# Testing for rational bubbles in the UK housing market

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## Abstract

Over the past decade, the UK has witnessed significant booms in the real estate market, and real estate prices have experienced increases. Since 1997, the housing price has almost tripled which is far beyond the long-term trend. To identify the existence of housing bubbles is a crucial issue for any country to prevent possible damage to economies and outbreaks of financial crises. The objective of this paper is to empirically discuss the existence of a house price bubble in the UK through employing a co-explosive vector autoregression (VAR) model, originally applied to stock markets. The results demonstrate that both house price and rental price show explosive behaviour during their growth, which provides litle evidences to support the presence of real estate bubbles in the UK.

**Keywords**: real estate bubble, housing price, VAR, co-explosive, cointegration tests

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## 1. Introduction

During the past two decades, real house prices have experienced fast growth and have increased greatly globally (Muellbauer, 2012). Many major countries have encountered unprecedented increases in housing price since 1970. The case is true in not only developing economies but also developed countries, including the UK. Indeed, the average housing price level in the UK has increased over the past few years, and it continues to grow at an unprecedented rate. In particular, the annual rate of growth in real estate prices was estimated at 10.1% in March 2016, an extremely high level not seen since July 2014 (FT, 2016.4.7). Housing in the UK is an important sector because it makes vital contributions to economic activity and growth (Cooper, 2004). Therefore, the rapid development of the real estate market has raised concerns of the public about the possible presence of a housing bubble. Soaring real estate price levels have also become subjected to heated debate among academics; a review on property bubbles given by Grover and Grover (2014).[[1]](#footnote-1)

Motivated by the above concerns of an overheating global real estate market (Muellbauer, 2012) – and based on the present value model for house price determination – this study seeks to identify the presence of a speculative bubble in the housing market in the UK. The risk of a collapse of the house price bubble was at the heart of the sub-prime mortgage crisis in 2007 in the US and subsequently of the global financial crisis in 2008. Due to the subprime mortgage financial crisis started in the US in 2007, housing prices show significant movements which affected the state of the economy worldwide. However, it is noted in the literature that the increase in housing prices prior to the 2007 financial crisis was also large. The lessons learned by the global financial crisis need to be used to reshape financial regulation by targeting housing price bubbles (Martin, 2011). Therefore, it is interesting to examine the behaviour of housing prices. According to Kivedal (2013) “an important reason for monitoring housing prices is the substantial negative effects affecting households if the housing prices decrease”. Iacoviello (2005) explains that an increase in housing prices will cause a positive wealth effect for the households (i.e. it may increase aggregate demand). The presence of housing bubbles is a crucial topic for the global market for the purpose of preventing possible damage on economies and outbreak of financial crisis. Furthermore, the recent financial crisis produced major shocks in the UK housing market, and UK house prices have experienced a number of large swings (Tse et al., 2014, Miles, 2015).

The dynamics of the UK housing market are complex (Antonakakis & Floros, 2016). House prices react immediately and strongly to monetary policy shocks, while house price movements are function of other factors as well. For example, the 2007 financial crisis shows regional differences in London due to the fact that London is a world financial centre. Also, UK has experienced large financial innovations over the last decade. Overall, there have been changes in UK housing which can lead to booms, busts and breaks (Miles, 2015). The last 20 years have seen much volatility in UK house prices. The boom and bust had consequences in the housing sector as the drop in house and building prices was associated with an economy-wide recession, which was by some measures the most severe since the Great Depression. Accordingly, for an important financial market like the UK, the unawareness of the presence of bubbles tends to cause significant negative consequences on not only the soundness of its own economy but also the worldwide economic development. In the view of policymakers, this study would be applied to establishing effective policy approaches (Liang & Cao, 2007).

A comprehensive range of literature has covered the examination of the real estate sector all around the world. Many studies focus on the house price behaviour, the ripple effect in house prices and the price-volume relationship (Tsai, 2014, Clayton et al., 2010, Cook & Thomas, 2003). According to Tsai (2014), a significant gap usually exists between the buying and selling prices in the UK. He reports that the 2000 dot.com bubble and the 2008 global financial crisis caused by the bankruptcy of Lehman Brothers in the US, resulted in house price convergence correction or adjustment behaviour. Other studies focus on the determination of whether a bubble exists in the housing market. For instance, Dreger & Zhang (2013), Hou (2010), Hui & Yue (2006), Ren et al (2012) and Shih et al (2014) have built an insight into the real estate market in China, while Goodman & Thibodeau (2008), Mikhed & Zemčík (2009) and McCathy & Peach (2004), have examined the house price bubble in the US. There is also previous literature such as Bone & O’Reilly (2010), Clark et al (2010), Garino & Sarno (2004) and Zhou & Sornette (2003) focusing on the UK situation. Some studies report a bubble in UK housing (Barrell et al., 2004, Zhou & Sornette, 2003), while others report no evidence (Nickell, 2005; Cameron et al., 2006). It is generally accepted that the UK housing industry has become a faster growing sector all around the world, and these worldwide real estate conditions have further emphasized the significance of solving the problem of potential housing bubbles. However, there is a debate in the existing literature on whether there is a bubble in the real estate market. Moreover, the UK housing bubble problem has gradually become a significant issue for the global researchers to prevent economic crisis. In order to test the existence of real estate bubbles, diverse methods and models have been proposed in previous studies. For example, unit root and cointegration methodology using panel data is applied by Mikhed & Zemčík (2009), Chan et al. (2001) and Dreger & Zhang (2013). Roche (2001) and Kim & Min (2011) propose a regime-switching regression model. However, little attention has attracted the co-explosive behaviour of housing price and rental price. It can be viewed as a powerful bubble detecting model, that allows for both cointegration between housing price and fundamentals, together with an explosive bubble component. In this regard, Kivedal (2013) is an exception.[[2]](#footnote-2) Against this background, the aim of our study is to investigate the existence of a real estate bubble in the UK by means of a co-explosive VAR model. To this end, we use UK data over the period of 1980 Q4 to 2007 Q4 of real estate price and actual rental price. The UK has experienced episodes of strong increases in real house prices, as well as in price-income and price-rent ratios (Giglio et al., 2016); accordingly, between 1995 and 2005, the price-rent ratio in the UK had more than doubled. Our research findings shed light on the explosive behaviour not only in house prices but also in rental prices. Our findings do not support the presence of a house price bubble in the UK during the sample period.

The remainder of this paper is organised as follows. Section 2 provides a critical review of existing literature on the real estate bubble. In Section 3, the methodology and data are described and justified. In Section 4, research findings are presented. Finally, section 5 concludes and summarises the main findings and provides some relevant implications.

## 2. Literature review

### 2.1.Background

Housing has been the subject of bubble-related attention in recent years (Giglio et al., 2016). In the past decade, the remarkable upward housing prices and the potential bubble concern has absorbed the attention of the public and scholars. The total value of residential property in developed economies has increased nearly $40 trillion between 2000 and 2005, which reached the combined GDP of these countries (Economist, 16th July 2005). After the 2007 US financial crisis and the following global financial crisis, this controversy has been raised for academic interests, frequently. The real estate sector experienced an unprecedented appreciation in the UK. House prices tripled during the decade from 1997 to 2007, over and above the long run trend (Bone & O'Reilly, 2010). The upward trend was then reversed in 2007 following the outbreak of the US subprime mortgage crisis and the global financial crisis (Clark et al, 2010). However, in 2014 the housing price was 7.8% higher than in the preceding year in the UK, the highest annual rate of growth since 2007 (BBC, 2014.3.6). Moreover, this price level was just below the peak of the last burst with no signs of slowing (Blackmore, 2014.2.28).

The reason why the issue of housing bubbles has become a prevalent topic, is that there is certain mechanisms in theory under which a house price bubble would cause disadvantageous influences. Primarily, the gross value of real estate in most of the economies is much more significant than the value of financial assets invested by household, and the proportion of house in the whole household wealth is crucial (Cerný et al, 2010). Indeed, a collapse in the house price bubble can have adverse effects on the economy (McCathy & Peach, 2004, Mikhed & Zemčík, 2009, Dreger & Zhang, 2012 & Kim & Min, 2011). For instance, the housing bubble is generally viewed as the key element of the recent global financial crisis (Galí, 2014). Under the circumstance when bubble exists, the whole economic growth is retarded even in the long run (Grossman & Yanagawa, 1993). This is because a bubble is equivalent to an unproductive asset; the trading of real estate generally absorbs capitals away from the productive area. Housing bubbles can also affect the economy through inefficient wealth allocation and influence the stability of the financial sector (Kim & Min, 2011). If the housing bubble is neglected, national or even global crisis can be an ultimate consequence of such events (Zhou & Sornette, 2003, Kim & Min, 2011 & Hou, 2010).

### 2.2. Conceptual framework

In theory, the fundamental factors are linked to house prices through certain mechanisms. The Interest rate, for example, is closely connected with the changes in the house price level through two channels. Primarily, lower interest rates would be displayed in lower mortgage rates, which raises the public demand for houses and therefore house prices because of lower cost in purchasing houses (Courchane & Holmes, 2014 & Basco, 2014). Easier access to credit based on low mortgage rates, drives purchasers into the real estate industry (Macdonald, 2010). Also, once there is a lagged decrease in mortgage rates, borrowers would in the short run increase their repayment transactions to finish the house purchase process earlier before the costs increase. This also motivates the upward movements in real estate prices (Courchane & Holmes, 2014). Conversely, if the cost of mortgage becomes a heavy burden as a result of higher rates, buyers may be pushed away from the market (Macdonald, 2010). Secondly, in a circumstance of lower interest rates, the return of other assets with fixed incomes, such as bonds, would be decreased compared with the return on houses. This could increase the need for real estate and thus raise the real estate price (Courchane & Holmes, 2014). Moreover, when interest rates are low, creditors will explore substitute investment tools rather than lending. Housing investment with speculative purpose, which is not ideal at higher interest rate, can then become an optimal choice (Arce & López-Salido, 2011). Also, excess liquidity into the market resulting from the low interest rate is also an essential channel through which the house price is boosted (Kim & Min, 2011).

Rent, being regarded as the future dividend or return of the investment in houses, is also closely linked to house price (Courchane & Holmes, 2014). Primarily, it is regarded in theory as the main component of formulating the fundamental housing price. Fundamental-based property price should reflect the present value of the future dividend flows, which is rental income (Black et al, 2006). On the other hand, due to the fact that the house stock cannot react to changes directly, the increase in rent leads more people to purchase houses rather than renting, which would cause higher real estate price (Gholipour, 2013). Lower user cost of housing relative to market renting implies that it is cheaper to buy than to rent. Therefore, growth in the demand to buy a house can occur and thereby house price increases (Dreger & Zhang, 2013). Moreover, real estate prices can have an impact on rent price return. Higher house price indicates higher return from constructing houses, which would generate larger house stocks and lower rents in the future. Thus, the result of lower discounted present value implies that fundamental-based price is reduced comparing to the market price, and bubble is generated (Blanchard &Watson, 1983).

Finally, some economic factors are expected to make a contribution to the change in house price. For instance, economic activities such as, employment function through affecting household income, and GDP, are used as an indication of economic activities. These are all key elements in considering the issue of demand for real estate, and thus real estate price level (Gholipour, 2013). When the unemployment rate in one city is lower, it brings a speedy inflow of population seeking jobs in that city (Macdonald, 2010). Since these people would have a demand for houses as their homes, this demand drives the real estate price level up.

### 2.3. Related studies

It is generally accepted that the housing industry has become a fast growing sector all around the world, and worldwide real estate conditions have further emphasized the significance of solving the problem of potential housing bubbles (Muellbauer, 2012). However, there is a debate in existing literature on the existence of a bubble in the real estate market.

Several studies analyse the controversy of the existence of housing bubbles, and diverse methods and models have been proposed (see Shi, 2017; Martínez-García & Grossman, 2010; Xie et al., 2019; Xu & Oxley, 2018; Pan, 2019, among others). Unit root and cointegration methodology using panel data applied by Mikhed and Zemcík (2009), Chan et al (2001), Dreger & Zhang (2012) among others, has been a popular method of testing real estate bubbles. This approach has been widely used in the bubble test in many countries and cities. For instance, regarding house as an investment instrument, Mikhed and Zemcík (2009) construct a present-value model to illustrate the relationship between house price and cash flows in the US. The cointegration and Granger causality tests between house price and rent are then conducted. Similar to this viewpoint, the study of Chan et al (2001) investigating Hong Kong, uses a rental income as a fundamental to construct a fundamentals-based model with misspecification errors and rational bubbles. For the case of the UK, Black et al (2006) include quarterly data of real disposable income, discount rate and retail price index from 1973 to 2004. Dreger & Zhang (2012) and Shih et al (2014) are examples that employ cointegration analysis in China’s real estate market. It is noteworthy that Hui & Yue (2006) make a combination between cointegration test and generalized impulse response analysis, in exploring housing price bubbles in Hong Kong, Beijing and Shanghai from 1997 to 2003. Furthermore, regime-switching based model is also prevalent among previous research examining the house price bubble problem in various economies. By using a regime-switching regression model, Roche (2001) examines the dynamics of house prices in Dublin, whereas Kim & Min (2011) estimate the housing bubbles in Korea from a national scale. Wilhelmsson, (2020), examines the importance of the housing market for the transmission mechanism by estimating a structural VAR (SVAR) model for the Swedish economy. Nocera and Roma, (2017), use a Bayesian stochastic search variable selection SVAR model to investigate the heterogeneous impact of housing demand shocks on the macro-economy and the role of house prices in the monetary policy transmission, across euro area countries. Bulligan, (2010), presents an empirical analysis of the role of the housing market in the macroeconomy in Italy. Also using an SVAR model, he finds evidence that monetary policy strongly affects the behavior of real house prices and investment. Unlike the aforementioned studies, Zhou & Sornette (2003) apply a log-periodic power-law model over the period of 1992-2003 for the UK to identify the presence of housing bubble. In the study of Lai & Van Order (2017), a dividend discount model is adopted in the housing market of US areas, to test for the long run and short run relationships between house prices and rent to price ratios. Furthermore, the explosive feature in a bubble model, has been investigated in previous studies such as Homm and Breitung (2012) and Phillips, Shi & Yu (2015). Homm and Breitung (2012) propose a comparison among several tests such as Chow-type DF and the. Busetti–Taylor and supremum ADF tests which are used to examine explosive rational bubbles. Similarly, Phillips, Shi & Yu (2015) apply a generalised supremum ADF test, to test for explosiveness over unit root in stock prices. Karakoyun and Yildirim, (2017), examine demand-side factors of the real estate sector in Turkey in order to examine whether house price increases in the country can be designated as a bubble. According to their results, it can be asserted that the house price increases in Turkey cannot be evaluated as a bubble in the long run. Asal, (2019), investigates the presence of a housing bubble using Swedish data and finds evidence for rational housing bubbles with explosive behavioural components beginning in 2004.

Among these previous studies, Zhou & Sornette (2003), Black et al (2006), and Garino & Sarno (2004) find unambiguous evidence of bubble-type behaviour in the real estate market. Through comparing the situation of the US and the UK during the same period, Zhou & Sornette (2003) assert that a real estate bubble had been generated steadily in the UK from 2000 to 2003, and it could cause negative influence on the recovery of the economy. In addition, Garino & Sarno (2004) state that there are two bubbles present in the UK real estate market that cannot be justified by fundamentals during the sample period. One at the end of 1980s and the in the late 1990s, which is coherent with history; the other still continuing at the end of the period in 2002. McMillan & Speight (2010) also suggest clear and significant evidence supporting a non-fundamental part with explosive features in UK real estate prices. The above results are in contrast with the conclusion proposed by Black et al (2006), who excludes the possibility of a rational housing bubble created by non-fundamental factors during the period of 1973-2004 in the UK. However, he proposes a non negligible role of intrinsic bubble in generating market house prices. The overvalued portion in the real estate price can be explained evenly by an intrinsic part and price dynamics. Clark et al. (2010) not only states that there are signs of bubbles in the path of real estate prices during the period of 2000 to 2007, but also raise a view that people who are in the market obtain tacit knowledge about whether to invest in properties. Finally, Giglio et al. (2016) examine the housing markets in Singapore and the UK during a period of boom-bust cycles (1995-2013), and provide a setting with a good ex ante chance of detecting a bubble; however, their results show that no classic rational bubble is actually present.

### 2.4. Gaps in literature

In the literature review, the housing bubble problem has gradually become a significant issue for researchers to prevent economic crisis. In order to test the existence of real estate bubbles, diverse methods and models have been proposed in previous studies through different aspects. Unit root and cointegration methodology using panel data has been a popular way of testing real estate bubble (Mikhed&Zemčík, 2009, Chan et al, 2001 & Dreger & Zhang, 2013). Roche (2001) and Kim & Min (2011) conducted their research to examine the dynamics of house prices using a regime-switching regression model. However, none of the previous models are capable of analysing both cointegration and explosiveness at the same time (Engsted, Hviid& Pedersen, 2016). To this end, co-explosive vector autoregression (VAR) model has been introduced, which is an approach that was originally utilized in testing bubbles in the stock market; one example is Engsted and Nielsen (2012). It is seldom applied to the real estate sector although the rental income for housing is similar to dividends for equities. One exception is Kivedal (2013) who adopts this method to the housing market in the US. The advantage of this co-explosive approach is to allow for both unit root and explosive root in the time series so that the housing price and rental price do not necessarily have a common trend (Engsted et al., 2016). Apart from the non-stationary cointegration between housing price and fundamentals, this model also allows for an explosive component representing the bubble part. This is a vital character for bubble detecting which was failed to be addressed in the previous research (Engsted et al., 2016). As a result, the primary aim of our research is to conduct the empirical test of house price bubble in the UK through the co-explosive VAR approach.

### 2.5. Contributions

In general, this study may provide new knowledge and perspective into the previous viewpoint on the existence of real estate bubbles in the UK. Contrary to the statements that housing bubble in the UK is examined in many past studies, such as McMillan & Speight (2010) and Clark et al (2010), this study raises the new consideration of explosiveness of both real estate and rental prices. With the application of the co-explosive VAR model, this study proposes the possibility of non-bubble behaviour in explosive housing price, when there is an explosive pattern in rental price as well. Comparatively new focus has been guided into testing for housing bubbles in the UK to provide a new concept for regulators when monitoring and regulating the development of the real estate sector. It is especially important to construct a well-considered and suited analysis to test the housing bubble for the UK, considering that UK is a vital financial market to support effective policy approaches. It might also be a good reference for profit-seeking investors in the UK, in order to reshape their knowledge in setting up their invested portfolios and avoid bubble burst risk.

## 3. Data and Methodology

### 3.1. Data description

Our sample period includes many major events occuring in the UK housing market – for example, the deregulation of the mortgage market in the 1980s, and the decrease in demand following the early 1990s recession (Zhang et al., 2020). We extend the recent papers of Domeij and Ellingsen (2020) and Zhang et al. (2015) using data from 1980s. Domeij and Ellingsen (2020) argue that none of their analysis constitutes evidence in favor of a rational bubble in UK housing markets for the period 1995–2013.

This paper examines the house price bubble assuming the rental price represents the fundamental-based price based on a present value model. Therefore, the house prices of all properties and the actual rental prices for housing in the UK are the two time series data included in our tests. Specifically, the actual rental prices are calculated with the total rentals for housing and the dwelling stock being rented in the market. Both of the two data series are seasonal adjusted quarterly data from 1980Q4 to 2013Q4. The actual house price is taken from the *Nationwide Building Society*, the second largest savings and mortgages provider in the UK through the official *Nationwide* website, while data of rentals for houses is collected from the economic and financial database *DataStream*. Since there is no available statistic of rental price, the actual rental price is calculated with the total rental for housing and the dwelling stock being rented in the market. The statistics for the dwelling stock being rented in the market are gathered from the *Home office* website. The sample chosen in our tests is from 1980Q4 to 2007Q4 due to the fact that the house price climbed significantly until 2007Q4, followed by a severe drop in the global crisis. Since this method applies the idea of explosive component in the house price, it is practical in diagnose bubbles before the time they burst (Kivedal, 2013). It shows that both of these two variables have significant increase path over the time period. For UK housing market description, see Antonakakis et al. (2018).

### 3.2. The Model

Based on the present value model that is measured by the present value of the expected future income, this paper examines the problem of rational housing bubbles. Most papers follow the assumption of rational bubbles, see Gomez-Gonzalez et al. (2017). Recently, Brzezicka (2020) presents a detailed review of the literature relating housing price bubbles and comments on the theory, models and various assumptions. We follow the works of Gomez-Gonzalez et al. (2017) and Brzezicka (2020), and extend the recent paper of Domeij and Ellingsen (2020) on rational bubbles in UK housing markets who use data from 1995-2013. Further, we extend the work of Zhang et al. (2015) on UK house price bubbles; they argue that the UK house price is explosive between October 1999 and April 2008, supporting the evidence of rational bubbles in the UK house prices prior to the Subprime crisis. For more information about the existence of UK housing bubbles and rational bubbles, see Whitehead and Scanlon (2012), Vogiazas and Alexiou (2017), and Brzezicka (2020). Under the concept of rational bubbles, housing investors believe their decision-making is rational, and they are willing to buy overpriced houses with a bubble component growing at an expected rate $i$. They can ultimately receive returns from the price increase at this growth rate (Homm & Breitung, 2012). According to Giglio et al. (2016), the debate over the existence of housing bubbles is an empirical question. The test in this paper, is based on the present value model for house price determination including house prices (P ) and house rental prices (R ). The fundamental price of houses is formulated as the present value of all the future cash flows, known as rental incomes. This is modelled by:

$P\_{t}=\frac{1}{1+i}E\_{t}(P\_{t+1}+R\_{t+1})$ (1)

$M\_{t}=P\_{t}+R\_{t}-(1+i)P\_{t-1}$ (2)

where $E\_{t-1}M\_{t}=0$ is martingale difference under the hypothesis of efficient market. $P\_{t}$ is the house price, $R\_{t}$ is the rental price, and $i$ represents the discount factor. In addition, the definition of “spread” describes the relationship between house prices and rental prices, correcting for $i$. This is shown as:

$S\_{t}≡P\_{t}-{R\_{t}}/{i}$ (3)

Therefore, (2) could also be written as:

$M\_{t}=\left(1+i\right)Δ\_{1}P\_{t}-i∙S\_{t}$ (4)

where$ Δ\_{1}$ shows the first difference of the variable. For the house price dynamic system, the price can be composed by a fundamental component and a bubble part:

$P\_{t}=\sum\_{j=1}^{\infty }(\frac{1}{1+i})^{j}E\_{t}R\_{t+j}+bB\_{t}$ (5)

where $B\_{t}=(1+i)^{-1}E\_{t}B\_{t+1}$, i.e. $B\_{t+1}=\left(1+i\right)B\_{t}+ξ\_{t+1}$and$ξ\_{t+1}$ is a forecast error. Moreover, in order to make the bubble part explosive so as to generate an explosive house price pattern, $i$ needs to be larger than zero.

The economic model under which housing bubble is tested, is Vector autoregressive model (VAR). Assuming $X\_{t}=(P\_{t}, R\_{t})'$ , the unrestricted VAR is primarily conducted.

$X\_{t}=\sum\_{j=1}^{k}A\_{j}X\_{t-j}+μ+ε\_{t}$(6)

Under an error correction form, it is reformulated as:

$∆\_{1}X\_{t}=ΠX\_{t-1}+\sum\_{j=1}^{k}Γ\_{j}Δ\_{1}X\_{t-j}+μ+ε\_{t}$ (7)

where $Γ\_{1}=-(A\_{j+1}+A\_{j+2}+…+A\_{k})$ and $Π=-\left(Ι-A\_{1}-…-A\_{k}\right). $This is model **M**. Since this is a co-explosive model, the largest root should be explosive, which means larger than unity so that this model can be reached. After verifying the model, Cointegration analysis is conducted to test the rank. In this case, the rank is $r=1$. Moreover, after imposing this restriction to the model, the largest root still needs to be more than one. Model **M1** is constructed:

$∆\_{1}∆\_{ρ}X\_{t}=α\_{1}β\_{1}^{'}∆\_{ρ}X\_{t-1}+α\_{ρ}β\_{ρ}^{'}∆\_{1}X\_{t-1}+\sum\_{j=1}^{k-2}Φ\_{j}Δ\_{1}Δ\_{ρ}X\_{t-j}+μ+ε\_{t}$ (8)

where $∆\_{ρ}X\_{t}=X\_{t}-ρX\_{t-1}$ ,$Φ\_{j}=\sum\_{l=j+1}^{k-1}ρ^{j-1}Γ\_{1}$.$β\_{1}$ describes the cointegrating vector, whereas $β\_{ρ}$ represents the co-explosive vector. In order to prove the existence of a bubble in the house prices rather than the rental prices, the hypothesis of non-explosive rental price HR: $βρ=(0, 1)'$ is tested, thus we reduce the model to the restricted model **M1R** as follows:

$∆\_{1}∆\_{ρ}X\_{t}=α\_{1}β\_{1}^{'}∆\_{ρ}X\_{t-1}+α\_{ρ}∆\_{1}R\_{t-1}+\sum\_{j=1}^{k-2}Φ\_{j}Δ\_{1}Δ\_{ρ}X\_{t-j}+μ+ε\_{t}$ (9)

The hypothesis pertaining to the spread in (3) is also tested in the model. Furthermore, $i$ is the discount factor which is linked to the explosive root $ρ=1+i$, reaching the hypothesis $H\_{s}: β1=(1, -1/i)$. To this end, the bubble model **M1RS** is constructed.

$∆\_{1}∆\_{ρ}X\_{t}=α\_{1}∆\_{ρ}S\_{t-1}+α\_{ρ}∆\_{1}R\_{t-1}+\sum\_{j=1}^{k-2}Φ\_{j}Δ\_{1}Δ\_{ρ}X\_{t-j}+μ+ε\_{t}$ (10)

Finally, the house bubble is tested through the efficient market hypothesis. First of all, the martingale restriction outlined in (4) is applied in the model. The model **M1R** (9) is then rewritten as:

$∆\_{1}∆\_{ρ}(P\_{t}+R\_{t})=ι^{'}α\_{1}∆\_{ρ}S\_{t-1}+ι^{'}α\_{ρ}∆\_{1}R\_{t-1}+ι^{'}\sum\_{j=1}^{k-2}Φ\_{j}Δ\_{1}Δ\_{ρ}X\_{t-j}+ι^{'}α\_{1}ζ\_{1}+ι^{'}ε\_{t}$ (11)

where $ι^{'}=(1,1)$. Therefore, it reduces to $M\_{t}=ι^{'}ε\_{t}$ which is denoted as εM after imposing HB:

$$H\_{B}: ι^{'}α\_{1}=-1, ι^{'}α\_{ρ}=-\frac{\left(1+i\right)^{2}}{i}, ι^{'}Φ\_{j}=0, ζ\_{1}=0$$

With the restriction of HS and HB, **M1R** can be reparametrized into the model **M1RSB** according to the marginal equation for $M\_{t}$and condition equation for $∆\_{1}R\_{t}$

$M\_{t}=ε\_{M, t}$ (12)

$∆\_{1}R\_{t}=α\_{1, R}∆\_{ρ}S\_{t-1}+\left(α\_{ρ,R}+ρ\right)∆\_{1}R\_{t-1}+\sum\_{j=1}^{k-2}Φ\_{j,R}∆\_{1}∆\_{ρ}X\_{t-j}+ωM\_{t}+ε\_{R,M,t}$(13)

where $ε\_{R,M,t}=ε\_{R,t}-ωε\_{M, t}$ and $ε\_{M, t}$ are not correlated such that given a known $i=1-ρ$ (12) and (13) are unrelated. Therefore, this model is estimated with the restrictions above to test the bubble issue.

Primarily, the unrestricted VAR is estimated, and this model has been developed using the following tests through the specification testing. The tests for autocorrelation, normality and autoregressional conditional heteroskedasticity are included to guarantee the validity of the model. Residual autocorrelation is the main factor that should be focused on. Accordingly, the optimal lag length is decided as the minimum lag length to fulfil no autocorrelation in residuals. Under this unrestricted VAR, since this is a co-explosive model, in the characteristic roots test the largest root should be explosive, which means larger than unity. After verifying the model, cointegration analysis is conducted to test the rank. In this model with only two variables, the rank r should be equal to 1 in order to make the cointegration test valid, and the largest root should still be explosive after imposing this. Diverse hypotheses targeting for the housing bubble issue, are summarized in Table 2, to explore the relationship between house prices and rental price.

<<Table 2 – About Here>>

Firstly, the cointegration vector error correction model is estimated from model **M** (7) through imposing the rank $r=1$. This gives the co-explosive model **M1** (8). Secondly, this model assumes that the explosive behaviour exists in real estate price not the rental price. Accordingly,$H\_{R}: βρ= (0, 1)’$is tested to guarantee the non-explosive rental price given $r=1$ and $ρ>1$. This generates model **M1R**. Estimate this model with a given ρ from the largest root, and in this reduced rank regression the likelihood is maximized. Then a profile argument over the root $ρ$ is conducted to maximize the likelihood. Next, we consider the hypothesis for spread in (3), $H\_{s}: β1=(1, -1/i)$ imposed in the reduced model. Furthermore, based on the linkage between the discount factor and explosive root ρ=1+i, the bubble model **M1RS** (10) is built. We estimate **M1RS** imposing general restrictions, and the likelihood is also maximized over ρ with a profile argument. Finally, the house bubble is tested through the efficient market hypothesis HB. This model is estimated with the restrictions, and likelihood is maximized by a profile argument over $i$.

## 4. Estimation Results

The line chart for the house prices and rental prices is shown in Figure 1. The trend of the house price level appears to include explosiveness on the surface before the break in 2007 due to the global financial crisis, whereas that of rental prices looks smooth. Assuming a fixed interest rate, the results are shown below.

<<Figure 1 – About Here>>

The optimal lag length for the initial unrestricted VAR model is set to 6, considering that this is the minimum number of lags to prevent residual autocorrelation. The misspecification test is listed in Table 3. It is shown that the model does not contain residual autocorrelation.

<<Table 3 – About Here>>

Also, the characteristic roots for the unrestricted model are presented in Table 4. The results show that the characteristic roots are 1.017, 0.9514 -0.03655, -0.03655, and so on. The largest root is 1.017, which identifies one explosive root in the model. At the same time, one of them cannot be rejected as a unit root. This coincides with the hypothesis of explosiveness. Moreover, the cointegration rank test is displayed in Table 4, and the hypothesis of rank 1 is not rejected in the result.

<<Table 4 –About Here>>

<<Table 5 – About Here>>

After imposing a unit root in the model to set rank to 1, the model **M1** is estimated, and the likelihood value received here is -1242.95356. Furthermore, the updated roots result is listed in Table 6. Whereas the largest root is still 1.017, the second one is restricted to be 1.000 due to the cointegration restriction. This result is in favour of the anticipated outcome in which there is one explosive root and one unit root in the model.

<<Table 6 – About Here>>

In the next step, the hypothesis pertaining to the non-explosiveness of rental prices HR is imposed in **M1** so that the model **M1R** is estimated. Now the likelihood value achieved in this model is -1257.6612, which is reduced compared to the -1242.95356 in **M1**. This might either be a result of imposing a restriction, or the value for ρ is not the one that could maximize likelihood. Therefore, a profile argument over ρ is made, and the result is presented in Table 7. As shown in the table, the root $ρ$=1.0275 is the one that can provide the maximum likelihood. As a consequence, this outcome also concurs with the explosiveness assumption in the model, which fulfils the condition for the further analysis. The results for testing each hypothesis are summarized in Table 8. The hypothesis for non-explosive rental price is rejected, according to the result. This means that the assumption that the explosive behaviour belongs only to house price rather than rental price, cannot be proved.

<<Table 7 – About Here>>

<<Table 8 – About Here>>

Testing the spread hypothesis $H\_{s}: β1= (1, -1/i)$ also provides us with a high likelihood ratio, for this reason we reject the hypothesis that there is a stationary spread between house and rental prices. Since $i=ρ-1$, where $ρ$ =1.0275 that maximizes the likelihood, the restricted $i$ equals 0.0275. This seems a reasonable estimation of the expected annual return. Furthermore, the hypothesis regarding the bubble HB are also tested, with the results rejecting the hypothesis. The excess part of return does not present to be a martingale difference, which might indicate that the rental price did not explain fully the changes in house price. However, since the hypothesis of non-explosive rental price is rejected, the existence of housing bubble cannot be proved. The accelerated development of property renting sector in the UK has an effect on the explosive rental price, which then explains this outcome. Nevertheless, with a non-martingale difference between housing and rental price, further research is needed to confirm the housing bubble in the UK.

## 5. Conclusion

This paper presents an empirical study investigating the existence of a real estate bubble in the UK applying time series quarterly data over the period of 1980Q4 to 2007Q4. It contributes to the previous literature by adopting the co-explosive model (originally employed for the stock market) to the real estate market. This method assumes that house price which involves a bubble component will present an explosive growth pattern. In this research, rental price acts as the fundamental-based price for real estate. The findings of this study, however, cannot prove the presence of house price bubble in the real estate market, considering that the hypothesis of non-explosive rental price is rejected. Both of real estate and rental price show the sign of explosive behaviour in this analysis for the UK data, which means there is insufficient evidence to indicate the existence of housing bubble.

The real estate industry has vast potential in supporting and stimulating the economic growth and social improvement, while the potential bubble in housing price raises the possibility of a burst and financial crisis. Therefore, only through discovering whether the booming house prices is contributed by a bubble and then adopting the corresponding measures to curb the imbalance increase in the real estate market can be brought into full play. Considering that there are possibilities for a house price bubble to either exist or not in the UK real estate market, the rental market also booms fast in the UK through an explosive development. The evidence provided in this study is not enough to justify the presence of real estate bubble. The outcome of this paper needs to be noted regarding to its limitations, and different methodologies can be applied in order to investigate the housing bubble issue in the UK. Moreover, further research is necessary to address the issue of structural break in the sample period, such as different subsamples. Evidence considering the housing bubble situation after 2007 in the UK is also necessary to be considered and tested.

Despite its exploratory nature, this study provides an insight into the implications for policymakers regarding the real estate market in the UK so as to guarantee appropriate oversight. In consideration of the explosive nature of house price and rental price, policymakers might focus more to control and supervise the fluctuation of real estate price. Finally, it is still necessary for policymakers to provide proper guidance for investors in making investment decisions and prevent speculative behaviour.

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**Fig.1**. The UK real house prices, seasonally adjusted (solid line P, on left vertical axis). The UK quarterly rental prices, seasonally adjusted (Dashed line R, on right vertical axis).

**Table 1.** Descriptive statistics

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Average | Maximum | Minimum | Std.Dev. | Skewness | Kurtosis | Jarque-Bera |
| HI | 56.44 | 112.39 | 22.72 | 29.77 | 0.57 | 1.72 | 24.53 |
| RP | 73.17 | 100.76 | 41.53 | 20.99 | -0.11 | 1.38 | 22.50 |

**Table 2.** Testable hypotheses

|  |  |  |
| --- | --- | --- |
| Model | Hypothesis | Description |
| M1 | H1, $r=1$ | Rank $r=1$ |
| M1R | H1, HR | Test for non-explosive rental price |
| M1RS | H1, HR, HS | Spread $S\_{t}=P\_{t}-{R\_{t}}/{i}$ as a cointegrating relation |
| M1RSB | H1, HR, HS, HB | Efficient market hypothesis |

**Table 3**. Specification tests for unrestricted VAR model

|  |  |
| --- | --- |
| Residual autocorrelation AR 1-2 | F(8, 170)=1.2617(0.2667) |
| Test for normality | $$χ^{2}\left(4\right)=22.605(0.0002)$$ |

**Table 4**.Characteristic root test for unrestricted VAR model

|  |  |  |
| --- | --- | --- |
| real | Imag | modulus |
| 1.017 | 0.0000 | 1.017 |
| 0.9514 | 0.0000 | 0.9514 |
| -0.03655 | -0.9206 | 0.9213 |
| -0.03655 | 0.9206 | 0.9213 |
| … | … | … |

**Table 5**. Cointegration rank test

|  |  |  |
| --- | --- | --- |
| Hypothesis | Test statistic | p-Value |
| r≤0 | 21.571 | 0.005 |
| r≤1 | 1.9773 | 0.160 |

**Table 6**. Updated characteristic root test

|  |  |  |
| --- | --- | --- |
| real | imaginary | modulus |
| 1.017 | 0.0000 | 1.017 |
| 1.000 | 0.0000 | 1.000 |
| -0.03828 | -0.9216 | 0.9224 |
| -0.03828 | 0.9216 | 0.9224 |
| … | … | … |

**Table 7**. Profile likelihood values under **M1R**

|  |  |
| --- | --- |
| **ρ** | **Log likelihood** |
| 1.017 | -1257.6612 |
| 1.02 | -1257.50391 |
| 1.025 | -1257.35124 |
| 1.026 | -1257.33915 |
| 1.027 | -1257.33363 |
| 1.0275 | -1257.33339 |
| 1.028 | -1257.33484 |
| 1.03 | -1257.35789 |
| 1.04 | -1257.89672 |

**Table 8.** Tests of the rational bubble restrictions

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Model** | **Hypothesis** | **Log-likelihood** | **Test statistic** |  | **d.f.** |
| M1 | H1,$r=1$ | -1242.95356 |  |  |  |
| M1R | H1,HR | -1257.6612 | LR(M1R|M1) | 29.42 | 1 |
| M1RS | H1,HR, HS | -1279.54105 | LR(M1RS|M1R) | 43.76 | 1 |
|  |  |  | LR(M1RS|M1) | 73.17 | 2 |
| M1RSB | H1,HR, HS,HB | -1414.85258 | LR(M1RSB|M1RS) | 270.62 | 3 |
|  |  |  | LR(M1RSB|M1R) | 314.38 | 4 |
|  |  |  | LR(M1RSB|M1) | 343.8 | 5 |

1. The most prevalent definition of housing bubbles in academic literature is based on the notion of fundamentals. When house price cannot be justified merely by underlying fundamentals, then the bubble is defined as the difference between the actual market price and the “fundamentals-based” price (Dreger & Zhang, 2012, Kim & Min, 2011, Mikhed & Zemčík, 2009 &Walks, 2014). The fundamentals-based price is typically characterised as the sum of expected future dividends discounted to the present (Black et al, 2006). The existence of a bubble builds upon a rational or irrational belief that the future expected house price will rise and a profit can be earned through selling property at a higher price in the future (Goodman & Thibodeau, 2008, Dreger & Zhang, 2012 & McCathy & Peach, 2004).According to Miles (2015), a bubble by definition is when house prices may have risen to higher levels than could be justified by fundamentals. [↑](#footnote-ref-1)
2. Kivedal (2013) uses a co-explosive vector autoregression (VAR) model to study the presence of speculative bubbles in the US housing market. [↑](#footnote-ref-2)