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Do house prices overreact to relevant information? New evidence from the UK housing market.

by

Hanxiong Zhang*, Viktor Manahov, Robert Hudson and Hugh Metcalf

Abstract

We use recent panel data and various empirical models to investigate the validity of the irrational expectations hypothesis and the feedback theory in the UK housing market. We provide the first empirical evidence to justify the statistically significant and positive feedback causality effect between the changes in bubbles and the contemporaneous changes in house prices. While we have found evidence to support the idea that the irrational expectation hypothesis best fits the UK housing market in the short-run, we failed to find evidence in support of the feedback theory. We observe that an increase in bubbles could cause a subsequent decrease in house prices, *ceteris paribus*, suggesting that people also learn from their mistakes and attempt to compromise by acting as rationally as possible. Overall, we observe that the causality effects are asymmetrical, being more significant from bubble to house price than they are from house price to bubble.

JEL Classification: C13; C23; G02; G10.

Keywords: Panel Data, Endogeneity, House Price, Bubble, Expectation Hypotheses.

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1 Introduction

This paper considers whether the bounded rationality expectation hypothesis best fits the UK housing market in terms of panel data analysis. Furthermore, we also look at whether the feedback theory (Shiller, 1990,2007) is supported in the UK housing market. On the one hand, the bounded rationality expectation hypothesis captures the idea that house prices, especially intrinsic house price bubbles, overreact to relevant information on fundamentals due to people's cognitive and psychological limitations. Black *et al.*, (2006) argue that house price bubbles will be more highly correlated with fundamental factors than with prices themselves in terms of magnitude, meaning that the dominant driving force is fundamentals rather than peoples' irrational activities.

On the other hand, the feedback theory proposed by (Shiller, 1990,2007) suggests that when house prices as a whole appreciate significantly they generate many investor success stories. These stories entice potential investors, who naively extrapolate that they will also achieve the same success if they invest. While this process is leading to an increase in house prices, the feedback theory implies that the same process could be reversed when house prices decrease. The feedback theory appears as a type of irrational expectation hypothesis, which means that people usually form their expectations of house prices by looking backward at the past price movement rather than fundamentals. Moreover, the theory states that there is a positive feedback causal relationship between house price bubbles, which reflect people's biased expectations, and subsequent house prices.

However, Mayer (2007) argues that Shiller (2007) overstates the case by ignoring the role of interest rates and using an outdated dataset. This has led to the introduction of panel data analysis for as a tool for investigation of more recent house price behaviour.

There are two broad categories of literature study of house prices using panel data analysis. The first category focuses on the linkages between some fundamental factors and housing prices.

For instance, Holly et al. (2010) investigate the determination of real house prices by using a spatio-temporal model in a panel of 49 US states over a period of 29 years. Holly et al. (2011) propose a novel way to model the spatial-temporal dispersion of shocks in non-stationary systems in a panel of 11 UK regions. Holly et al. (2011) suggest that the effects of a shock decay more slowly along the geographical dimension when compared to the decay along the time dimension. The second category places emphasis on whether the house prices are supported by fundamentals. For example, Cameron et al. (2006) examined the bubbles hypothesis using a dynamic panel data model in a panel of the UK regional property prices from 1972 to 2003, but failed to find a bubble. Recent studies (Mikhed and Zemčík, 2009; Clark and Coggin, 2011) suggest that there is a house price bubble in the US, according to the univariate and panel unit root and co-integration tests.

Nevertheless, the majority of the studies related to the topic have a major shortcoming. They failed to quantify the level of housing price bubbles by using panel data analysis, let alone modelling the direction of causality between the changes in house price and the changes in bubble.

In contrast, this paper uses the most recent UK dataset to quantify the regional changes in bubbles using a time series approach, namely the user cost framework in a state space model. Also, this study provides the first empirical evidence to justify the statistically significant feedback causality between the changes in bubbles and the contemporaneous changes in house prices by using the Fixed Effects Model (FEM).

Relative to the pure aggregate time-series analysis, we implement panel data analysis using the regional data, which possesses several advantages such as: (1), panel data normally provides a large number of data points, thereby raising the degrees of freedom and eliminating the multicollinearity among independent variables; (2), controlling for individual heterogeneity; (3), micro panel data collected on individual regions may be more precisely measured than similar variables measured at the macro level; (4) better ability to investigate the dynamics of economic states; (5) panel allows researchers to investigate causality (Hsiao, 2003; Frees, 2004; Wooldridge, 2010).

To summarise the main contribution of this study is three-fold. First, our findings indicate that the changes in the UK house price bubbles best fit the irrational expectation hypothesis in the short-run, given that past price movement rather than fundamentals are dominating the UK house price bubbles. However, an increase in a bubble could cause a subsequent decrease in house prices, *ceteris paribus*, suggesting that people learn from their mistakes and attempt to compromise by acting as rationally as possible. Therefore, there is also weak evidence to support the bounded rationality expectation hypothesis. As the paper uses log differenced stationary dataset, co-integration is outside the scope of this study and all of the empirical evidences characterise by a short-run effect.

Second, we have found that feedback causality between the changes in bubbles and the contemporaneous changes in house prices is robust, even when taking the mortgage rate and the more recent datasets into account. Moreover, our empirical findings suggest that the feedback theory may not hold. We observe that an increase in bubbles could cause a subsequent decrease in house prices, *ceteris paribus*, suggesting that people also learn from their mistakes and attempt to compromise by acting as rationally as possible.

Third, we contribute to the literature on how regional heterogeneity may affect a region's housing market. Chi (2005) argues that when some regional heterogeneity is unobservable, a fixed effects model helps to capture the effect of the unobservable variables and therefore alleviates the endogeneity problem resulting from the omitted variable bias. We observe that the causality effects are asymmetrical, being more significant from bubble to house price than the effects from house price to bubble in the presence of the observable and unobservable regional characteristics.

The remainder of the paper is organised in the following way: Section 2 presents the methodology; Section 3 describes the data in detail; Section 4 reports and discusses the empirical results, and the paper concludes in Section 5.

2 Methodology

Section 2.1 presents how to estimate the regional changes in bubbles using the user cost framework in a state space model, which is a typical time series approach. Section 2.2 exhibits the causality tests in the context of the fixed effects model. Throughout this paper, lower case letters for time-dependent variables represent the natural logarithm of their capital counterparts. Δ_1 denotes first difference.

2.1 Estimation of Changes in Bubble

Given that asset price is a combination of fundamental, non-fundamental, or bubble and model misspecification error (Wu, 1997), we can write the changes in house price as

$$\Delta_1 ph_t = \Delta_1 ph_t^f + \Delta_1 b_t + \varepsilon_t \tag{1}$$

Where, $\Delta_1 ph_t$ is the changes in house price, $\Delta_1 ph_t^f$ is the changes in fundamental house price, and $\Delta_1 b_t$ is the changes in bubble, ε_t is error term. Because $log_e(HPI_t^f) = log_e(HPI_t^f / HRI_t) + log_e(HRI_t)$, we can rewrite equation (1) as

$$\Delta_1 ph_t = \Delta_1 ph_t^f + \Delta_1 b_t + \varepsilon_t = (\Delta_1 pr_t^f + \Delta_1 hri_t) + \Delta_1 b_t + \varepsilon_t \tag{2}$$

$\Delta_1 pr_t^f = \Delta_1\, log_e(HPI_t^f / HRI_t)$ is the changes in fundamental price-rent ratio, $\Delta_1 hri_t = \Delta_1 log_e(HRI_t)$ is the changes in house rent index. In equation (2), the changes in fundamental house price-rent ratio $\Delta_1 pr_t^f$ and the changes in bubble $\Delta_1 b_t$ are not directly observable and need some algebraic estimation.

First, we estimate the fundamental house price-rent ratio pr_t^f by using the user cost framework. The user cost framework suggests that at the equilibrium house price HPI_t^f, the cost of holding a house per year $UC_t \times HPI_t^f$ equals the cost of renting the house HRI_t for that period, namely,

$$HRI_t = UC_t \times HPI_t^f \tag{3}$$

UC_t is the user cost of holding a house per year at the percentage level. Then, the fundamental house price-rent ratio PR_t^f is the inverse of the user cost UC_t.

$$PR_t^f = \frac{HPI_t^f}{HRI_t} = \frac{1}{UC_t} \tag{4}$$

At the percentage level:

$$UC_t = R_t^m + PT_t + MC_t + RP_t - MT_t(R_t^m + PT_t) - CG_{t+1} \tag{5}$$

Where, R_t^m is the foregone mortgage rate, PT_t is the property tax rate, MC_t is the maintenance cost, RP_t is the risk premium for the larger uncertainty of purchasing relative to renting, MT_t is the marginal tax rate for the house buyer. CG_{t+1} is the expected capital gain over the next year. Equation (4) implies that the user cost should be positive, as neither the theoretical house price nor the actual market rent should be negative. We calculate the risk premium RP_t and expected capital gain CG_{t+1} as

$$RP_t = CG_{t+1} - \frac{HRI_{t+1} - HRI_t}{HRI_t} \tag{6}$$

$$CG_{t+1} = \frac{HPI_{t+1}}{HPI_t} - 1 = \frac{HPI_{t+1} - HPI_t}{HPI_t} \tag{7}$$

Equation (6) calculates the risk premium as the difference between the house price appreciation and the rent appreciation over the next year. Equation (7) calculates the expected capital gain as the realized capital gain over the next year. Then,

$$RP_t = CG_{t+1} - \frac{HRI_{t+1} - HRI_t}{HRI_t} = \frac{HPI_{t+1} - HPI_t}{HPI_t} - \frac{HRI_{t+1} - HRI_t}{HRI_t} \tag{8}$$

Equation (8) implies that the net effect of the risk premium and the expected capital gain equals the changes in rent over the next year. Due to the fact that we use quarterly data, the expect annual changes in rent are the changes in rent over the next four quarters. We estimate the maintenance cost and depreciation rate as $MC_t = 2\%$ (Himmelberg *et al.*, 2005; Girouard *et al.*, 2006; Finicelli, 2007). We exclude property tax and set $PT_t = 0$ for two reasons. Firstly, property tax payment is not deductible from income tax under the UK tax system. Secondly, in the UK, the tenant rather than the landlord is responsible for paying the property tax. As property tax is usually not included in the rent, property tax should also be removed from the user cost.

In accordance with the UK Mortgage Interest Relief at Source (MIRAS) scheme, over some historic periods, a borrower has paid the lender the interest less the tax relief. The rate of relief from 1995-96 to 1997-98 was 15%, and for 1998-99 and 1999-2000 it was 10%. The relief on mortgage interest repayments was removed on 6 April 2000. Accordingly, we set the UK marginal tax rate $MT_t = 15\%$ from 1996Q2 to 1998Q1, $MT_t = 10\%$ from 1998Q2 to 2000Q1, and $MT_t = 0$ thereafter. Furthermore, the paper uses the composite mortgage rates from Building Societies and Banks over the sample period 1996Q1-2011Q1 to proxy the R_t^m.

Because the quarterly changes in regional house prices are quite large, a few of the user costs are negative. In such cases, the negative user costs are replaced by the previous positive figures.

As a second step, the paper estimates the changes in bubble $\Delta_1 b_t$ by using a state space modelling.

Measurement equation:

$$\Delta_1 ph_t = c_1 \Delta_1 pr_t^f + c_2 \Delta_1 hri_t + \Delta_1 b_t + c_3 \tag{9}$$

State equation:

$$\Delta_1 b_t = c_4 \Delta_1 b_{t-1} + c_5 \tag{10}$$

$$c_3 \sim i.i.d. N(0, R) \tag{11}$$

$$c_5 \sim i.i.d. N(0, V) \tag{12}$$

$$E(c_3, c_5') = 0, E(c_3, b_0') = 0 \text{ and } E(c_5, b_0') = 0 \tag{13}$$

c_3 and c_5 are the error terms. b_0' is the initial state vector. There are no constants in equation (9) and equation (10), given that the expected value of housing will be zero when the fundamental value and bubble are both zero. The five unknown parameters $\left(c_1, c_2, \sigma_{c_3}^2, c_4, \sigma_{c_5}^2\right)'$ are hyperparameters and are estimated by Maximum Likelihood Estimation (MLE) with Marquardt algorithm. The rationale for using an AR(1) for the changes in bubble process is based on the assumption that people will naively extrapolate the most recent changes in bubble into the next period (Wu, 1997). The state space model step simplifies the model building process relative to Wu (1997) and Black *et al.* (2006) while maintaining the advantages of a state space model.

2.2 Panel Data Causality Tests

From the perspective of econometrics, there are four possible causal relationships between the changes in bubbles and the changes in house price: (1) changes in bubbles drive subsequent changes in house price; (2) changes in house price drive subsequent changes in bubbles; (3) feedback effect, the changes in house price affects the changes in bubbles, or causality runs both ways; (4) changes in bubbles and changes in house price are not directly related, but are spuriously associated through other variables which are either observable or unobservable. Condition (3) and condition (4) refer to the endogeneity, which is one of the most significant challenges in applied econometrics.

We follow Chi (2005) to determine the following fixed effects models:

$$\Delta_1 ph_{i,t} = \propto_1 + \beta \Delta_1 b_{i,t-1} + \sum_{k=1}^{K} \beta_k C_{k,i,t} + u_i + \varepsilon_{i,t} \tag{14}$$

$$\Delta_1 b_{i,t} = \propto_2 + \theta \Delta_1 ph_{i,t-1} + \sum_{k=1}^{K} \theta_k C_{k,i,t} + \mu_i + \epsilon_{i,t} \tag{15}$$

Where, $\Delta_1 ph_{i,t}$ is the changes in house price index for region i at time t. $\Delta_1 b_{i,t}$ is the changes in bubble for region i at time t. $\propto_1$ and $\propto_2$ are constants. i represents different regions, t represents time, and k is the number of Control Variables. For instance, $C_{k,i,t}$ is the $k\text{-}th$ control variable for region i at time t. β and θ are the coefficients on the underlying independent variables. u_i and μ_i are the fixed effects, indicating the effects of any and all time-invariant covariates on each variable, along with time-specific error terms ε and ϵ. The fixed effects model includes all of the unobserved effects and then provides a good control for endogeneity (Chi, 2005; Schroeder, 2010; Wooldridge, 2010). The key motivation of using a fixed effects model is to alleviate the omitted variable bias, not because the unobservable regional heterogeneity is fixed over time. Furthermore, the fixed effects model controls for the endogeneity by extracting the unobservable regional heterogeneities u_i and μ_i from the error terms ε and ϵ respectively. It is possible to estimate equations (14) and (15) simultaneously, such as in the typical panel data Granger causality tests (Hoffmann *et al.*, 2005; Schroeder, 2010). However, estimating equations (14) and (15) separately allows for more flexibility in specifying the model.

Frees (2004) and Chi (2005) identify three criteria for inferring causality such as the presence of statistically significant relationship; the causal variable must precede the other variable in time; the association between two variables must not be resulting from another, omitted, variable. Given equations (14) and (15) control for these observable and unobservable regional heterogeneity (criterion 2 and criterion 3), one can infer that the causality effect primarily depends on the significance of the relevant coefficients. For example, the statistical significance of β would indicate changes in bubbles cause subsequent changes in house price, *ceteris paribus*. The statistical significance of θ indicates that changes in house price would cause changes in bubbles, *ceteris paribus*. The Random Effects Model (REM) is another popular panel data model.

REM assumes the omitted time-invariant variables are irrelevant with the involved time-varying covariates. REM is often estimated by the Generalized Least Square (GLS) estimator, while FEM is often estimated within the OLS estimator. REM outperforms FEM because of its greater efficiency, leading to statistical power to detect effects and smaller standard errors. Given that there is almost always some omitted variables bias, FEM appears to be more suitable than REM from a causal inference perspective. Both random and fixed effects models have implicit restrictions that are infrequently examined but, if incorrect, could bias the estimated results. For example, both models assume that the unexplained variance remains the same over time. Moreover, the autoregressive relations with lagged dependent variables are assumed to be nil. When the lagged dependent variables are included in the Arellano Bond dynamic model, the dataset has to be a large number of regions (N) and short time period (T) (Arellano and Bond, 1991; Bond, 2002). Although the Hausman test is widely used to distinguish between REM and FEM, the choice is never straightforward, and it tends to be harder still when the number of observations is small (Hsiao, 2003; Bollen and Brand, 2008,2010).

3 Description of data

The dataset in this study covers the twelve regions of the UK regional Halifax seasonal adjusted House Price Indices (HPI). The UK aggregate House Rent Index (HRI) is proxied by the Consumer Price Index (CPI) component of actual rents for housing, and the composite mortgage rate of Building Societies and Banks from the Bank of England. Black *et al.* (2006) suggest that the Halifax house price index tracks price changes of a representative house rather than average prices by using the hedonic regression. The price of the representative house is then estimated for each period using the implicit prices of each attribute, as extracted from the hedonic regression.

We estimate the changes in national house rent index as identical to the changes in regional house rent index across the UK, given that the regional house rent index is unavailable. As all the variables used in the main regressions are first log differenced and stationary, co-integration and long-run equilibrium are beyond the consideration of this paper. Therefore, all of the findings in this paper are short-run effect.

All the quarterly UK time series data are collected from DataStream with a time span from 1996Q1 to 2011Q4. The start and end dates are chosen by the availability of data for the House Rent Index. All of the indices are set to 100 in 2005Q2. The twelve regions of the UK are: Northern Ireland, Scotland, Wales and the nine regions of England, namely, East Anglia, East Midlands, Greater London, North, North West, South East, South West, West Midlands, and Yorkshire and the Humber. The full dataset has long time periods ($T = 60$) with small individuals ($N = 12$) at the first log difference scale. All of the variables in this paper are not adjusted for inflation. Given that 'there is a great deal of confusion about the role of inflation expectations in the demand for housing' (Schwab, 1982), it is interesting to study the linkages between house prices and its determinants in nominal terms. Akerlof and Shiller (2010) suggest that people often fail to exclude the effect of inflation on their house investments in reality.

A preliminary statistics and correlation matrix about the changes in HPI, changes in HRI, changes in fundamental price-rent ratios and changes in bubbles are available in Appendix Table A1 and Table A2, respectively.

4 Empirical Results and Discussion

4.1 Findings from the Full Sample

Table 1 shows the results of panel data unit root tests for changes in house price index $\Delta_1 ph_{i,t}$, changes in fundamental house price-rent ratio $\Delta_1 pr_{i,t}^f$, changes in house rent index $\Delta_1 hri_{i,t}$ and changes in bubbles $\Delta_1 b_{i,t}$. We implement the Harris–Tzavalis (HT) test, Levin–Lin–Chu (LLC) test and Im-Pesaran-Shin (IPS) test as our applied unit root tests. The dataset includes all twelve UK regions over the period 1996Q2 to 2011Q1. As expected, all of these variables are stationary at the 1% significance level.

Figure 1 displays the changes in regional bubbles against the changes in regional house prices. In Figure 1, the quarterly changes in bubbles report significant regional heterogeneities with values ranging from -8% to 10%, which indicates that the bubbles do not follow the explosive paths. Hence, we reject the rational expectation hypothesis proposed by (Diba and Grossman, 1988). Apart from a few exceptions such as Northern Ireland, the difference between changes in bubble and changes in house price is minute for a given region. The bubbles increase across the UK from 1996 to 2007, given that the changes in bubbles $\Delta_1 b_{i,t}$ are positive during most of that time. During the Subprime Crisis, the bubbles decreased significantly thereafter and demonstrated varied recovery after 2009.

Table 2 shows the impact of changes in bubbles on changes in housing price in terms of the Fixed Effects Model (FEM) and Random Effects Model (REM). Model 1 of each approach regresses the changes in house price $\Delta_1 ph_{i,t}$ against the changes in fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$ and the changes in rent $\Delta_1 hri_{i,t}$. The coefficients on changes in fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$ are statistically significant with a value of -0.031 in both FEM and REM, so, one percent increases in the changes in fundamental price-rent ratio will significantly cause housing return decreases by 0.031 percent, *ceteris paribus*. The coefficients on changes in rents $\Delta_1 hri_{i,t}$ are -0.167, but are insignificant in both FEM and REM.

Model 2 (Table 2) regresses the changes in house prices $\Delta_1 ph_{i,t}$ against the changes in fundamental price-rent ratio $\Delta_1 pr^f_{i,t}$, the changes in rent $\Delta_1 hri_{i,t}$ and the changes in bubbles $\Delta_1 b_{i,t}$. Model 2 suggests that after controlling for the changes in the fundamental price-rent ratio $\Delta_1 pr^f_{i,t}$ and the changes in rent $\Delta_1 hri_{i,t}$, the coefficients on the changes in bubbles $\Delta_1 b_{i,t}$ are statistically significant with a value of 1.209 and 1.124 in the FEM and REM, respectively. Given that bubble is a component of house price, approximately one percent change in bubbles drives one percent changes in house price after controlling for the effect of the fundamental variables. In contrast to Model 1, the coefficients on the changes in rents $\Delta_1 hri_{i,t}$ turn positive but are still statistically insignificant.

Relative to Model 2, Model 3 includes the lagged changes in bubbles $\Delta_1 b_{i,t-1}$ as another independent variable. The coefficients on the changes in bubbles $\Delta_1 b_{i,t}$ remain significant, but are more positive in both FEM and REM. The coefficients on the lagged changes in bubbles $\Delta_1 b_{i,t-1}$ are significantly negative with a value of -0.434 and -0.484, respectively, which indicates that the previous increases in bubbles tends to reduce the subsequent increases in house prices, *ceteris paribus*. Hence, the significant but negative coefficients on the lagged changes in bubbles $\Delta_1 b_{i,t-1}$ do not support the feedback theory. Given that the bubbles reflect people's biased expectations, the negative coefficients on lagged changes in bubbles $\Delta_1 b_{i,t-1}$ suggest that people learn from their past mistakes and try to adjust the current house prices in order to converge to their fundamental values which, in turn, justify the arguments of the bounded rationality expectation hypothesis. The net effect of changes in bubble $\Delta_1 b_{i,t}$ and lagged changes in bubble $\Delta_1 b_{i,t-1}$is approximately one unit, *ceteris paribus*. Additionally, the coefficients on the changes in rents $\Delta_1 hri_{i,t}$ become more positive and statistically significant.

In Models 4 and 5, the paper adds two interactive variables, $\Delta_1 b_{i,t} * \Delta_1 pr_{i,t}^{f}$ and $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$, to control for the interaction effects. $\Delta_1 b_{i,t} * \Delta_1 pr_{i,t}^{f}$ is the interaction of changes in bubbles and changes in fundamental price-rent ratio. $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$ is the interaction of changes in bubble and changes in rent. Throughout the paper, all of the interactive variables are scaled down by multiplying them by 100. This is because the first log differenced variables, such as $\Delta_1 hri_{i,t}$ and $\Delta_1 pr_{i,t}^{f}$, represent the continuous compounded returns on the underlying variables. However, the interaction variables represent the multiplying effect of return on return. The scaling only affects the coefficients of scaled variables, but it does not influence the coefficients of other variables and the fit of the model.

The interaction effect of changes in bubbles and changes in fundamental price-rent ratio $\Delta_1 b_{i,t} * \Delta_1 pr_{i,t}^{f}$ is significantly positive, with a coefficient of 0.2% in FEM and 0.1% in REM, which indicates that the effect of changes in bubbles on the changes in house price is positively dependent on the changes in the fundamental price-rent ratio. On the contrary, the coefficient on the interaction effect of changes in bubbles and changes in rent $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$ is significantly negative, with a value of -0.104 in FEM and -0.154 in REM, implying that increasing bubbles combined with declining rents make it more attractive to buy than rent because of higher capital gain on ownership, *ceteris paribus*.

The coefficients on changes in bubbles $\Delta_1 b_{i,t}$ and lagged changes in bubbles $\Delta_1 b_{i,t-1}$ remain significant and on their signs after controlling for the interaction effects.

Table 2 shows a series of interesting findings. First, the significantly negative coefficients on changes in fundamental price-rent ratio $\Delta_1 pr_{i,t}^{f}$ and the significantly positive coefficients on changes in rent $\Delta_1 hri_{i,t}$ jointly indicates that with the changes in house price the changes in the fundamental house price are less than the changes in rent, *ceteris paribus*. On the one hand, Britain has probably the most liberalised private renting market in the European Union (EU) since 1989. Less security of tenure and the long-term taxation imbalance between the rental and the owned makes it more attractive to rent rather than own than ever before. On the other hand, the structure of the privately rented market has been changed over the past two decades. The typical landlord has treated buy-to-let as the mainstream for personal investment, and the tenants are now composited by far more immigrants and younger people. Consequently, although changes in rent may be less than the changes in market house price, they can easily exceed the changes in the fundamental house price in the UK, at least in the nominal term.

Second, the significance tests reject the null hypothesis that changes in bubbles and lagged changes in bubbles are jointly insignificant, $H_0\colon \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$, at the 1% significance level. Therefore, the changes in bubbles $\Delta_1 b_{i,t}$ and the lagged changes in bubbles $\Delta_1 b_{i,t-1}$ jointly cause the contemporaneous changes in house prices $\Delta_1 ph_{i,t}$, *ceteris paribus*.

Third, throughout the paper, the FEMs use regional fixed effects which assume the potential omitted variable bias from variables that vary across regions but are constant over time. The paper does not exhibit the results of the fixed time effects, primarily because the results of fixed time effects are highly consistent with the results of FEM with regional fixed effects.

Furthermore, the paper does not present the fixed regional and time effect model, given that the paper's dataset is not large enough to end up as a reasonable model fit.

Fourth, the explanatory power of fundamental factors, in particular the changes in fundamental price-rent ratio $\Delta_1 pr^f_{i,t}$ and the changes in rent $\Delta_1 hri_{i,t}$, on the changes in house price $\Delta_1 ph_{i,t}$ is quite low, as the R^2 is just 0.16 in Model 1. After incorporating the changes in bubbles $\Delta_1 b_{i,t}$, the R^2 dramatically increases to above 0.81 in Model 2, which indicates that the changes in bubbles can significantly explain the changes in house prices. The marginal effect of lagged changes in bubbles $\Delta_1 b_{i,t-1}$ and the interaction effects on changes in house price is quite low, as the marginal increase in R^2 is less than 0.05 in Models 2 through 5.

Finally, the F-tests for the fixed effects are statistically significant in Models 2 through 5, which indicate that the FEMs are superior to the Pooled OLS in these four models. The Lagrange Multiplier (LM) random effects test fails to reject the null hypothesis of variances across individuals as zero in Models 1 through 5. Therefore, the Pooled OLS outperforms REM in all five models. The Hausman test suggests that REM outperforms FEM in Model 1, as the Hausman test fails to reject that the null hypothesis of REM is preferred. However, the Hausman tests break down in the remaining four models, given the $\chi^2 < 0$. This is because the model fitted on these data fails to meet the asymptotic assumptions of the Hausman Test. Consequently, Pooled OLS works best in Model 1. FEMs are superior to Pooled OLS and REM in Models 2 through 5.

For the five FEMs, the LM independence tests indicate that the residuals are serially correlated. The Pasaran Cross-Sectional (CD) tests suggest that the residuals are correlated across individuals, except for Model 3.

The heteroskedasticity tests reject the null hypothesis of homoskedasticity. Because the diagnostics tests suggest the FEMs violate two or three model assumptions, the findings of the FEMs in Table 2 might be either more or less biased.

In order to avoid empirical biases and provide appropriate test of robustness, we implemented the Panel-Corrected Standard Errors (PCSE) with AR(1), the Feasible Generalized Least Squares (FGLS) with heteroscedasticity (Table 3, Panel A) and the Fixed Effects Models with robust standard errors test proposed by White in 1980 (Table 3, Panel B). Both approaches in Table 3 (Panel A) correct the panel residuals for group-wise heteroskedasticity, contemporaneous correlation, and serial correlation. PCSE is an alternative to FGLS. When AR(1) is not specified, PCSE produces OLS estimates of the coefficients, while the standard errors are estimated differently. When AR(1) is specified, PCSE estimates the coefficients by using the Prais-Winsten regression, which is conditional on the estimates of the autocorrelation coefficients. The FGLS estimation is conditional on the estimation of the residual covariance matrix and is conditional on any autocorrelation coefficients that are estimated. Either the PCSE or FGLS estimator is consistent when the conditional mean is properly specified. FGLS is more efficient than PCSE as long as the assumed covariance is correctly structured. After controlling for heteroscedasticity the findings of Fixed Effects Models with robust standard errors reported in Table 3 (Panel B) are consistent with the findings in Table 2 and Table 3 (Panel A).

However, the full FGLS variance-covariance estimates might be biased when the applied dataset consists of 10-20 regions with 10-40 time periods. The datasets, especially the subsamples, used in this paper falls roughly into this category. PCSEs are helpful in precisely assessing the variance across regions, as they purport to create higher standard errors in an effort to generate more conservative results.

PCSE with AR(1) and FGLS with heteroskedasticity may provide a better statistical estimation, especially for the standard errors. However, they are unsuitable to control the omitted variable bias as FEM does. In general, the findings of Table 3 (Panel A and Panel B) are highly consistent with Table 2. Therefore, we can conclude that the economic implications of the Table 2 are sound and reliable.

Table 4 investigates whether the changes in house prices $\Delta_1 ph_{i,t}$ cause changes in bubbles $\Delta_1 b_{i,t}$ in terms of fixed effects model with a robust standard error (White, 1980), and PCSE with AR(1). From Table 4, Model 1 regresses changes in bubbles $\Delta_1 b_{i,t}$ against changes in the fundamental price-rent ratio $\Delta_1 pr_{i,t}^{f}$ and changes in rent $\Delta_1 hri_{i,t}$. The coefficients on changes in the fundamental price-rent ratio $\Delta_1 pr_{i,t}^{f}$ are significantly negative, with a value of -0.008 in FEM and -0.006 in PCSE with AR(1), respectively. The coefficients on changes in rent $\Delta_1 hri_{i,t}$ are significantly negative, with a value of -0.251 in FEM; but statistically insignificant in PCSE with AR(1).

After controlling for changes in the fundamental price-rent ratio $\Delta_1 pr_{i,t}^{f}$ and changes in rent $\Delta_1 hri_{i,t}$, Model 2 suggests that the coefficients on the changes in house price $\Delta_1 ph_{i,t}$ are significantly positive, with a value of 0.648 in FEM and 0.488 in PCSE with AR(1).

Therefore, Model 2 of FEM suggests that one percent changes in house prices drive 0.65 percent changes in bubbles, *ceteris paribus*.

Model 3 adds the lagged changes in house price $\Delta_1 ph_{i,t-1}$ as another independent variable. The coefficients on changes in house price $\Delta_1 ph_{i,t}$ are still significant and positive, *ceteris paribus*. The coefficients on lagged changes in house price $\Delta_1 ph_{i,t-1}$ are significantly positive, with a value of approximately 0.2, which indicates that the one percent changes in house price will cause about a 20% subsequent change in bubbles, *ceteris paribus*. Moreover, the PCSE with AR(1) approach indicates the coefficient on changes in the fundamental price-rent ratios $\Delta_1 pr^f_{i,t}$ become significantly positive at the 5% significance level, implying that the changes in bubbles reflect people's overreaction to changes in the fundamentals (Black *et al.*, 2006).

Model 4 and Model 5 include interaction variables, changes in house price and changes in the fundamental price-rent ratio $\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$, and changes in house price and changes in rent $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$. After controlling for the interaction variables, the coefficient on changes in house price remains significantly positive. The coefficients on $\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$ are insignificant. The coefficients on $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$ are significant and negative, while the figures of coefficients are quite small in both FEM and PCSE with AR(1).

From Table 4, the causality test indicates that the changes in house price $\Delta_1 ph_{i,t}$ and lagged changes in house price $\Delta_1 ph_{i,t-1}$ are jointly significant in driving the changes in bubbles $\Delta_1 b_{i,t}$. Overall, the findings of FEM are highly consistent with PCSE with AR(1), except for a few exceptions.

Tables 2 through 4 suggest that there are statistically significant feedback effects between the changes in bubbles and the changes in contemporaneous house prices between 1996Q2 and 2011Q1. However, the effect is asymmetric. After controlling for the fundamental variables, one percent changes in contemporaneous bubbles drives approximately one percent changes in house prices, given that the bubble is a component of house price. In particular, the coefficients on lagged changes in house price $\Delta_1 ph_{i,t-1}$ are significantly higher than those for the fundamentals in terms of magnitude, thereby implying that past price dynamics are more important than contemporary fundamentals in driving the UK house price bubbles, which favours the irrational expectation hypothesis, at least in the short-run.

4.2 Robustness Tests

Following the modelling procedure in Table 2, Table 5 investigates whether the changes in bubbles cause the changes in house prices in terms of FEM with robust standard errors (White, 1980) for the subsamples 1996Q2-2000Q4, 2001Q1-2006Q4 and 2007Q1-2011Q1. The three subsamples roughly match the recovery, boom, and recession of the UK housing market, respectively.

The findings of Table 5 are highly consistent with Table 2. Broadly speaking, Table 2, Table 3 and Table 5 exhibit parameter instability, which means that the coefficient on any given variable changes from model to model and over time. Moreover, the coefficients on the changes in rent and the interaction variables exhibit more changes than those for the reminder of the variables in terms of magnitude and sign. From an economics perspective, the time varying coefficients reflect the dynamics of the underlying economy and people's economic behaviour (Brown *et al.*, 1997). Given that the sample size is relatively small, the changes in coefficients over time are quite modest, even in the presence of the Subprime Crisis between 2007 and 2009.

Following Table 4, Table 6 studies whether the changes in house price cause the changes in bubble by using FEM with robust standard errors (White, 1980) for the subsamples 1996Q2-2000Q4, 2001Q1-2006Q4 and 2007Q1-2011Q1. The general findings in Table 6 are highly consistent with Table 4, except for the modest parameter instability. More detailed econometric results of Tables 5 and 6 are available upon request.

5 Conclusion

This paper considers whether the bounded rationality expectation hypothesis best fits the UK housing market in terms of panel data analysis. Furthermore, we investigate whether or not the feedback theory is supported in the UK housing market.

We have found evidence to support the idea that the irrational expectation hypothesis best fits the UK housing market in the short-run. However, we failed to find support for the feedback theory because an increase in bubbles could cause a subsequent decrease in house prices, *ceteris paribus*. We observe that the statistically significant and positive feedback causal relationship between the changes in house price and the contemporaneous changes in bubbles are asymmetrical. One percent changes in bubbles could drive approximately one percent change in house prices after controlling for the fundamental variables. Therefore, it is the build-up of bubbles which is driving the changes in house prices over time. We have found weak evidence to support the bounded rational expectation hypothesis. The lagged changes in bubbles could cause significant subsequent changes in house prices in a reverse direction, which suggests that people learn from their past mistakes and try to adjust the house prices to converge to their fundamental value. However, the adjustment effect is not powerful enough to offset the negative effects of biased expectations in the current period, *ceteris paribus*. The changes in fundamental variables could significantly drive the changes in bubbles, thereby implying that the bubbles are not dominated by people's purely irrational behaviour. These evidences jointly suggest that fundamentals also play an important role in driving the UK housing prices and house price bubbles in the short-run. Moreover, the modest time varying coefficients for a given variable indicate that there are institutional changes which, in turn, suggest that people adjust their behaviours according to the dynamics of the underlying economy. There are several avenues for future research in this area. In another study we would like to explore whether the results of the UK housing market can be implemented in other developed housing markets such as the U.S. market or any developing country market. We think that the outcome of this particular study could be very useful for policy makers and the general public worldwide.

Appendices

Table A1 Preliminary Statistics (1996Q2-2011Q1)

Variable	Mean	St. Dev.	Minimum	Maximum	No. of Obs.
$\boldsymbol{\Delta_1 ph_{i,t}}$	.016	.037	-.172	.157	60
$\boldsymbol{\Delta_1 hri_{i,t}}$	.007	.006	-.002	.029	60
$\boldsymbol{\Delta_1 pr^f_{i,t}}$	.004	.488	-2.647	2.011	60
$\boldsymbol{\Delta_1 b_{i,t}}$	.010	.026	-.099	.114	60

Notes: $\Delta_1 ph_{i,t}$ is the changes in house price index. $\Delta_1 hri_{i,t}$ is the changes in house rent index. $\Delta_1 pr^f_{i,t}$ is the changes in fundamental price-rent ratio. $\Delta_1 b_{i,t}$ is the changes in bubbles.

Table A2 Correlation Matrix (1996Q2-2011Q1)

	$\boldsymbol{\Delta_1 ph_{i,t}}$	$\boldsymbol{\Delta_1 hri_{i,t}}$	$\boldsymbol{\Delta_1 pr^f_{i,t}}$	$\boldsymbol{\Delta_1 b_{i,t}}$	$\boldsymbol{\Delta_1 ph_{i,t-1}}$	$\boldsymbol{\Delta_1 b_{i,t-1}}$
$\boldsymbol{\Delta_1 ph_{i,t}}$	1.000					
$\boldsymbol{\Delta_1 hri_{i,t}}$	-.024	1.000				
$\boldsymbol{\Delta_1 pr^f_{i,t}}$	-.397	-.027	1.000			
$\boldsymbol{\Delta_1 b_{i,t}}$	.831	-.058	-.155	1.000		
$\boldsymbol{\Delta_1 ph_{i,t-1}}$	.362	-.009	-.048	.596	1.000	
$\boldsymbol{\Delta_1 b_{i,t-1}}$	.544	.017	-.189	.784	.835	1.000

Notes: $\Delta_1 ph_{i,t}$ is the changes in house price index. $\Delta_1 hri_{i,t}$ is the changes in house rent index. $\Delta_1 pr^f_{i,t}$ is the changes in fundamental price-rent ratio. $\Delta_1 b_{i,t}$ is the changes in bubbles.

Tables

Table 1 Panel Data Unit Root Tests

	$\Delta_1 \boldsymbol{ph_{i,t}}$	$\Delta_1 \boldsymbol{pr^f_{i,t}}$	$\Delta_1 \boldsymbol{hri_{i,t}}$	$\Delta_1 \boldsymbol{b_{i,t}}$
Harris–Tzavalis (HT) Test	.000	.000	.000	.000
Levin–Lin–Chu (LLC) Test	.000	.000	.000	.0053
Im-Pesaran-Shin (IPS) Test	.000	.000	.000	.0002

Notes: Δ_1 means first difference. $\Delta_1 ph_{i,t}$ denotes for changes in house price index for region i at time t. $\Delta_1 pr^f_{i,t}$ denotes for changes in fundamental house price-rent ratio for region i at time t. $\Delta_1 hri_{i,t}$ is changes in house rent index for region i at time t. $\Delta_1 b_{i,t}$ denotes for changes in bubbles for region i at time t. The figures presented in Table 1 are $p\text{-}values$.

Table 2 Changes in Bubbles cause Changes in HPIs: Fixed Effects Models vs. Random Effects Models

Dependent Variable $\boldsymbol{\Delta_1 ph_{i,t}}$	Fixed Effects Models (1996Q2-2011Q1)					Random Effects Models (1996Q2-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\boldsymbol{\Delta_1 pr^f_{i,t}}$	-.031***	-.020***	-.022***	-.026***	-.026***	-.031***	-.021***	-.023***	-.026***	-.026***
	(.003)	(.001)	(.001)	(.001)	(.001)	(.003)	(.001)	(.001)	(.002)	(.002)
$\boldsymbol{\Delta_1 hri_{i,t}}$	-.167	.136	.232**	.232**	.349***	-.167	.115	.224**	.224**	.397***
	(.201)	(.094)	(.095)	(.093)	(.102)	(.200)	(.107)	(.108)	(.107)	(.116)
$\boldsymbol{\Delta_1 b_{i,t}}$		1.209***	1.538***	1.479***	1.557***		1.124***	1.500***	1.455***	1.571***
		(.024)	(.034)	(.035)	(.044)		(.026)	(.038)	(.040)	(.051)
$\boldsymbol{\Delta_1 b_{i,t-1}}$			-.434***	-.395***	-.414***			-.484***	-.456***	-.483***
			(.034)	(.034)	(.035)			(.039)	(.039)	(.040)
$\boldsymbol{\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}}$				.002***	.002***				.001***	.001***
				(.0004)	(.0004)				(.0004)	(.0004)
$\boldsymbol{\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}}$					-.104***					-.154***
					(.037)					(.042)
Constant	.017***	.003***	.003***	.004***	.003***	.017***	.004***	.004***	.005***	.003***
	(.002)	(.001)	(.001)	(.001)	(.001)	(.002)	(.001)	(.001)	(.001)	(.001)
Causality Test			.000	.000	.000			.000	.000	.000
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes					
Time Fixed Effects	No	No	No	No	No					
No. Observation	720	720	720	720	720	720	720	720	720	720
Within $\boldsymbol{R^2}$	.160	.818	.853	.858	.860	.160	.817	.851	.857	.858
F-test for Fixed Effect	.997	.000	.000	.000	.000					
LM Random Effect Test						1.000	1.000	1.000	1.000	1.000
Hausman Test	.999	$\chi^2 < 0$	$\chi^2 < 0$	$\chi^2 < 0$	$\chi^2 < 0$	.999	$\chi^2 < 0$	$\chi^2 < 0$	$\chi^2 < 0$	$\chi^2 < 0$
LM Independence Test	.000	.000	.000	.000	.000					
Pasaran CD Test	.000	.000	.374	.028	.004					
Heteroskedasticity Test	.000	.000	.000	.000	.000					

Notes: The interaction variables, $\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying them by 100. $\chi^2 < 0$ means the Hausman test fails as the model fitted on these data fails to meet the asymptotic assumptions. The values presented for the diagnostics tests are $p\text{-}values$. The null hypothesis of the Causality Test is $H_0: \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$. The null hypothesis of the LM Independence Test is the residuals across regions are not correlated. The null hypothesis of the Pasaran Cross-sectional Dependence (CD) Test is the residuals are not correlated across regions. The null hypothesis of Heteroskedasticity test is homoskedasticity. Coefficient standard deviations are in parentheses.

Table 3 Changes in Bubble cause Changes in HPI (Panel A): PCSE with AR(1) vs. FGLS with Heteroskedasticity

Dependent Variable $\boldsymbol{\Delta_1 ph_{i,t}}$	PCSE (AR1) (1996Q2-2011Q1)					FGLS (Heteroskedasticity) (1996Q2-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\boldsymbol{\Delta_1 pr^f_{i,t}}$	-.031***	-.023***	-.023***	-.027***	-.027***	-.029***	-.023***	-.026***	-.028***	-.028***
	(.002)	(.001)	(.001)	(.002)	(.002)	(.002)	(.001)	(.001)	(.001)	(.001)
$\boldsymbol{\Delta_1 hri_{i,t}}$	-.012	.133	.214*	.218*	.375***	-.198	.068	.111	.101	.291***
	(.244)	(.119)	(.112)	(.115)	(.132)	(.183)	(.081)	(.079)	(.079)	(.089)
$\boldsymbol{\Delta_1 b_{i,t}}$		1.159***	1.477***	1.409***	1.515***		1.081***	1.560***	1.550***	1.657***
		(.037)	(.042)	(.046)	(.056)		(.020)	(.031)	(.033)	(.040)
$\boldsymbol{\Delta_1 b_{i,t-1}}$			-.463***	-.418***	-.442***			-.516***	-.513***	-.541***
			(.042)	(.044)	(.044)			(.031)	(.033)	(.032)
$\boldsymbol{\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}}$				.002***	.002***				.001***	.001**
				(.0004)	(.0004)				(.0003)	(.0003)
$\boldsymbol{\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}}$					-.142***					-.138***
					(.046)					(.032)
Constant	.015***	.003**	.004***	.005***	.004***	.017***	.002***	.002***	.002***	.001
	(.005)	(.001)	(.001)	(.001)	(.001)	(.002)	(.001)	(.001)	(.001)	(.001)
Causality Test			.000	.000	.000			.000	.000	.000
No. Observation	720	720	720	720	720	720	720	720	720	720
$\boldsymbol{R^2}$	.328	.737	.791	.793	.797					
$\boldsymbol{Prob > \chi^2}$	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

Notes: Δ_1 means first difference. The interaction variables, $\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying them by 100. The null hypothesis of the Causality Test is $H_0: \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$. $Prob > \chi^2$ tests for whether all of the coefficients in the model are jointly significant. Coefficient standard deviations are in parentheses. ***, ** and * stands for statistical significance at the 1%, 5% and 10% level, respectively.

Table 3 Fixed Effects Models with robust standard errors (Panel B)

Dependent Variable $\boldsymbol{\Delta_1 ph_{i,t}}$	Fixed Effects Models (Robust St. Dev.) UK (1996Q2-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\boldsymbol{\Delta_1 pr^f_{i,t}}$	-.031***	-.021***	-.023***	-.026***	-.026***
	(.003)	(.004)	(.005)	(.005)	(.005)
$\boldsymbol{\Delta_1 hri_{i,t}}$	-.167	0.115	.224	.224	.397**
	(.139)	(.143)	(.172)	(.163)	(.150)
$\boldsymbol{\Delta_1 b_{i,t}}$		1.124***	1.50***	1.455***	1.571***
		(.093)	(.248)	(.231)	(.218)
$\boldsymbol{\Delta_1 b_{i,t-1}}$			-.484**	-.456**	-.483**
			(.191)	(.177)	(.171)
$\boldsymbol{\Delta_1 b_{i,t}} * \boldsymbol{\Delta_1 pr^f_{i,t}}$				.0015*	.0013
				(.001)	(.001)
$\boldsymbol{\Delta_1 b_{i,t}} * \boldsymbol{\Delta_1 hri_{i,t}}$					-.154***
					(.036)
Constant	0.017***	.004	.004**	.005**	.0035*
	(.001)	(.002)	(.002)	(.002)	(.002)
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	No
No. Observation	720	720	708	708	708
Within $\boldsymbol{R^2}$	.159	.779	.807	.811	.814
Causality Test			.000	.000	.000

Notes: Δ_1 means first difference. The White (1980) robust standard deviation controls for heteroskedasticity. The interaction variables, $\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. Values presented for the diagnostics tests are p-values. The null hypothesis of Causality Test is $H_0: \beta_{\Delta_1 ph_{i,t}} = \beta_{\Delta_1 ph_{i,t-1}} = 0$. Coefficient standard deviations are in parentheses. ***, ** and * stands for statistical significance at the 1%, 5% and 10% significance level, respectively.

Table 4 Changes in HPI cause Changes in Bubble: Fixed Effects Models vs. PCSE (AR1)

Dependent Variable $\Delta_1 b_{i,t}$	Fixed Effects Models (Robust St. Dev.) (1996Q2-2011Q1)					PCSE (AR1) (1996Q2-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\Delta_1 pr^f_{i,t}$	-.008***	.011***	.009***	.009***	.012***	-.006***	.009***	.008***	.008***	.011***
	(.003)	(.003)	(.002)	(.002)	(.002)	(.001)	(.001)	(.001)	(.001)	(.001)
$\Delta_1 hri_{i,t}$	-.251**	-.143	-.141	-.140	-.130	-.123	-.134	-.120**	-.129**	-.136**
	(.099)	(.108)	(.104)	(.124)	(.117)	(.126)	(.109)	(.058)	(.063)	(.063)
$\Delta_1 ph_{i,t}$		.648***	.555***	.555***	.580***		.488***	.507***	.504***	.531***
		(.074)	(.064)	(.056)	(.057)		(.021)	(.014)	(.017)	(.018)
$\Delta_1 ph_{i,t-1}$			.237***	.237***	.228***			.194***	.194***	.187***
			(.013)	(.013)	(.014)			(.012)	(.012)	(.012)
$\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$				-.001	-.005				.005	.004
				(.024)	(.021)				(.018)	(.018)
$\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$					-.001***					-.001***
					(.0002)					(.0001)
Constant	.012***	.001	-.002*	-.002*	-.002**	.009*	.003**	-.0003	-.0003	-.001
	(.001)	(.001)	(.001)	(.001)	(.001)	(.005)	(.002)	(.001)	(.001)	(.001)
Causality Test			.000	.000	.000			.000	.000	.000
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes					
Time Fixed Effects	No	No	No	No	No					
No. Observation	720	720	708	708	708	720	720	708	708	708
Within R^2	.029	.790	.889	.889	.893	.072	.615	.723	.725	.731
$Prob > \chi^2$						.000	.000	.000	.000	.000

Notes: Δ_1 means first difference. The Robust St. Dev. stands for White (1980) robust standard deviation which controls for heteroskedasticity. The interaction variables, $\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. Values presented for the diagnostics tests are $p\text{-}values$. The null hypothesis of Causality Test is $H_0: \beta_{\Delta_1 ph_{i,t}} = \beta_{\Delta_1 ph_{i,t-1}} = 0$. $Prob > \chi^2$ tests for whether all the coefficients in the model are jointly significant. Coefficient standard deviations are in parentheses. ***, ** and * stands for statistical significance at the 1%, 5% and 10% level, respectively.

Table 5 Changes in Bubble cause Changes in HPI (Panel A): Fixed Effects Models

Dependent Variable $\boldsymbol{\Delta_1 ph_{i,t}}$	Fixed Effects Models (Robust St. Dev.) UK (1996Q2-2000Q4)					Fixed Effects Models (Robust St. Dev.) UK (2001Q1-2006Q4)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\boldsymbol{\Delta_1 pr^f_{i,t}}$	-.041***	-.031***	-.033***	-.036***	-.037***	-.018***	-.014***	-.018***	-.015**	-.015**
	(.003)	(.005)	(.005)	(.005)	(.005)	(.002)	(.003)	(.005)	(.006)	(.006)
$\boldsymbol{\Delta_1 hri_{i,t}}$	.070	.194*	.266*	.230	.353	-.629***	.189	.159	.152	.623***
	(.077)	(.105)	(.143)	(.136)	(.212)	(.169)	(.128)	(.170)	(.170)	(.174)
$\boldsymbol{\Delta_1 b_{i,t}}$		.941***	1.087***	1.063***	1.203***		1.263***	1.592***	1.610***	1.742***
		(.082)	(.117)	(.125)	(.131)		(.116)	(.261)	(.263)	(.269)
$\boldsymbol{\Delta_1 b_{i,t-1}}$			-.325***	-.254**	-.274***			-.490**	-.504**	-.519**
			(.079)	(.087)	(.080)			(.218)	(.220)	(.219)
$\boldsymbol{\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}}$				.004***	.004**				-.0006	-.001
				(.001)	(.002)				(.001)	(.001)
$\boldsymbol{\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}}$					-.162					-.202***
					(.146)					(.058)
Constant	.015***	.005***	.007***	.007***	.006***	.038***	.001	.005**	.005**	.001
	(.001)	(.001)	(.001)	(.001)	(.002)	(.001)	(.003)	(.002)	(.002)	(.002)
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	No	No	No	No	No	No
No. Observation	228	228	216	216	216	288	288	276	276	276
Within $\boldsymbol{R^2}$	.539	.794	.824	.834	.836	.107	.759	.806	.806	.814
Causality Test			.000	.000	.000			.000	.000	.000

Notes: Δ_1 means first difference. The White (1980) robust standard deviation controls for heteroskedasticity. The interaction variables, $\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. The values presented for the diagnostics tests are $p\text{-}values$. The null hypothesis of Causality Test is $H_0 \colon \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$. Coefficient standard deviations are in parentheses. ***, ** and * stands for statistical significance at the 1%, 5% and 10% level, respectively.

Table 5 Changes in Bubble cause Changes in HPI (Panel B): Fixed Effects Models

Dependent Variable $\boldsymbol{\Delta_1 ph_{i,t}}$	Fixed Effects Models (Robust St. Dev.) UK (2007Q1-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\boldsymbol{\Delta_1 pr^f_{i,t}}$	-.046***	-.027***	-.027***	-.024***	-.024***
	(.007)	(.007)	(.007)	(.006)	(.006)
$\boldsymbol{\Delta_1 hri_{i,t}}$	-.635*	-.152	.347	.313	.359
	(.312)	(.295)	(.269)	(.249)	(.347)
$\boldsymbol{\Delta_1 b_{i,t}}$		1.146***	1.459***	1.429***	1.406***
		(.105)	(.264)	(.259)	(.278)
$\boldsymbol{\Delta_1 b_{i,t-1}}$			-.469**	-.434*	-.432**
			(.207)	(.199)	(.200)
$\boldsymbol{\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}}$				.004***	.004***
				(.001)	(.001)
$\boldsymbol{\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}}$					.031
					(.118)
Constant	-.007***	.003	-.001	.001	.001
	(.002)	(.002)	(.002)	(.001)	(.002)
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	No
No. Observation	204	204	192	192	192
Within $\boldsymbol{R^2}$	.346	.784	.821	.831	.832
Causality Test			.000	.000	.000

Notes: Δ_1 means first difference. The White (1980) robust standard deviation controls for heteroskedasticity. The interaction variables, $\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. The values presented for the diagnostics tests are $p\text{-}values$. The null hypothesis of Causality Test is $H_0: \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$. Coefficient standard deviations are in parentheses. ***, ** and * stands for statistical significance at the 1%, 5% and 10% level, respectively.

Table 6 Changes in HPI cause Changes in Bubble (Panel A): Fixed Effects Models

Dependent Variable $\boldsymbol{\Delta_1 b_{i,t}}$	Fixed Effects Models (Robust St. Dev.) UK (1996Q2-2000Q4)					Fixed Effects Models (Robust St. Dev.) UK (2001Q1-2006Q4)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\boldsymbol{\Delta_1 pr^f_{i,t}}$	-.010**	.014***	.014***	.015***	.018***	-.003	.007**	.008**	.008**	.014***
	(.004)	(.003)	(.002)	(.002)	(.002)	(.002)	(.003)	(.003)	(.003)	(.003)
$\boldsymbol{\Delta_1 hri_{i,t}}$	-.132	-.173	-.135	.007	-.059	-.648***	-.284***	-.212**	-.324*	-.290
	(.113)	(.110)	(.109)	(.124)	(.136)	(.115)	(.082)	(.091)	(.169)	(.173)
$\boldsymbol{\Delta_1 ph_{i,t}}$		.586***	.623***	.713***	.698***		.578***	.533***	.512***	.539***
		(.080)	(.073)	(.068)	(.066)		(.083)	(.059)	(.060)	(.060)
$\boldsymbol{\Delta_1 ph_{i,t-1}}$			.203***	.193***	.196***			.230***	.231***	.220***
			(.031)	(.031)	(.022)			(.010)	(.010)	(.010)
$\boldsymbol{\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}}$				-.105**	-.059				.035	.022
				(.041)	(.039)				(.041)	(.042)
$\boldsymbol{\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}}$					-.001***					-.001***
					(.0004)					(.0003)
Constant	.010***	.002**	-.003***	-.004***	-.004***	.029***	.007**	.001	.002	.0008
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.003)	(.002)	(.002)	(.002)
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	No	No	No	No	No	No
No. Observation	228	228	216	216	216	288	288	276	276	276
Within $\boldsymbol{R^2}$	.112	.602	.734	.751	.777	.044	.742	.857	.858	.865
Causality Test			.000	.000	.000			.000	.000	.000

Notes: Δ_1 means first difference. The White (1980) robust standard deviation controls for heteroskedasticity. The interaction variables, $\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. Values presented for the diagnostics tests are $p\text{-}values$. The null hypothesis of Causality Test is $H_0\colon \beta_{\Delta_1 ph_{i,t}} = \beta_{\Delta_1 ph_{i,t-1}} = 0$. Coefficient standard deviations are in parentheses. ***, ** and * stands for statistical significance at the 1%, 5% and 10% significance level, respectively.

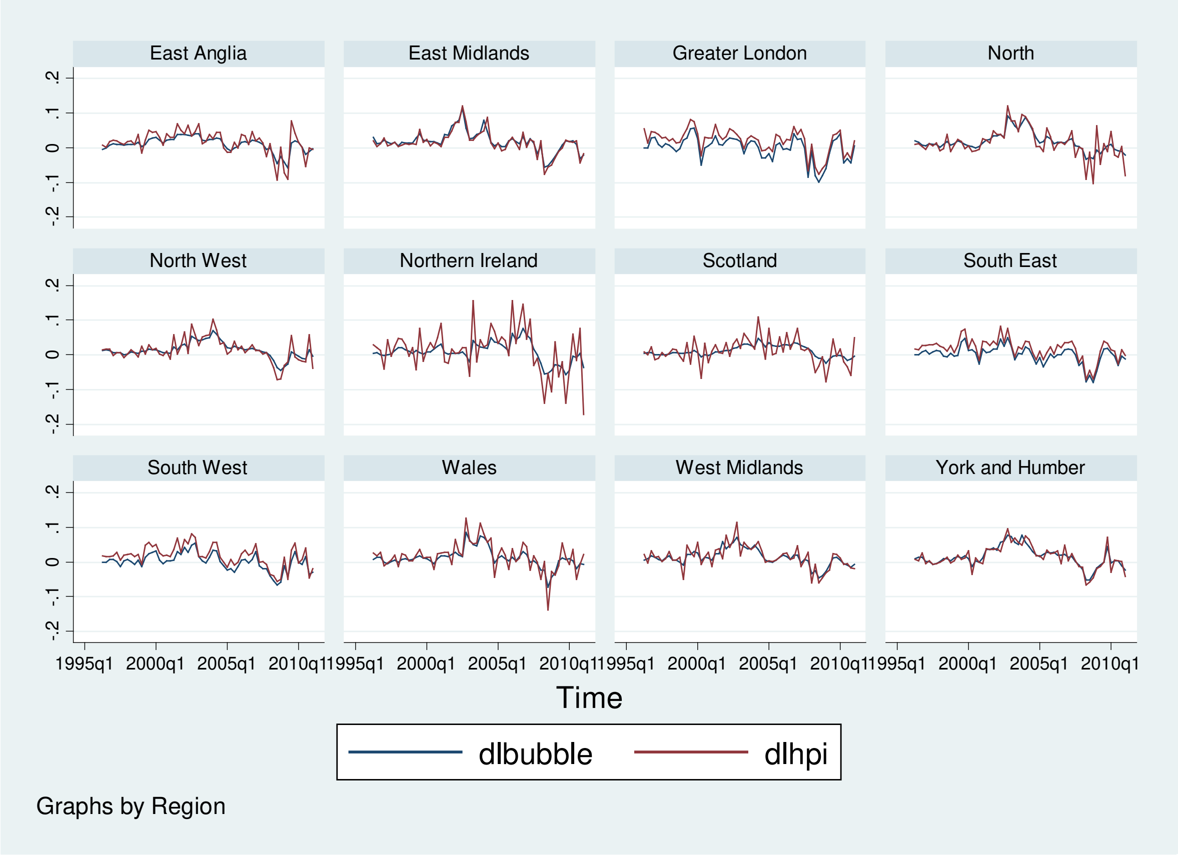
Table 6 Changes in HPI cause Changes in Bubble (Panel B): Fixed Effects Models

Dependent Variable $\boldsymbol{\Delta_1 b_{i,t}}$	Fixed Effects Models (Robust St. Dev.) UK (2007Q1-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\boldsymbol{\Delta_1 pr^{f}_{i,t}}$	-.017***	.010***	.008***	.008***	.008***
	(.004)	(.004)	(.002)	(.002)	(.002)
$\boldsymbol{\Delta_1 hri_{i,t}}$	-.422	-.050	-.181	-.186	-.155
	(.332)	(.228)	(.184)	(.198)	(.182)
$\boldsymbol{\Delta_1 ph_{i,t}}$		.585***	.528***	.530***	.542***
		(.083)	(.081)	(.078)	(.079)
$\boldsymbol{\Delta_1 ph_{i,t-1}}$			.223***	.223***	.216***
			(.012)	(.013)	(.013)
$\boldsymbol{\Delta_1 ph_{i,t} * \Delta_1 pr^{f}_{i,t}}$				-.003	-.0001
				(.031)	(.033)
$\boldsymbol{\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}}$					-.0007**
					(.0003)
Constant	-.009***	-.005**	-.003	-.003	-.004***
	(.002)	(.002)	(.002)	(.002)	(.001)
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	No
No. Obs	204	204	192	192	192
Within $\boldsymbol{R^2}$	.126	.712	.824	.824	.829
Causality Test			.000	.000	.000

Notes: Δ_1 means first difference. The White (1980) robust standard deviation controls for heteroskedasticity. The interaction variables, $\Delta_1 ph_{i,t} * \Delta_1 pr^{f}_{i,t}$ and $\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. Values presented for the diagnostics tests are $p\text{-}values$. The null hypothesis of Causality Test is $H_0\colon \beta_{\Delta_1 ph_{i,t}} = \beta_{\Delta_1 ph_{i,t-1}} = 0$. Coefficient standard deviations are in parentheses. ***, ** and * stand for statistical significance at the 1%, 5% and 10% significance level, respectively.

Figures

Figure 1 Changes in Regional House Price Bubble (dlbubble) vs. Regional House Price Index (dlhpi)



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