utilize either time series or panel data analysis. A case in point is Chen and Patel's (1998) study investigating the behaviour of house prices in Taipei. By using Granger causality tests, variance decomposition and impulse response functions found that household income, short-run interest rates, stock price index, construction costs and housing completions Granger-cause house prices. In the same study, evidence of cointegration was also established. In a different study, however, Chen, Tsai and Chang (2007) found no evidence of cointegration in the case of Taiwan. Such a finding was attributed mainly to the existence of structural breaks in the series. Similar evidence was also established by Meen (2002) for the US and UK housing markets, by Apergis (2003) for Greece and by McQuinn and O'Reilly (2008) for Ireland.

Recently, more studies have emerged suggesting that lack of evidence pointing to cointegration between house prices and economic fundamentals might be due to ignoring nonlinearities. More specifically, Kim and Bhattacharya (2009) in a study for the USA and four regions using a smooth transition autoregressive model that accounted for nonlinearities suggested that housing prices reflect nonlinearity and within this context, a few fundamentals Granger cause house prices. Similar results are reported by Zhou (2010) using data from 10 US cities. Finally, Bahmani-Oskooee and Ghodsi (2016) using quarterly data for 52 US states in the context of a nonlinear ARDL approach to cointegration framework, showed that changes in the fundamentals have asymmetric effects on house prices, in both the short and in the long run whereas evidence of cointegration between house prices and fundamentals was found in 30 states including the District of Columbia.

In view of the above, this paper that focuses on the drivers of housing prices purports to offer novel evidence for the UK's housing market by taking into account the nonlinearities in the data.

3. Data and Methodology

The dataset employed comprises annual observations for the UK, covering the period 1969 to 2017 (see Appendix, Table 4 for the definition of variables). As shown in Figure 1, the plot of the housing prices in the UK presents an upward trend, yet interrupted in 1989-90 and 2007-8.

INSERT FIGURE 1

As Figure 2 exhibits, the yearly changes in the housing prices climbed by 26.2% in 1972-73 and slumped by -14.3% in 1974-75. Wild fluctuations, but of lower scale are also evident in 1988-89 as well as in the period around the Global Financial Crisis. Lama and Denis (2014) posit that the UK market has experienced relatively the largest fluctuations in real house prices among the advanced countries. For a detailed account of the UK's bubbly housing market see also Vogiazas and Alexiou (2017).

INSERT FIGURE 2

3.1 The variables

As our analysis revolves around the determinants of house prices, the dependent variable is the real house price index, sourced from OECD's database. The price-to-rent ratio (PTR) and credit (CR) serve as the two key independent variables that are subjected to nonlinear testing while industrial production (IP), mortgage rates (MR) and the stock market index (EQ), are the control variables that proxy the business cycle, housing affordability, monetary conditions along with financial activity. Typically, the equity stock market is classified as a leading indicator of the economy.

We have opted to use the real house price index (HP) which is a reliable measure of residential prices as it instantly tells whether real prices are rising or falling. This key statistic is extensively used across the world by economic and monetary policymakers. Among its professional use, the HP serves also to monitor macroeconomic imbalances and risk exposure of the financial sector.

Our analysis is further supplemented by the price-to-rent ratio (PTR) which provides a fairly good measure of the profitability of owning a house. Furthermore, the PTR metric is perhaps the most commonly used indicator in the UK; it is easy to construct and has an intuitive interpretation (Meen, 2018). For these reasons, the PTR ratio is used as a benchmark for estimating whether it is cheaper to rent or own a property. It should be stressed that the PTR ratio is also used as an indicator for whether a housing market is fairly valued, or follows a pattern of a bubble. The dramatic increase in the PTR leading up to the 2008-09 housing crash in the US was, with hindsight, a red flag for the housing bubble.

Ultimately, the price-to-rent ratio should potentially affect consumer decisions to buy or rent as well as motivates investors' buying patterns (buy-to-hold or buy-to-rent). Normally, the price-to-rent ratio is expected to be positively related to house prices in so far as dwindling affordability (i.e. higher PTR) would cause house prices to go down. As with any metric, the PTR has also its deficiencies; it is well-known that while this ratio compares the economics of buying versus renting, it says little about the overall affordability of buying or renting in a given market and cannot readily be targeted by policy.

Noteworthy, the UK ranks among the OECD countries with the highest price-to-rent ratios as shown in Figure 3. Despite the fact that house prices in the UK seem to be overvalued, yet they continue to rise, hence, rendering the housing market vulnerable to the risk of price correction, especially if borrowing costs were to rise or income growth was to slow down.

INSERT FIGURE 3

Furthermore, persisting low mortgage rates along with a continued availability of mortgage finance imply that money is cheaper to borrow and therefore could boost consumer confidence. In view of this, housing developers jack up their prices as buyers feel confident they can afford more expensive housing. In general, the shortfall in housing stock and available mortgage finance at low rates means that house prices should rise, so a negative relationship between mortgage rates and house prices is expected.

The housing market is cyclical in its nature, thus sensitive to economic and regulatory changes. Research has shown that in most countries, the housing market tends to track the business cycle, with a tendency for the real house-price turning points to lag business cycle upturns and downturns. The lags, however, between house prices and the business cycle exhibit different patterns across different countries (Girouard et al., 2004). In some cases, after the output turning point was hit, house prices appeared to be accelerating hence suggesting that prices of residential properties adjust to cyclical conditions in an unpredictable fashion. We have opted for industrial production as a proxy for the business cycle. On the basis of the existing literature, the effect of the industrial production on housing prices is ambiguous, although intuitively one would expect a positive association as in a sense the chosen proxy measures the resilience of the economy. Broadly, the troughs and crests of industrial production coincide with the housing prices in our sample, although the pattern in industrial production appears smoother compared to housing.

The relationship between changes in credit supply and house prices has been extensively researched (see for instance Goodhart and Hofmann, 2008; Davis and Zhu, 2011; Arestis and Gonzalez, 2014). House prices can be seen as an asset price, thus determined by the discounted projected cash flows of the property. As credit supply increases, lending interest rates go down, hence, stimulating expected economic activity. The resulting lower discount factors in conjunction with higher expected returns cause house prices to rise.

The inclusion of the equities index purports to proxy activity in the financial system (see Gounopoulos et al., 2012). Fluctuating prices affects the value of the collateral as well as acts as a leeway for potential borrowers hence making such loans less risky (see also, Muellbauer and Gavin, 2000 and Baude 2005). A positive association between house prices and the equities index is expected.

3.2 The methodological framework

The standard ARDL approach to cointegration assumes that the adjustment of variables follows a linear path. However, recent empirical evidence suggests that house prices do not evolve in a linear manner. To untangle the knots of housing prices in the UK we use the nonlinear ARDL (NARDL) approach developed by Shin et al., (2014) which makes use of the decomposition strategy developed by Granger and Yoon (2002) and Schorderet (2002) to decompose a stationary variable into positive and negative variations. In this way, we can capture asymmetries in both the long run and in the short run as well as account for the extant asymmetries in the dynamic adjustment. Thus, the NARDL approach to cointegration not only introduces nonlinear adjustment process into testing procedure but also enables us to determine whether the short-run and long-run effects of the regressors on UK's housing prices are symmetric or asymmetric.

In passing, Pesaran et al. (2001) linear ARDL or bounds testing approach, which is the conventional cointegration approach, has several advantages over other cointegration methodologies, in that it is more efficient in modelling cointegrating relationships in small samples (Pesaran and Shin, 1999).

The estimation process consists of a number of steps First, we decompose the movements of CR and PTR into negative and positive partial sums. For the long-run effects to be valid, we initially establish cointegration. The stationarity of the variables is examined using standard unit root tests to determine their order of integration. It is worth noting that the Pesaran et al. (2001) bounds testing approach is equally applicable to Shin et al. (2014) specification (see also Bahmani-Oskooee and Ghodsi, 2016). Subsequently, the NARDL models are estimated by imposing a maximum of four lags (on each first-differenced variable and use the Akaike information criterion[1] (AIC) to select the optimum lags. Finally, the speed of adjustment to long-run equilibrium after a shock is captured by the error correction representation. The models are also subjected to a number of diagnostic - the Breusch-Godfrey LM test for serial correlation, the Breusch-Pagan-Godfrey test for heteroskedasticity, the CUSUM stability tests - to ensure that the estimation results are statistically robust.

[1] Stock and Watson (2007) recommend choosing the model suggested by AIC rather than Schwartz information criterion (SIC) arguing that including more parameters is better than omitting significant parameters which is the case in this paper.

The general form of the estimated model which is a variant of the models encountered in the literature (see for instance, Baffoe-Bonnie, 1998; Beltratti and Morana, 2010; Cesa-Bianchi et al. 2015; Liu et al. 2016) is expressed as follows:

$$HP_t = \beta_0 + \beta_1 X_t + \varepsilon_i \quad (1)$$

where β_0 is the constant; β_1, is the slope coefficients; ε_t is the error term satisfying the usual assumptions, and the subscript t stands for time; *HP* denotes real house price index and X is vector of other control variables such as the variable mortgage rate, total industrial production index, equities index, credit-to-GDP ratio and the price-to-income ratio.

4. Empirical Results and discussion

Prior to engaging with the estimation results, the unit root tests suggest that our dataset consists of a mixture of *I(0)* and *I(1)* variables as is the case in most macro variables (see Table 5 in Appendix).

INSERT TABLE 1

In Table 1, the F-statistics for the bounds testing exceed the 1% critical value for the upper bound in two cases ($NARDL_1$ and $NARDL_3$) and the 2.5% in one case ($NARDL_2$), i.e. rejecting the null hypothesis of *no long-run relationship*. More specifically, the bounds testing approach generated an F-statistic of 7.344, 3.840 and 11.575, hence rejecting the null hypothesis of no cointegration at the 1%, 2.5% and 1% respectively, level of significance.

Following Greenwood-Nimmo et al. (2013) we estimate NARDL specifications where a symmetry condition is imposed separately on a NARDL model with respect to PTR, a NARDL model with respect to CR and a NARDL model with respect to PTR and CR jointly, in order to avoid potential misspecification either of the long-run relationship or of the model dynamics.

Table 2 presents the short run estimates while Table 3 presents the long run ones for the three NARDL models. The short-run specifications of the NARDL models provide insight on the underlying dynamic relationships between house prices and the independent variables.

As far as the short-run effects of $NARDL_1$ are concerned, house prices are found to be positively affected by its own lagged values, and the nonlinear elements of the price-to-rent ratio. The rest of the variables have a negative and significant effect on house prices. When examining the nonlinear effects of the credit-to-GDP ratio in $NARDL_2$, the results appear to be akin to $NARDL_1$. It is worth noting, however, the negative and significant impact of only the positive nonlinear element of credit-to-GDP ratio and the positive effect of the equities index on houses prices in line with other studies (Davis and Zhu, 2011; Sutton, 2002). In the third NARDL model where nonlinearities of both PTR and CR are explored in the same regression specification, both variables exhibit significant nonlinear effects on house prices. The rest of the variables exhibit similar effects as in the previous two models. Finally, the coefficients of the error correction terms (ECM) in all models are found to be negative and statistically significant, hence, indicating a relatively speedy adjustment from disequilibria of the previous year's shock, back to the long-run equilibrium in the current year.

INSERT TABLES 2 AND 3

In the long run estimates, the presence of asymmetry for both the positive and negative PTR and MR in our models is established through Wald tests. As it can be seen in Table 3, the null hypothesis of equality is rejected, albeit marginally in $NARDL_2$, hence indicating that there is asymmetry in the *long run impact* of both PTR and CR on house prices.

The dynamic multipliers trace the evolution pattern of the price-to-rent ratio and credit at a given level, following a shock to a price at a different level, hence, providing us with the path to the new equilibrium. Figures 7-10 present the dynamic multipliers of the chosen variables for the three models o to house prices. As we can see in Figure 7, for instance, house prices respond at the same rate in the short run, to price-to-rent ratio increases and decreases whilst equilibrium correction takes place after 3-4 years; that is, it converges to the long-run estimate for the positive difference in about 3 to 4 years. The behaviour of dynamic multipliers is consistent with both short and long-run asymmetry. In so far as the significance of the rest of the variables is concerned, the equity market index (EQ) and the mortgage rates (MR) are found to be significant and of the expected signs only in the first NARDL model, whilst the results for industrial production is rather mixed. More specifically, in the second NARDL model, IP is found to be significant at the 10 percent level of significance bearing a negative sign whereas in the third NARDL model it is highly significant and bearing the expected sign. Finally, the CUSUM tests (Brown et al., 1975) for the selected NARDL models shown in Figures 4-6, indicate no issues of parameters' instability. As a robustness check to the results obtained through the NARLD approach, pairwise Granger causality tests were performed, presented in Table 5 in the appendix. The results of the Granger causality tests are broadly aligned with the NARDL specifications, thus confirming our baseline results.

Overall, it can be argued that the results confirm to a large extent the a-priori expectations from theory and empirical studies. Two qualifications, however, have to be made regarding the expected signs of the industrial production in $NARDL_2$ and the mortgage rate in $NARDL_1$. In particular, the negative sign of industrial production in one of the estimations might reflect the fact that the state of the business cycle is considered to be a coincident indicator of economic activity. A similar result is also reported by Adams and Fuss (2010) in their DOLS estimations across different countries. Mortgage rates (MR) are also being observed to exhibit an unexpected positive sign which to some extent can be explained by the impact of the zero lower bound on interest rates on the housing market as well as the institutional and wealth effects of investors in the particular market which are not captured in this study.

The inverse relationship between mortgage rates and house prices was largely observed until the Global Financial Crisis in 2007-8. In the aftermath of the financial meltdown the existing, up to that point, a negative relationship was, at least temporarily, broken as both interest rates and housing prices fell sharply. Further anomalies were also observed during the housing bubble of 1987-89 where house prices rose and mortgage rates rose significantly. The fact that a positive relationship was observed over that period with prices and interest rates rising in unison, raises questions about the consistency of the negative relationship.

Additionally, it should be stressed that rising mortgage rates do not occur in a vacuum in so far as these reflect an expanding and growing economy where inflation, employment, real wages, are rising, hence, improving house affordability for the workforce, increasing demand for houses, and consequently creating upward pressure on housing prices. Factors, such as limited new supply and population growth should also be considered. In a nutshell, anomalies do occur, which reflect a broader economic influence between interest rate variability and supply-demand conditions which cannot be reasonably accounted for due to data limitations.

Furthermore, the fact that the price-to-rent ratio is positively associated with the housing prices indicates that despite decreasing affordability and long-payback periods, both households and investors continue to buy houses, driving prices further up. Such behaviour might be due to several factors, one of which could be the presence of speculative behaviour across all different types of homebuyers. The issue of affordability and rental yield may be subrogated by the prospect of capital appreciation, which is in some way assisted by the availability of "cheap" and long-term mortgage credit fueled by the abundant liquidity in the system. Previous literature on the impact of credit expansions on housing price has also established a strong and positive link (see for instance, Kuang 2014 and Favara and Imbs 2015).

5. Conclusions

Undoubtedly, the UK housing market is one of the most volatile housing markets in the developed world, boasting four boom and bust cycles since the 1970s. The potential distortion in the housing market has driven up arrears and repossession rates, giving rise to disproportionately distributed wealth and housing (un)affordability. This paper revisits the housing price debate by focusing on the critical factors that affect UK's housing prices using the nonlinear ARDL approach driven by recent evidence on the nonlinearity of housing prices. The novelty and contribution of this study lie in the fact that, in the case of the UK, this is the first study that explores the underlying fundamental relationships by looking at nonlinearities, hence, allowing house prices to be tied by asymmetric relationships both in the long as well as in the short-run. In this context, two of the key variables envisaged in the literature - the price to rent ratio and credit - have provided the platform upon which nonlinearities have been scrutinized.

An interesting finding that merits attention is the positive association between house prices and the price-to-rent ratio which as a proxy of housing affordability points to a speculative buyer behaviour, hence suggesting that despite decreasing affordability and long payback period, both households and landlords continue to buy houses, inflating prices which in turn could lead to the formation of a housing bubble. Equally interesting are the findings pertaining to the linkages between house prices and mortgage rates and industrial production. The sign ambiguities observed are indicative of a more complex behaviour existing in broader economic factors that feedback into the UK housing market, a result supported by the pairwise Granger causality tests. In theory, prices for housing properties should be determined by the supply and demand conditions. In practice, however, it appears that such a contention might be questionable, in that existing prices in the UK are distorted by several factors and anomalies often unrelated to the fundamentals. Modelling the inherent nonlinearities in UK's housing prices provides valuable insight that can utilized for policymaking as well as forecasting purposes. In a deregulated financial environment credit expansion fueled by short housing supply can add significantly to the upward trend in house prices. A potential failure of the market to rectify the subdued supply implies that house prices can become overvalued, unaffordable as well as destabilizing factors for the entire economy. Housing affordability is, therefore, a key element that policymakers should consider when formulating housing policies. Standard measures of housing affordability as implied by the relationship between house prices, house rents, earnings and incomes suggest that the affordability gap is increasing uncontrollably. The fact that housing is not affordable from a social point of view vis-à-vis a strictly market equilibrium angle, poses risks for the UK that policymakers should address promptly.

Finally, in the context of the methodological framework utilized in this study, is should be noted that asymptotic critical values for the t and F cointegration tests (for both NARDL as well as ARDL approaches) are bound to suffer from size distortions in the direction of excessive rejection of the null, when the null is true. In view of this limitation, bootstrapping should be used to increase the confidence in the results generated.

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TABLES

Table 1. Bounds test estimates for ARDL and NARDL specifications.

Model Specification	F-statistic	Level of Significance	Low Bound	Upper Bound
$NARDL_{1\ (k=6)}$	7.344	1%	2.660	4.050
$NARDL_{2\ (k=6)}$	3.840	2.5%	2.320	3.590
$NARDL_{3\ (k=7)}$	11.575	1%	2.540	3.910

Note: The term k denotes the number of estimated parameters. The results suggest the presence of cointegration among the variables used.

Table 2. Short run effects for the three NARDL specifications

NARDL$_1$ / PTR (3, 3, 1, 2, 3, 3, 3)			NARDL$_2$ / CR (4, 4, 1, 4, 4, 4, 2)			NARDL$_3$ / PTR & CR (4, 2, 4, 4, 4, 4, 4, 4)		
Variable	Coefficient	Std. error	Variable	Coefficient	Std. error	Variable	Coefficient	Std .error
D(HP(-1))	0.3477	0.1213***	D(HP(-1))	0.3064	0.2383	D(HP(-1))	0.2523	0.1397
D(HP(-2))	0.5168	0.1824**	D(HP(-2))	0.7399	0.2581**	D(HP(-2))	0.4440	0.2134*
D(PTR$^+$)	0.5791	0.0692***	D(HP(-3))	0.4509	0.2424*	D(HP(-3))	0.5902	0.2415**
D(PTR$^+$(-1))	-0.0569	0.1816	D(CR$^+$)	-0.0984	0.1131	D(PTR$^+$)	0.5557	0.1387***
D(PTR$^+$(-2))	-0.2957	0.1803	D(CR$^+$(-1))	-0.2291	0.1217*	D(PTR$^+$(-1))	0.0002	0.2685
D(PTR$^-$)	0.8576	0.1049***	D(CR$^+$(-2))	0.0175	0.1296	D(PTR$^+$(-2))	0.4344	0.2505
D(CR)	-0.0319	0.0567	D(CR$^+$(-3))	0.1776	0.0898*	D(PTR$^+$(-3))	-0.6544	0.2036**
D(CR(-1))	-0.1400	0.0739*	D(CR$^-$)	0.2274	0.1388	D(PTR$^-$)	0.9672	0.2063***
D(EQ)	0.1245	0.0522**	D(PTR)	0.7550	0.0665***	D(PTR$^-$ (-1))	-0.2787	0.2467
D(EQ(-1))	-0.0416	0.0736	D(PTR(-1))	0.2050	0.2709	D(PTR$^-$ (-2))	0.1569	0.2431
D(EQ(-2))	-0.0465	0.0480	D(PTR(-2))	-0.1231	0.2615	D(PTR$^-$ (-3))	-0.1714	0.1930
D(MR)	0.3876	0.2352	D(PTR(-3))	-0.3246	0.1901	D(CR$^+$)	0.1635	0.1175
D(MR(-1))	-0.1497	0.2415	D(IP)	-0.1235	0.1705	D(CR$^+$(-1))	-0.2919	0.0745***
D(MR(-2))	-0.5612	0.2483**	D(IP(-1))	-0.1316	0.1685	D(CR$^-$)	0.1478	0.1207
D(IP)	-0.0034	0.1205	D(IP(-2))	-0.3563	0.1833*	D(CR$^-$(-1))	0.1625	0.1452
D(IP(-1))	-0.1164	0.1225	D(IP(-3))	0.1132	0.1240	D(CR$^-$(-2))	-0.3922	0.1238***
D(IP(-2))	-0.1843	0.0884**	D(MR)	0.3576	0.2986	D(CR$^-$(-3))	0.3076	0.1911
EC(-1)	-0.4284	0.1173***	D(MR(-1))	0.6031	0.4831	D(MR)	0.9129	0.2670***
			D(MR(-2))	0.2839	0.4968	D(MR(-1))	-0.2827	0.4601
			D(MR(-3))	-0.6815	0.3653*	D(MR(-2))	0.4816	0.5282
			D(EQ)	0.0916	0.0468*	D(MR(-3))	-1.3103	0.4237***
			D(EQ(-1))	0.0716	0.0527	D(EQ)	0.0785	0.0434
			EC(-1)	-0.6505	0.1925***	D(EQ(-1))	0.3109	0.0775***
						D(EQ(-2))	-0.1095	0.0613
						D(EQ(-3))	0.1142	0.0716
						D(IP)	-0.5722	0.1360***
						D(IP(-1))	-0.0058	0.1794
						D(IP(-2))	-0.5663	0.1442***
						D(IP(-3))	-0.1689	0.1293
						EC(-1)	-0.5367	0.1166***

Notes: (***), (**), (*) denote significance at 1%, 5% and 10% levels, respectively. The number of lags used for both the dependent variables and the dynamic regressors was four. The numbers in parentheses in the first line of the panel denote the optimal number of lags for each variable in accordance with the order of variables in the NARDL models.

Table 3. Long run estimates for NARDL specifications.

Long run coefficients (NARDL$_1$)			Long run coefficients (NARDL$_2$)			Long run coefficients (NARDL$_3$)		
Variable	Coefficient	Std. Error	Variable	Coefficient	Std. Error	Variable	Coefficient	Std. Error
PTR$^+$	0.8269	0.0712***	CR$^+$	0.1569	0.0472***	CR$^+$	1.4792	0.4990**
PTR$^-$	0.8682	0.1400***	CR$^-$	-0.1311	0.1053	CR$^-$	-1.3294	0.5767*
CR	0.1573	0.0856*	PTR	0.7382	0.0622***	PTR$^+$	-0.4840	0.5169
EQ	0.2742	0.1291**	IP	-0.1249	0.0653*	PTR$^-$	1.3838	0.2635***
MR	1.2236	0.6627**	MR	-0.7375	0.6676	MR	1.1563	0.7961
IP	0.0371	0.0909	EQ	0.1100	0.0723	EQ	-0.2997	0.2255
						IP	0.4830	0.1233***
Symmetry	5.014(0.04)		-1.486(0.16)			0.080(0.94)$_{CR}$ / -1.250(0.26)$_{PTR}$		
LM test	3.091(0.07)		2.945(0.09)			2.466(0.21)		
BPG test	0.893(0.60)		0.533(0.92)			4.123(0.06)		

Notes: LM stands for the Breusch-Godfrey test for serial correlation and BPG for the heteroskedasticity test of Breusch-Pagan-Godfrey; (***), (**), (*) denote significance at 1%, 5% and 10% levels, respectively.

Appendix

Table 4. The Dataset.

Name	Definition	Sources
HP	Real house price index (1969-2017)	OECD
PTR	Price to rent ratio (1969-2017)	OECD
IP	Production of Total Industry, index 2010=100, Annual.	OECD
MR	Variable Mortgage Rates in the United Kingdom, percent per annum.	Bank of England
EQ	Financial Markets, Equities, Index 2010=100.	IMF
CR	Credit-to-GDP ratio, credit to private non-financial sector.	BIS

Table 5. Unit root tests.

Variable	Order of integration
HP	*I(0)*
PTR	*I(1)*
IP	*I(1)*
MR	*I(0)*
EQ	*I(0)*
CR	*I(1)*

The order of integration was determined by both ADF and KPSS unit roots tests.

Table 5. Pairwise Granger Causality Tests (1969-2017)

Null Hypothesis	F-statistic	Prob.
HP does not Granger Cause IP	4.20478	0.0068
IP does not Granger Cause HP	1.26691	0.3009
HP does not Granger Cause CR	3.37211	0.0192
CR does not Granger Cause HP	2.88005	0.0362
HP does not Granger Cause EQ	1.71793	0.1681
EQ does not Granger Cause HP	2.65362	0.0492
HP does not Granger Cause PTR	2.09781	0.1013
PTR does not Granger Cause HP	2.69586	0.0461
HP does not Granger Cause MR	2.22952	0.0858
MR does not Granger Cause HP	4.69888	0.0038

Notes:
(a) We reject the null hypothesis that HR does not Granger cause IP; we cannot reject the one that IP does not cause HR (uni-directional causality).
(b) We reject the null hypothesis that HR does not Granger cause CR, and vice versa (bi-directional causality).
(c) We cannot reject the null hypothesis that HR does not Granger cause EQ; we reject the null hypothesis that EQ does not Granger cause HR (uni-directional causality).
(d) We cannot reject the null hypothesis that HR does not Granger cause PTR; we reject the null hypothesis that PTR does not Granger cause HR (uni-directional causality.
(e) We reject the hypothesis that HR does not Granger cause MR and vice versa (bi-directional causality).

FIGURES

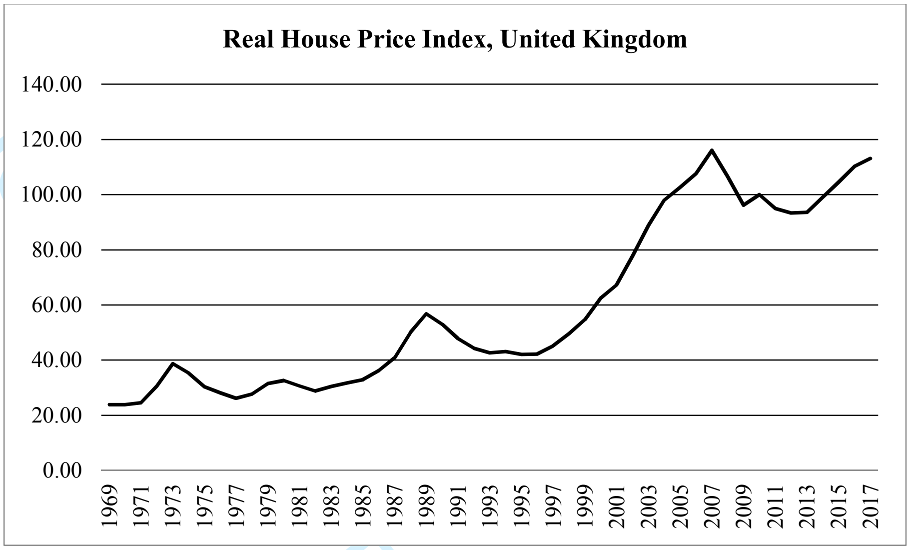


Figure 1. Real House Price Index, United Kingdom (2010=100)

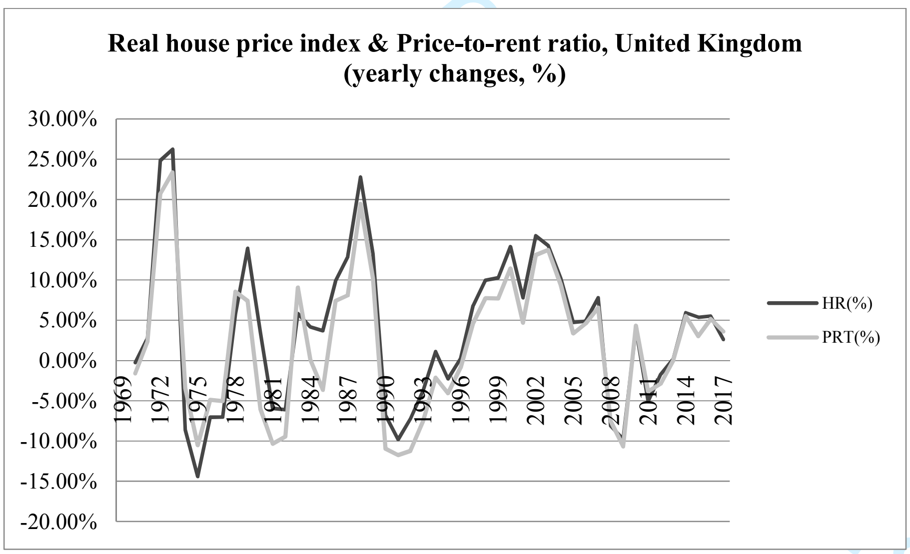
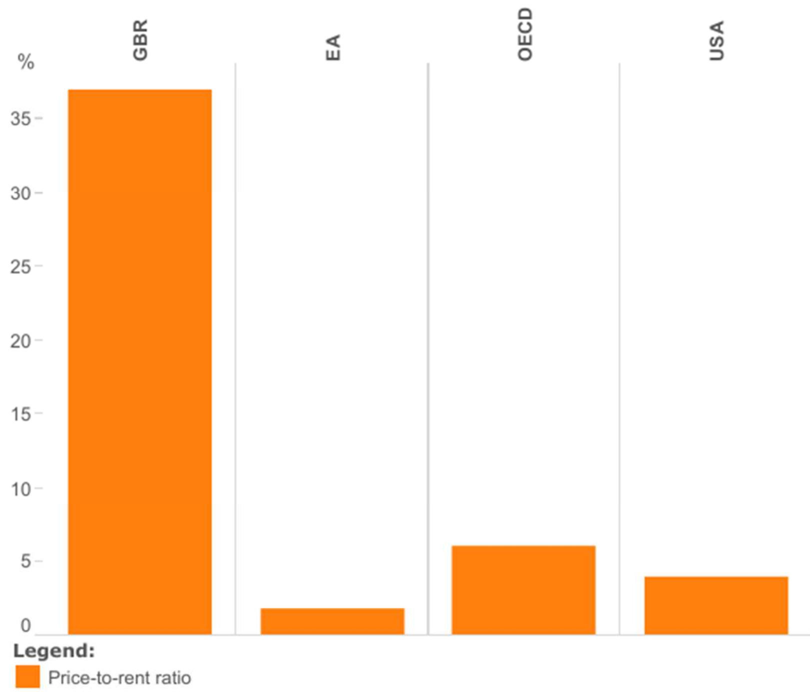


Figure 2. Real House Price Index (HR) and Price-to-Rent ratio (PTR), United Kingdom (yearly changes, %).



Source: OECD, Housing prices database and OECD Economic outlook database. GBR: Great Britain, EA: Euro area.

Figure 3. Price-to-rent percentage over or undervaluation relative to long-term average.

FIGURES APPENDIX

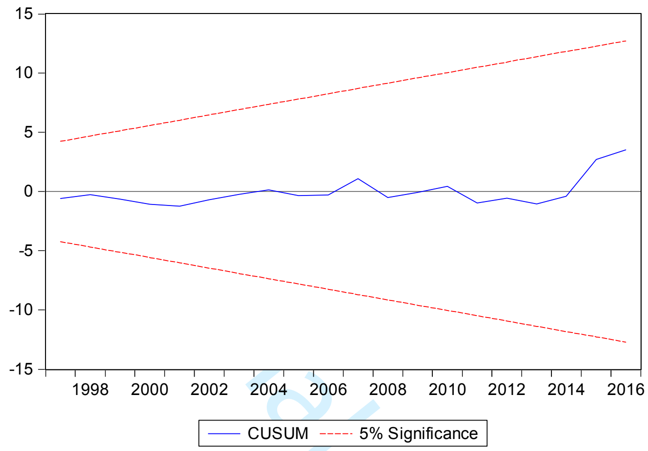


Figure 4 CUSUM Test for $NARDL_1$

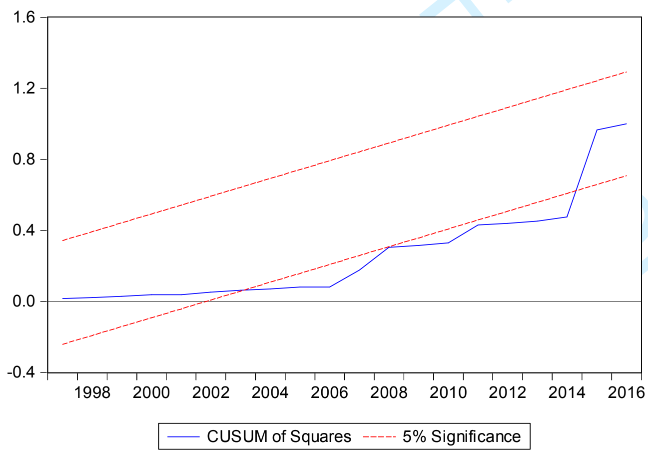


Figure 4.1 CUSUM of Squares Test for $NARDL_1$

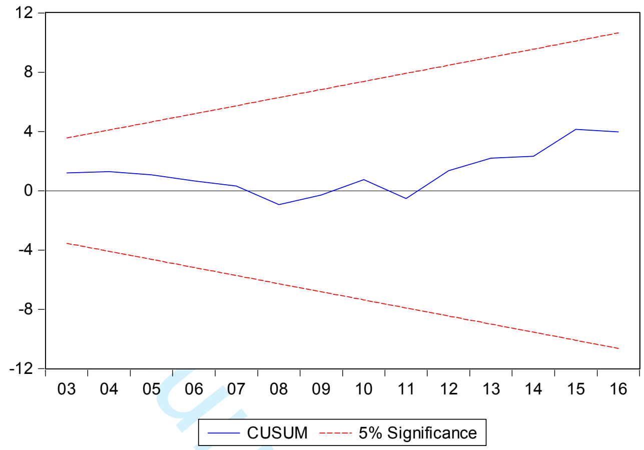


Figure 5 CUSUM Test for $NARDL_2$

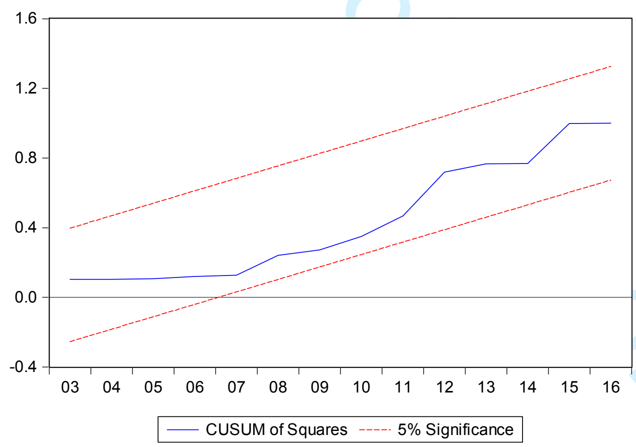


Figure 5.1 CUSUM of Square Test for $NARDL_2$

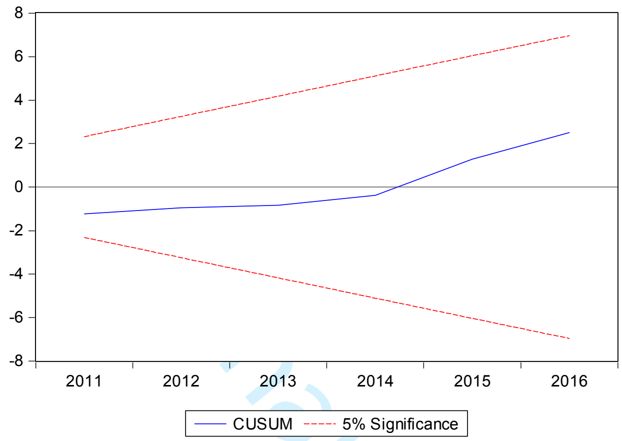


Figure 6 CUSUM Test for $NARDL_3$

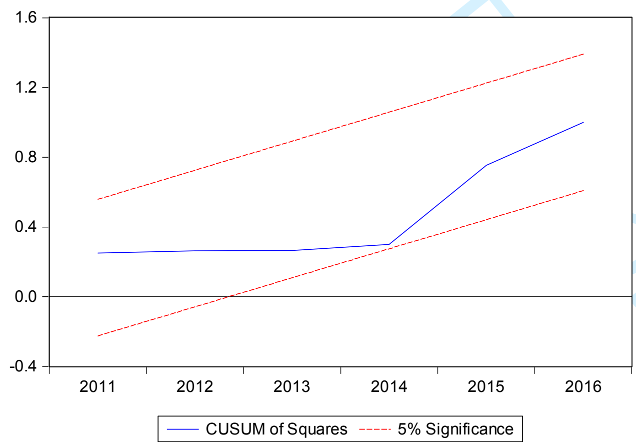


Figure 6.1 CUSUM of Squares Test for $NARDL_3$

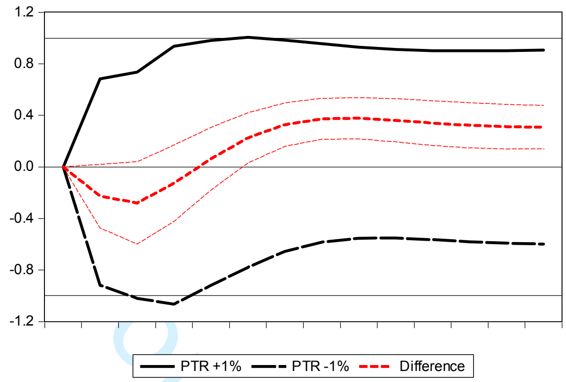


Figure 7 Multiplier Graph: Price to Rent ratio (PTR) /NARDL$_1$

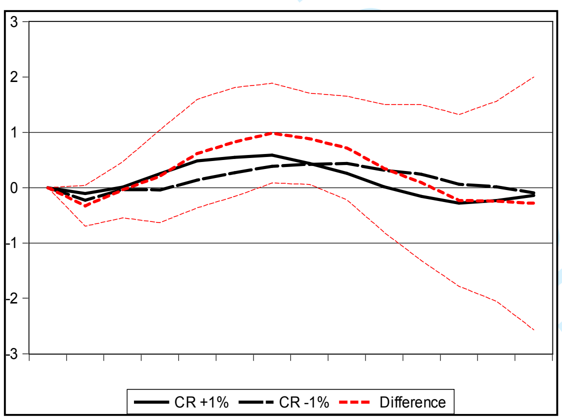


Figure 8 Multiplier Graph: Credit (CR) / NARDL$_2$

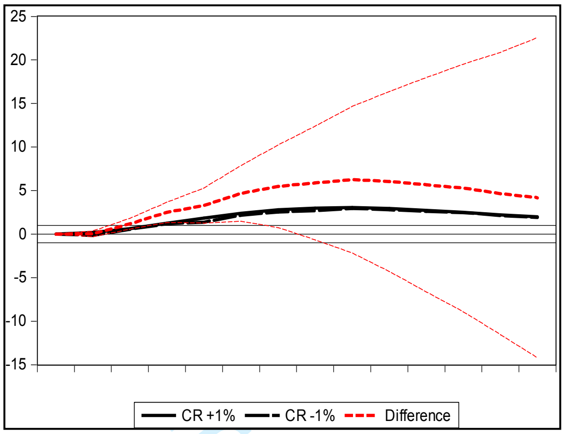


Figure 9 Multiplier Graph: Credit (CR) / $NARDL_3$

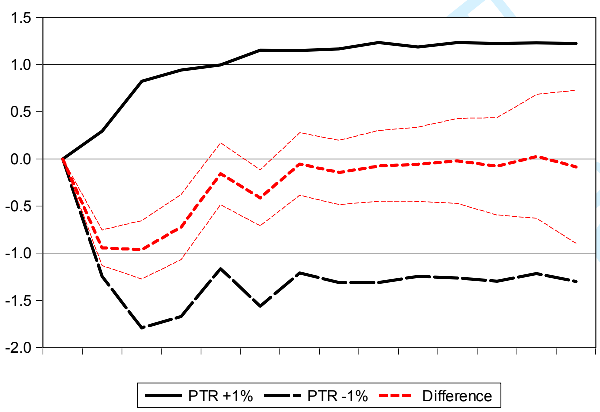


Figure 10 Multiplier Graph: Credit (PTR) / $NARDL_3$

Untangling the nonlinear ‘knots’ of UK’s housing prices

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