Empirica
https://doi.org/10.1007/s10663-023-09567-y

ORIGINAL PAPER

Housing price uncertainty and housing prices in the UK in a time-varying environment

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Accepted: 2 January 2023

Abstract
This study offers a new perspective on the dynamic causal relationship between housing price uncertainty and housing prices in a time-varying environment for the UK for the first time in the literature. This study aims to investigate whether housing market uncertainty has any time-varying effect on housing prices between 1998:Q1 and 2019:Q2. A key distinction of this study is the use of a news-based housing price uncertainty index. This index measures uncertainty pertaining especially to the housing market in the UK. To this end, we include two main classes using time-varying parameter, rolling estimation and recursive rolling estimation for robustness analysis. Furthermore, we add economic policy uncertainty into the models to see whether housing market uncertainty has predictive power after controlling for economic policy uncertainty because housing market uncertainty may be largely driven by economic policy uncertainty and key macro-economic indicators. It turns out that there is a part of housing market uncertainty beyond economic policy uncertainty that helps to predict housing prices in UK. These outcomes are reinforced by the results of time-varying Granger causality tests that real housing price index is largely driven by the housing price uncertainty index. Furthermore, it is found that the uncertainty variables have a negative impact on real housing prices. This position calls for insolation in the housing market in UK from externalities such as housing price uncertainty.

Keywords Housing price dynamic · Housing price uncertainty · Time-varying parameter Granger causality · Rolling and recursive-rolling estimation · United Kingdom

Responsible Editor: Paul Raschky.

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Published online: 30 January 2023

JEL Classification C32 · O18 · R31

1 Introduction

The UK housing prices have reached a record high stemming from the 2007 peak values. Housing price is rising in the metropolis like London. Statistics from nationwide newspapers reveal that in the metropolis, housing prices have more than doubled since the sub-prime mortgage crisis (Pavlidis et al. 2017). This trajectory regarding the hike in property prices in the UK and its metropolitan areas call for growing concern as expressed by housing market agents, central banks, and housing international bodies such as the international monetary fund. Thus, it is pertinent to understand the dynamic causality between house price uncertainty and real house prices i.e., to explore what causes what, and what factors drive house prices movements in the UK. The fluctuations in global house prices are credited to the catastrophic economic effects of the 2007 great recession as fueled by the subprime mortgage crisis that originated from the United States, which were more severe in the housing market than in other sectors of the economy (Nyakabawo et al. 2015). The aftermath of this crisis generated a lot of scholarly attention in the extant literature such as (see Strobel et al. 2020; Akinsomi et al. 2016; Leamer 2015; Miller et al. 2011; Gupta et al. 2010; Iacoviello and Neri 2010). Some researchers alluded to the fact that housing prices are a leading indicator of any economy since the slump in the housing prices led to a global economic downturn (e.g. Aye et al. 2014; Bernanke 2008; Leamer 2007).

Accordingly, the extant literature overwhelmingly presents the effect of various macro-economic variables on housing prices for several regions and countries with diverse statistical methods (see Coskun et al. 2020; Vogiazas and Alexiou 2017; Kishor and Marfatia 2017; Guerrieri and Iacoviello 2017; Emirmahmutoglu et al. 2016; Li et al. 2015; Cesa-Bianchi et al. 2015; Balcilar et al. 2014; Katrakilidis and Trachanas 2012). It is noteworthy that macroeconomic uncertainty is a crucial characteristic of the global economic market in general and the housing sector in particular. Macroeconomic uncertainty can affect the housing price through different channels such as first, shock emanating from uncertainty shows detrimental effect on house prices. However, this shock does not affect the volume traded. Second in scenarios where there is a dual shock of uncertainty and local demand, the effect of uncertainty is more severe on housing market as it dominates the local labour demand on several housing market indices (Strobel et al. 2020). Additionally, housing can be considered as an investment and a durable consumer good. As an investment good, housing is also regarded as an unalterable investment option. Hence, agents tend to delay their investment decisions under uncertainty to gather more information (Bernanke 2008). Thus, this delay leads to a decrease in housing supply. Furthermore, under incomplete markets and risk aversion, the relationship between uncertainty and investments is likely to be negative (Craine 1989). Whereas on the contrary, under complete market and risk neutrality, uncertainty and investment are probably positively related (Hartman 1972). Additionally, Caballero (1991) shows that the effect of uncertainty on investment depends on the degree of competition using the asymmetric adjustment cost model. As a consumption good, housing demand tends to decrease under the uncertainty about future income, wealth, and employment, since households in such case are oriented toward increasing their precautionary savings (Givazzi and McMahon 2012). Thus, households respond to uncertainty by cutting down on consumption of durable goods in anticipation of certainty (Bloom 2014). This response causes a slowdown in the housing demand and price (Ramcharan 2017). For instance, Christidou and Fountas (2017) analyzed the impact of housing price uncertainty on housing price inflation and housing investment growth for the U.S. The study revealed that the response of housing price uncertainty decreases the housing price inflation while it is inconclusive for the housing investment growth. Note that, the inconclusiveness of housing investment growth is because housing price uncertainty increases housing investment growth in some states and it decreases housing investment growth in other states. Furthermore, housing is unique from other financial assets; this is premised on its attributes of being a durable consumer good for households. Giving the trajectory of the literature, Li et al. (2015) explored the co-movement and causality between U.S housing and stock markets using time and frequency domain methodology to offer a new perspective on the causality between house price and stock market. More recently, Balcilar et al. (2020) used state-level data to highlight the nexus between consumption-(dis)aggregated wealth ratios i.e., financial and housing are strong predictors of housing return.

Additionally, despite the notable contribution of Christidou and Fountas (2017) in the scanty housing uncertainty literature, their study suffers from at least two shortcomings namely. First, the omission of macroeconomic variables such as interest rate, unemployment, etc. which are key determinants of housing market price (Balcilar et al. 2014; Li et al. 2015), are not controlled for in the model. Hence, our study comprehensively captures macroeconomic variables such as short-term interest rate, population, and real GDP in the model. This may help provide insights for robust policy formulation. Second limitation identified is in broadness of study scope as the study leverages on uncertainty which is not specific to housing price like housing price uncertainty for more precise and policy crafting like the case of the present study.

The current literature has focused more on the determinant of housing prices, its effect on stock markets, and investment options. The present study focuses on the UK which has received few documentations in the extant literature. The objective of this study is to investigate the predictability power of real housing price uncertainty index on the housing price while controlling for population, the interest rate and economic policy uncertainty index by using the time-varying Granger causality test for the United Kingdom (UK). However, scrutiny into the housing literature shows that previous empirical studies appeared to have ignored the predictive power of housing price uncertainty on the housing price. Thus, we seek to bridge this gap in the literature holistically. To the best of our knowledge, this is the first study to explore the highlighted co-variates in a time-varying Granger causality environment between housing price uncertainty and housing price while controlling some selected macroeconomic variables such as, population, and interest rate for the UK.

The choice of the UK is motivated from the fact that property prices are on high record mostly in metropolitan areas in the UK and fear of more spillover effects are anticipated on democratic indices like population, income levels and more. Thus, the need to underscore the factors driving housing prices in terms of causality i.e., predictability power of one variable on another are pertinent for policy decisions in the real estate sector. Further motivation for the UK stems from the fact that in the last three decades the UK housing sector has witnessed distinct recessions specifically between 2008Q2 and 2009Q2. The UK housing crisis are not a new occurrence, it can be dated back to over three decades ago. The building blocks for the housing issues can be traced back to the end of the World War 1 and more recently global financial sub-prime mortgage crises in 2007–2009.

Furthermore, the motivation for the UK is also driven by the availability of data on housing price uncertainty available at the public domain.[1] Also, the current study data covers mainly from 1998Q1 to 2019Q2 which also highlights several business cycles and global financial and European Union sovereign debt episodes. Worthy of mentioning also is that the present study data covers the recent Brexit process and hence, study into the role of uncertainty in predicting real housing price in the UK is pertinent and it has shown to be a key indicator historically for the country (Plakandaras et al. 2020), which is an ongoing case of interest. The plausible explanation is because the Brexit process could potentially be a good predictor for the UK housing market as a driver that might lead to a decline in foreign investment to the housing market and deter buyers given the increase housing uncertainty generally. Additionally, after the European Union referendum, the uncertainty index increased reasonably almost reaching the 2008Q3 level given the takeoff point of about 306 in 2016Q3. Whereas, during the first six months of 2018, the index dropped considerably to near 100, thereafter started increasing by the remaining part of the same year and climaxed at 211 at the beginning of 2019. Currently, the index is marked at 158. It is expedient to note that uncertainty may be caused by the following: (a) Inside domestic political condition, (b) given the withdrawal agreement, discussions with the EU, (c) the Aftermath of Brexit vis-à-vis its consequences do have a significant impact on the housing market. It is evident that from 2007 to date, the volatility of the index has been on the increase consistently. Given the above highlights there exist the need to explore the predictability power of housing price uncertainty and house prices in the context of UK using recent data.

The present study distinction and addition to the current body of knowledge in the existing housing literature involves addressing the pertinent question “is whether housing market uncertainty has any effect on housing prices. A novelty of this study is the use of a news-based housing price uncertainty index.[2] This index measures

[1] The period of the data is determined by the data availability. Particularly, the house price uncertainty is available until 2019Q4 while the economic policy uncertainty data starts in 1998Q1.

See https://uk.housing-observatory.com/resources.html.

See https://www.nationwide.co.uk/about/house-price-index.

See https://www.policyuncertainty.com

[2] Constructed by United Kingdom Housing Observatory. See https://uk.housing-observatory.com/resources.html

uncertainty pertaining especially to the housing market in the UK which previous studies fail to account for rather they relied on general board macroeconomic uncertainty. However, real house price uncertainty shows more variation relative to the previous uncertainty proxies employed in the extant literature which are not derived from housing price uncertainty such as financial uncertainty and macro-economic uncertainty previously highlighted. Thus, the present study makes the claim that results from real house price uncertainty for the UK are more robust especially in a time-varying parameter framework. Additionally, the uniqueness of the present study other than applying the real house price uncertainty is that, we added economic policy uncertainty into the models to see whether housing market uncertainty has predictive power after controlling for economic policy uncertainty because housing market uncertainty can be largely driven by economic policy uncertainty. It turns out that there is a part of housing market uncertainty beyond economic policy uncertainty that helps to predict housing prices.

Furthermore, the present study adds to the housing market literature in terms of methods. As it is known that the traditional Granger causality test is built on the Vector Autoregressive (VAR) model and it is sensitive to instabilities. Specifically, it has some issues when adopted to examine causality relationships involving time-series data that are related to the financial market which is characterized by regime fluctuations, episodes and structural breaks (Rossi 2013; Clark and McCracken 2006; Boivin and Giannoni 2006). Thus, to address these issues using time-varying parameter (TVP), rolling estimation and recursive rolling estimation for robustness analysis are adopted which is known to produce a consistent and robust result in a time-varying environment. Thus, empirical results from this test are ample for policy design in the UK housing market.

Our study empirical results from the time-varying analysis conclude that housing price uncertainty is a key predictor for real housing price index in the UK. Given the predictive power of housing price uncertainty on real housing price index. This suggests that in an uncertainty prone environment, housing price uncertainty imposes a negative effect on the economy and deteriorates macroeconomic indicators like the ones accounted for in our study such as interest rate, employment, population, and real output (GDP). This will, in turn, transmits via spillover effects to real house prices as real estate developers can delay future construction activities thereby decreasing housing supplies and increasing housing demand and real house prices. Given our study outcome, a key policy implication for policymakers is that housing price uncertainty could be used as pertinent uncertainty measure that aid in formulating prompt housing market policies.

The remainder of this study follows next with section two on data and methodological procedure. Subsequently, section three presents the empirical results in a stylized manner. Section four renders the concluding remarks and policy implications.

2 Data and methodology

2.1 Data

This study aims to examine whether housing price uncertainty has causal effect on real housing prices in the UK. Thus, the present study adopted quarterly frequency data on UK real housing price index (RHPI), housing price uncertainty index (HPU), economic policy uncertainty index (EPU), population (POP) (in thousand), 3-month treasury bill rate (IRATE) which is proxy for the short-term interest rate (in percentage), and real GDP (RGDP) for the period from 1998Q1 to 2019Q2.[3] The news-based housing price uncertainty index measures uncertainty pertaining especially to the housing market in the UK.

The housing price uncertainty index is constructed by Yusupova et al. (2020) and is currently available from the United Kingdom Housing Observatory.[4] Yusupova et al. (2020) adopt the methodology of Baker et al. (2016) to construct the HPU index for the UK. In order to construct the HPU index, the five large newspapers in the UK, namely The Guardian, The Independent, The Times, Financial Times, and Daily Mail, are searched for house price uncertainty related terms, and search counts are used to construct the index on a quarterly basis. They use the digital archives of these five large newspapers to obtain a quarterly search count of articles that contain the following three terms: ‘uncertainty’ or ‘uncertain’; ‘housing’ or ‘house prices’ or ‘real estate’; and one of the following: ‘policy’, ‘regulation’, ‘Bank of England, ‘mortgage’, ‘interest rate’, ‘stamp-duty’, ‘tax’, ‘bubble’ or ‘buy-to-let’. The search keywords also include variants like ‘uncertainties’, ‘housing market’ or ‘regulatory’. An article is only included in the search count if it contains terms in all three categories. After obtaining the counts of the articles meeting the inclusion criteria for each quarter and forming a raw quarterly series of counts, the counts are scaled by the total number of articles in the given newspaper and in the given quarter. Lastly, the EPU index is obtained by taking an average over the series for the five newspapers and normalizing the index to have a mean of 100.

The real housing prices data is calculated as national average and derived from the Nationwide Building Society website.[5] The economic policy uncertainty index was developed by Baker et al. (2016).[6] The population, short-term interest rate, and real GDP data were sourced from the Organization for Economic Co-operation and Development (OECD) database. The description and source of the data are provided in “Appendix” section (see Table 3).

The motivation for the outlined variables in the study stems from the fact that there is need to underscore driving factors for housing prices in the UK. To this end, the present study drives strength from previous empirical studies such as; Balcilar

[3] The period of the data is determined by the data availability. Particularly, the house price uncertainty is available until 2019Q2 while the economic policy uncertainty data begins from 1998Q1.

[4] See https://uk.housing-observatory.com/resources.html.

[5] See https://www.nationwide.co.uk/about/house-price-index.

[6] See https://www.policyuncertainty.com

et al. (2021); Salisu et al. (2022). For instance, Case and Shiller (1990) highlight the pertinent the role of population, real income and interest rate as key determinants of housing price in US. Furthermore, this study leverages on well-established housing price modelling where both the demand–supply side of the housing market dynamics are perceived as crucial predictors for housing market prices. This preposition aligns with the United Nation Sustainable Development Goals (UN-SDGs-11). Generally, empirical studies such as (Vogiazas and Alexiou 2017; Aye et al. 2014; Balcilar et al. 2014) highlight that housing markets are affected by business cycles. In our study case, following the study of Case and Shiller (1990) that opined that financial variables interact in the boom-and-bust episodes of assets prices. Often, the macroeconomy is measured by indices such as inflation rate, unemployment, GDP among others. On the other hand, financial indices are measured by monetary conditions such as interest rate, money supply. These indices are widely considered to drive real housing prices globally (Fan et al. 2019). Our study makes exception by the inclusion of EPU and house price uncertainty for more robust predictability power for drivers of real house prices for the UK. The present study claims that the inclusion of both monetary macroeconomic variables, financial variable will produce more robust results for policy crafting for the UK housing market.

All the variables are expressed in the natural logarithm form. As we describe below, the time-varying causality technique requires stationary data. According to the unit root test results, only housing price uncertainty and economic policy uncertainty index are stationary at their levels, I(0). Thus, they enter into the model as a log-level while other variables are non-stationary, I(1), so they are considered with their first differences logs, i.e. log growth rates.[7] Also, if a "D" precedes the variable name which means its first differenced. Figure 1 shows the time series plot for all variables under consideration.

2.2 Time-varying parameter vector autoregressive models

Granger (1969) proposes the standard linear Granger causality method to test in-sample predictability. The conventional linear Granger causality test built on the Vector Autoregressive (VAR) model is sensitive to instabilities. Specifically, it has some technical problems in examining the relationship involving time-series data that are related to the financial market which is characterized by regime fluctuations and structural breaks (Rossi 2013; Clark and McCracken 2006; Boivin and Giannoni 2006). Also, the possibility of nonstationarity in the time series data is not accounted for by the conventional Granger causality approach. Hence, the test results may lead to an erroneous inference when the instability is prevalent (Balcilar, et al. 2019). To address these shortcomings, Rossi and Wang (2019) suggest a robust Granger causality test, subsequently to the time-varying Granger causality test approach (Rossi 2005). In this study, a robust Granger causality test is applied to take into account possible structural changes in the time series for four different

[7] For the brevity of space, complete details of the unit root tests are provided in the Appendix section (see Table 4).

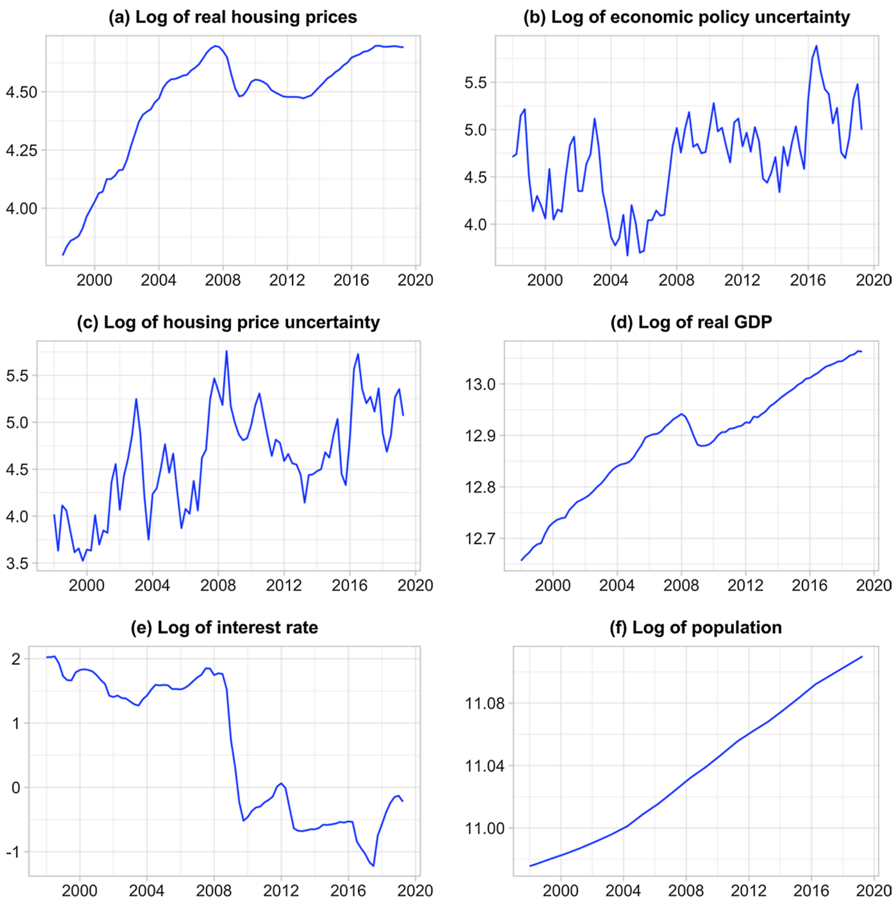

Fig. 1 Time series plots of the variables

models. The testing approach is based on a reduced form TVP-VAR model, which can be specified as follows:

$$y_t = A_{1,t}y_{t-1} + A_{2,t}y_{t-2} + \cdots + A_{p,t}y_{t-p} + u_t \tag{1}$$

where $A_{j,t}, j = 1, \ldots., p$, are an $(n \times n)$ time-varying coefficient matrices, $y_t = [y_{1,t}, y_{2,t}, \cdots, y_{n,t}]'$ is an $(n \times 1)$ vector, and u_t is an identically and independently distributed (iid) n-vector process with zero mean and constant variance matrix Σ, $u_t \sim iid(0, \Sigma)$.

The Granger causality test of Rossi (2005) can be applied on both the reduced form TVP-VAR in Eq. (1) as well as the direct multi-step local projection (Jordà 2005) time-varying VAR (TVP-VAR-LP) which is obtained by linear projection of y_{t+h} on $\left(y_{t-1}, y_{t-2}, \ldots, y_{t-p}\right)'$. The TVP-VAR-LP model can be written as:

$$y_{t+h} = \Phi_{1,t}y_{t-1} + \Phi_{2,t}y_{t-2} + \cdots + \Phi_{p,t}y_{t-p} + \varepsilon_{t+h} \tag{2}$$

where $\Phi_{j,t}, j = 1, \dots, p$, are an $(n \times n)$ time-varying coefficient matrices are functions of $\{A_{1,t}, A_{2,t}, \dots, A_{p,t}\}$ and ε_{t+h} is a moving average of the reduced form errors $\{u_t, u_{t+1}, \dots, u_{t+h}\}$. The TVP-VAR-LP assumes heteroskedastic and serially correlated idiosyncratic shocks. Thus, the time-varying Wald tests we use are robust to heteroskedasticity and serial correlation.

In the empirical analysis of the study, we estimate four different models with the following specifications of the variables. First, a model without any control variables is estimated to determine whether real housing prices are predictable using only HPU as the predictor (see Model 1); second, the baseline model is extended to incorporate EPU to ascertain if the additional variable would improve the forecast performance (see Model 2); the third incorporates some macroeconomic variables (GDP, IRATE, POP) to extend the second model (see Model 3); fourth, a model constructs that incorporates all the aforementioned variables to explore the impact on the predictability power of all exogenous variables on real housing price (see Model 4).

$$\text{Model 1}: y_t = \left[DLRHPI_t, LHPU_t\right]'$$
$$\text{Model 2}: y_t = \left[DLRHPI_t, LHPU_t, LEPU_t\right]'$$
$$\text{Model 3}: y_t = \left[DLRHPI_t, LHPU_t, DLGDP_t, DLIRATE_t, DLPOP_t\right]'$$
$$\text{Model 4}: y_t = \left[DLRHPI_t, LHPU_t, LEPU_t, DLGDP_t, DLIRATE_t, DLPOP_t\right]'$$

Model 1 and Model 2 might be misspecified since they exclude important variables that may affect housing prices. Model 3 and Model 4 are estimated to check the robustness of findings in a multivariate case. Our focus is on whether housing price uncertainty has any effect on housing prices. Hence, the null hypothesis is that housing price uncertainty (LHPU) does not Granger cause real housing prices (LRHPI) for all t where the null hypothesis of the robust Granger causality test is $H_0{:}\theta_{j,t}^{DLRHPI,LHPU} = 0,\ j = 1, \dots, p,$ for all $t = 1, 2, \dots, T,$ given that $\theta_{j,t}$ is an appropriate subset of vec $\left(\Phi_{1,t}, \Phi_{2,t}, \dots, \Phi_{p,t}\right)$. According to Rossi (2005), Exponential Wald tests (*ExpW*), the mean Wald tests (*MeanW*), the Nyblom tests (*Nyblom*), and the Quandt likelihood ratio tests (*QLR*) can be used to test the null hypothesis in the Eq. (2). The lag order is determined in a linear standard constant parameter model for each model type. The optimum lag order selected is using the Schwarz Information Criterion (SIC) and 1 for all models with maximum order specified as 4. We have also estimated TVP-VAR models with a maximum likelihood approach-based state-space form of the models to select the lag order. The TVP-VAR models also suggest a lag order of 1 for all models, with a maximum lag order of 4 considered in the selection. Multivariate portmantua tests for serial correlation with a lag order of 16 show that the models estimated with a lag order of 1 have white noise residuals. After determining the lag order for all models as 1, we further use the SIC to select a benchmark model as the model that has the minimum SIC among the four models we consider. The SIC values given the lag order 1 for all models are 3.995, 4.041, 7.703, and 7.921, respectively, for Models 1 to 4. Therefore, Model 1 is selected as the benchmark model. We use Models 2–3 as the extended models to check the robustness of Model 1. In estimating the time-varying test statistics based on the TVP-VAR models, a 10% trimming rate is applied to both ends of the sample, so test statistics are calculated for the period 2000:Q1–2017:Q2. The TVP-VAR Granger causality tests are robust to a trimming size of 15%, as the results are qualitatively the same with 15% trimming.

2.3 Rolling and recursive-rolling models

Although the TVP models are conceptually flexible and look appealing for economic time series model in the presence of structural breaks, they may generate spurious change in the coefficients that can extremely reduce the empirical performance of the model (see D'Agostino et al. 2011). The TVP-VAR model has random walk parameters that evolve gradually over time, which may rule out adaptation to abrupt changes. Indeed, a random walk parameter process has unit root memory, and it will not forget the past in the absence of any new shock. The TVP-VAR model imposes a pre-specified random walk parameter structure on the parameter time variation which may be restrictive. Thus, the TVP-VAR Granger causality tests may not have good performance for economic time series with a few abrupt changes and long periods of constant parameters.

Rolling and recursive rolling approaches (Balcilar et al. 2010; Balcilar and Ozdemir 2013; Shi et al. 2018, 2020) are alternative approaches for time-varying Granger causality testing. The parameter time variation in these approaches is governed by the data, thus, they adapt to abrupt changes more flexibly than the TVP model. Thus, we check robustness of our results using the rolling and recursive-rolling approaches. The Wald tests used in the rolling and recursive-rolling approaches are heteroskedasticity consistent.

3 Empirical results

This section of the study presents the empirical results and interpretation accordingly. First, we explore the basic summary statistics of the outlined variables. These statistics include central tendencies like average, minimum, maximum, and measures of the dispersion (standard deviation). Furthermore, we also investigate the symmetric properties of these variables as reported by skewness and kurtosis. Subsequently, to account for autocorrelation. Furthermore, we also investigated Ljung-Box statistics as presented by Q(1) and Q(4), respectively. To ensure homoscedastic, ARCH-LM statistics are reported. This study also explored the growth rate of the variables under consideration as reported at the bottom of Table 1. From Table 1, we observed the GDP at the level form shows the higher average as well as minimum and maximum over the investigated period. Additionally, population follows the second-ranked mean value while interest rate exhibits the lowest mean over the sample period. The symmetric nature of the series, interest rate, GDP, economic policy uncertainty, real housing price uncertainty, real housing price index are negative skewed while population has a positive skewness. Regarding the peakedness of the

Table 1 Descriptive statistics

	IRATE	GDP	POP	EPU	HPU	RHPI
Log level series						
Mean	−3.983	12.891	11.037	4.673	4.600	4.453
S.D	1.088	0.109	0.043	0.490	0.545	0.245
Min	−1.223	12.656	10.976	3.670	3.525	3.797
Max	2.037	13.064	11.110	5.885	5.758	4.698
Skewness	−0.145	−0.386	0.154	−0.041	−0.089	−1.240
Kurtosis	−1.765	−0.717	−1.370	−0.500	−0.768	0.431
JB	11.107***	3.782	6.704**	0.720	1.951	23.775***
Q(1)	84.816***	81.267***	83.733***	59.738***	62.501***	79.896***
Q(4)	303.924***	284.854***	309.250***	146.104***	153.943***	270.175***
ARCH(1)	66.154***	84.017***	84.472***	36.613***	25.706***	84.214***
ARCH(4)	67.735***	81.413***	81.997***	35.405***	28.013***	81.127***
Log growth rates (%)						
Mean	−2.643	0.478	0.158	0.337	1.234	1.052
S.D	15.752	0.591	0.042	29.407	30.091	2.162
Min	−78.631	−2.087	0.068	−70.262	−67.377	−7.059
Max	47.404	1.822	0.209	74.310	73.969	5.821
Skewness	−1.733	−1.826	−0.469	−0.052	0.022	−0.696
Kurtosis	7.149	6.235	−1.119	−0.560	−0.486	2.527
JB	237.587***	196.583***	7.305**	0.931	0.650	32.149***
Q(1)	33.146***	32.580***	75.174***	0.263	0.066	45.572***
Q(4)	44.590***	50.145***	247.281***	4.461	5.644	80.990***
ARCH(1)	7.965***	43.488***	69.836***	0.084	1.764	32.735***
ARCH(4)	13.587***	52.101***	67.805***	4.672	4.018	34.466***

The table reports the descriptive statistics for interest rate (IRATE), real gross domestic product (GDP), population (POP), economic policy uncertainty (EPU), housing price uncertainty (HPU), and real housing price (RHP). The quarterly data covers the period from 1998:Q1 to 2019:Q2. The table reports mean, standard deviation (S.D.), minimum value (Min), maximum value (max), skewness, excess Kurtosis, Jarque–Bera normality test (JB), first [Q(1)] and fourth [Q(4)] order serial correlation test, and first [ARCH(1)] and fourth [ARCH(4)] order autoregressive conditional heteroskedasticity test

***Indicates the rejection of the null hypothesis at the 1% significance

variables, all outlined variables show a light tail as none of the variables' kurtosis value greater than 3. Additionally, we observed the ARCH effect and autocorrelation in the sample as the null hypothesis of no ARCH effect and no autocorrelation is rejected at a 1% significance level. This outcome resonates with the behavior of each variable in its growth form. Thus, these basic pieces of information about these variables are informative to construct the Time-varying VAR Granger causality which proceeds in the next section.

Table 2 shows the constant parameter and time-varying Granger causality test results. Given that, the null hypothesis of no-Granger causality from housing price uncertainty index to real housing price index is strongly rejected under all the test

Table 2 Constant parameter VAR and time-varying parameter VAR Granger causality tests

Statistic	h	Model 1	Model 2	Model 3	Model 4
$\chi^2(1)$	–	9.986***	5.691***	5.716***	0.463
ExpW	0	137.547***	108.887***	385.369***	113.406***
ExpW	3	269.702***	269.702***	362.540***	258.301***
MeanW	0	61.080***	68.906***	220.412***	52.569***
MeanW	3	157.416***	157.416***	233.408***	213.701***
Nyblom	0	1421.023***	3696.915***	2980.976***	1787.214***
Nyblom	3	505.784***	505.784***	3950.759***	9204.423***
SupLR	0	283.508***	225.778***	779.153***	235.227***
SupLR	3	547.748***	547.748***	733.423***	524.945***

***Indicates the rejection of the null hypothesis at the 1% significance

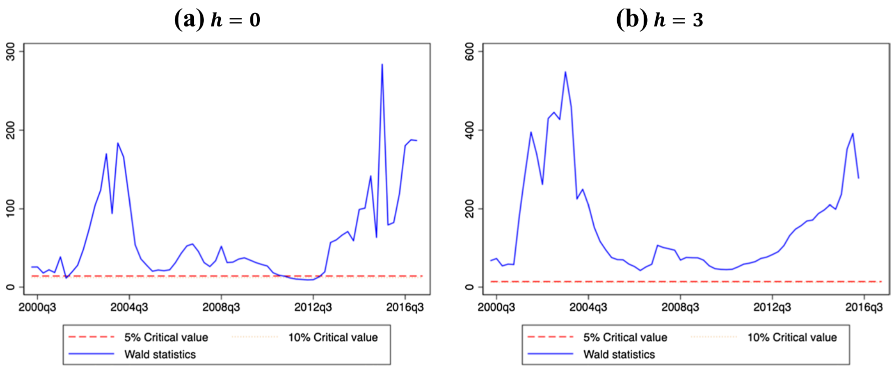

Fig. 2 Time-varying Wald statistics for the Granger causality from housing price uncertainty to housing price for the benchmark model. *Note* Critical values are taken from Rossi (2005)

statistics of Rossi and Wang (2019) for all models with $h = 0$ and $h = 3$, respectively. These results are also consistent with the constant parameter Granger causality test results except for Model 4. This result suggests that the housing price uncertainty index is a key predictor of the real housing price index in the UK. Thus, implying that externalities such as real housing price uncertainty causes the real housing price index in the UK. This result is in line with the study of Salisu et al. (2021) who reported that housing price uncertainty has include predictive power for housing price movements in 12 regions of the UK. Also, Noh (2020) found that house price uncertainty has an impact on housing prices in US.

To obtain more detailed information on when the Granger-causality occurs, Fig. 2 plots the whole sequence of the Wald statistics across the sample period from 2000:Q1 to 2017:Q2 for the benchmark model (Model 1) with $h=0$ and $h=3$. In Fig. 2a, barring a few periods such as 2001:Q2, 2011:Q1–2013:Q1, housing price uncertainty Granger causes real housing prices index over the all sample period for Model 1 with $h=0$.

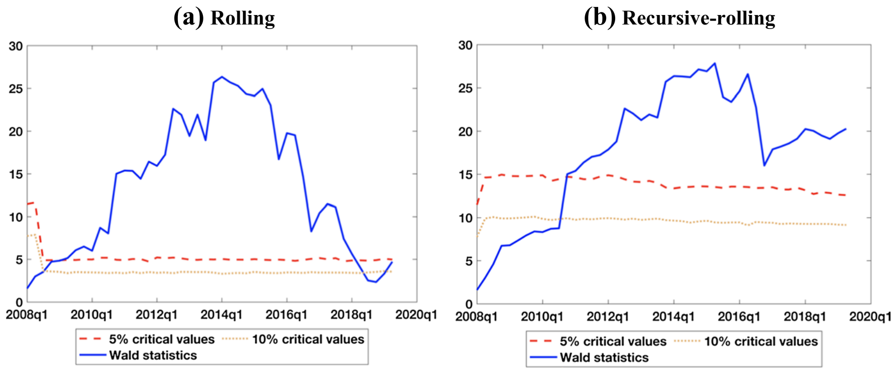

Fig. 3 Rolling and recursive-rolling Wald statistics for the Granger causality from housing price uncertainty to housing price for the benchmark model. *Note* Critical values are obtained with 2000 bootstrap replications

To control for possible omitted variable bias, we introduce economic policy uncertainty into Model 1 to examine that the housing market uncertainty index has predictive power after controlling for economic policy uncertainty because housing market uncertainty can be largely driven by economic policy uncertainty index. The estimation results for this extended model (Model 2) are presented in Fig. 7 in the "Appendix". It turns out that there a part of housing market uncertainty beyond economic policy uncertainty that helps to predict housing prices.

Figure 7 in the "Appendix" also presents results for the two other extended models (Models 3 and 4), which are larger models compared to Models 1 and 2. The time-varying Wald statistics regarding the trivariate model with $h=0$ have been presented in Fig. 7a. Given that, there Granger causality relationship is originated from housing price uncertainty index to real housing price index for all periods except for 2010:Q1 and 2012:Q3 periods. Moreover, we added crucial macroeconomic variables such as population, interest rate, real GDP variables instead of economic policy uncertainty index for Model 3. According to Fig. 7c, d, housing price uncertainty index has predictive power on the real housing price index over the entire sample period. Furthermore, we built Model 4 to consider the effect of all the aforementioned variables. To this end, we added economic policy uncertainty index into Model 3. In Fig. 7e, we report the results of the time-varying Wald statistics of Model 4 with $h=0$ which indicates that housing price uncertainty index does not Granger causes on the real housing price index for 2000:Q3, 2001:Q4–2007:Q1. In contrast to these mixed findings, housing price uncertainty index is a key predictor for the real housing price index for all models with $h=3$ over the entire sample period as it is shown in Figs. 2b and 7b, d, f.

Figure 3 plots the rolling and recursive-rolling Wald test statistics for the Granger causality link from housing price uncertainty index to real housing price index over the periods from 2008:Q1 to 2019:Q2 for the benchmark model (Model 1). The results for the extended models (Models 2–4) are given in Fig. 8 in the "Appendix". We estimate same specifications (Models 1–4) using the same optimal lag order.

The window size is 40 quarters (10 years). The Wald statistics are calculated for the period 2008:Q1–2019:Q2 since we lost 40 observations from the beginning to initiate the estimation. Critical values of the rolling and recursive rolling tests are obtained using the parametric bootstrap method with 2000 replications. Since the TVP-VAR Wald test statistics are calculated for the period 2000:Q1–2017:Q2. So, the class has overlapping test statistics for the period 2008:Q1–2017:Q2. The major finding of the comparison is that there is a conflict about the decision of the null hypothesis between Figs. 2 and 3 except for the subperiods of 2013–2017. Specifically, in contrast to the evidence given in Fig. 2, there is a lack of Granger causality relationship from housing price uncertainty to real housing price index for the beginning of the sample period for all models in Figs. 3 and 8. The rolling Wald test results show more time-varying Granger causal links between the variables. This is because rolling method has superior ability to detect true structural break than recursive rolling method. However, recursive rolling method shows considerable sensitivity to heteroskedasticity. Since, the variables indicate the existence of the ARCH effect, the consideration of recursive-rolling results is more plausible. Time-varying Wald statistics for all models with $h=3$ results are more consistent with recursive Wald statistics than for all models with $h=0$. Based on the recursive-rolling Wald statistics, the results of Model 1, Model 2 and Model 3 are similar to each other. For these 3 models, housing price uncertainty index is a key predictor for real housing price index between 2010:Q4 and 2019:Q2. According to Model 4, there is a lack of Granger causal link originated from housing price uncertainty index to real housing price index for the periods of 2008:Q1–2012:Q3 and 2016:Q3–2017:Q4 at 10% significance level.

We further estimate the models after removing the effect of economic policy uncertainty on housing price uncertainty to ensure that our results are robust to misspecification errors. We can then determine if the Granger causality of housing price uncertainty is partially due to the effect of broader economic policy uncertainty. To do so, we regress LHPU on LEPU and substitute LHPU in Models 1–4 with the residuals from this regression, dropping the variable LEPU. To put it another way, we estimate the following model:

$$LHPU_t = \alpha + \beta LEPU_t + v_t \tag{3}$$

with ordinary least squares (OLS). Let the residuals of the model in Eq. (3) be $\hat{v}_t = LHPU_t - \hat{\alpha} - \hat{\beta} LEPU_t$, where $\hat{\alpha}$ and $\hat{\beta}$ are the OLS estimates. The residual based housing price uncertainty ($\hat{v}_t$) obtained in this way would be net of the effect of the economic policy uncertainty. Using $\hat{v}_t$ instead of $LHPU_t$ leades to more parsimonus models and likely to more robust to specification errors. Replacing $LHPU_t$ with $\hat{v}_t$ and excluding the variable $LEPU_t$ from Models 1–4, will make Model 2 equivalnt to Model 1 and Model 4 equivalent to Model 3. Thus, we only need to estimate Model 1 and Model 3 with $\hat{v}_t$.

Figure 4 shows the Wald statistics for time-varying Granger causality tests performed with $\hat{v}_t$ for Models 1 and 3 with forecast steps of $h = 0$ and $h = 3$, which is similar to Figs. 2 and 7. The Granger causality tests shown in Fig. 4 are analogous to those shown in Figs. 2 and 7, implying that our findings are unaffected

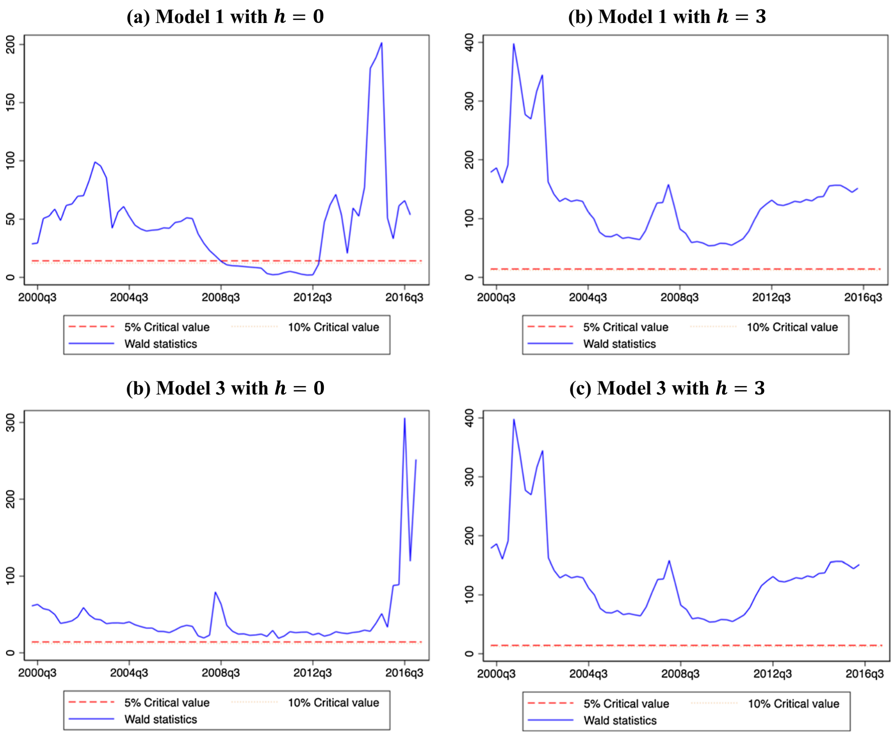

Fig. 4 Time-varying Wald statistics with the effect of EPU removed from HPU. *Note* Critical values are taken from Rossi (2005)

by wide economic uncertainty. Figure 4a shows that the result of Model 1 with $h = 0$ has nearly the same non-rejection periods as Fig. 2a, but other findings in Fig. 4 show that housing price uncertainty has significant predictive potential for all periods. This confirmation of a significant predictive capacity of HPU aligns with the existing empirical evidence of Christidou and Fountas (2017). Christidou and Fountas (2017) used uncertainty in housing prices which is calculated by using bivariate GARCH models for 48 US states. Although the method of using housing price uncertainty variable is different from this study, the result affirm that housing price uncertainty is good predictor for house price inflation.

We further check the robustness of rolling and recursive-rolling tests results by estimating Models 1 and 3 with $\hat{v}_t$ replacing $LHPU_t$. Analogues to TVP-VAR Granger causality tests case, we only need to estimate Models 1 and 3. Figure 5 displays these rolling and recursive-rolling Granger causality test results. Comparing the results in Fig. 5 with same model results in Figs. 2 and 7, we can conclude that the results are qualitatively the same. The results for Model 1 in Fig. 5a, b are also numerically analogous to their counterparts in Fig. 2a, b. For Model 3, the test values are in general lower than the one reported in Fig. 7 and there are two short periods (2013Q2 and 2016Q2) where rolling Granger causality tests are

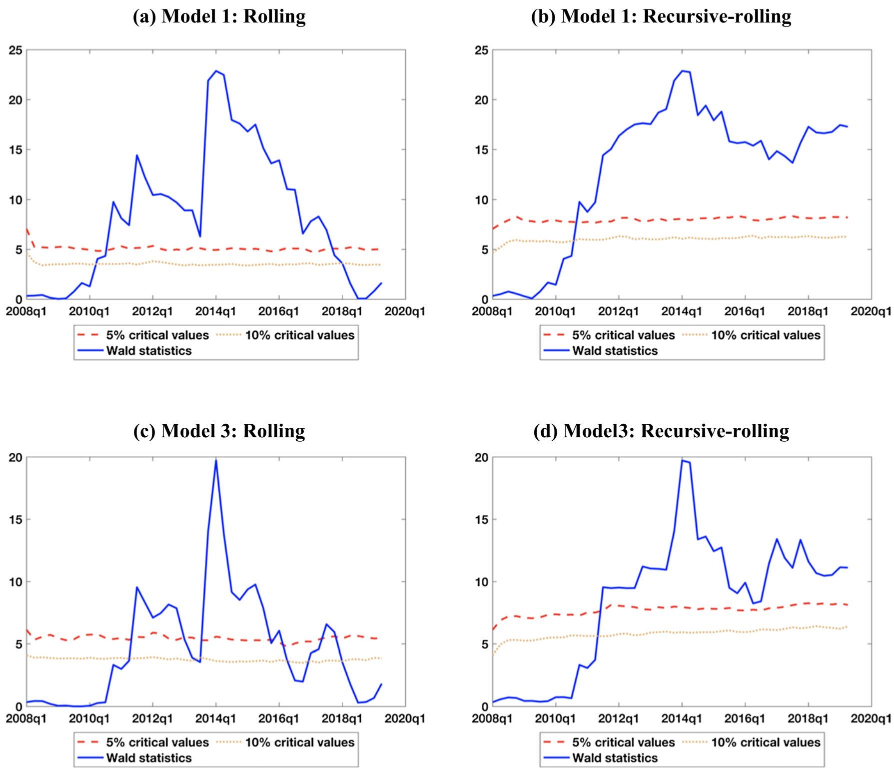

Fig. 5 Rolling and recursive-rolling tests with the effect of EPU removed from HPU. *Note* Critical values are obtained with 2000 bootstrap replications

insignificant. Except this minor difference, the rolling and recursive-rolling tests are not influenced by the effect of broad economic uncertainty on the housing price uncertainty.

Models 1 and 3 are estimated with $\hat{v}_t$ replacing $LHPU_t$ to ensure that the results of rolling and recursive-rolling tests are robust. We only need to estimate Models 1 and 3 as in the TVP-VAR Granger causality tests case. The results of the rolling and recursive-rolling Granger causality tests are shown in Fig. 5. We may conclude that the findings in Fig. 5 and the same model results in Figs. 3 and 8 are qualitatively equivalent. Model 1's results in Fig. 5a, b are numerically equivalent to their counterparts in Fig. 3a, b. Model 3's test values are often lower than those shown in Fig. 8, and rolling Granger causality tests are insignificant for two short periods (2013:Q2 and 2016:Q2). Except for this slight difference, the effect of broad economic uncertainty on housing price uncertainty has no bearing on the rolling and recursive-rolling tests.

The third robustness assessment we provide is to see if the housing price uncertainty is exclusive to the housing market and does not pertain other factors. We test Granger causality from consumer sentiment to real home prices for this reason. As a measure of consumer sentiment, we use the DataStream database's consumer confidence index for the UK. In Models 1–4, we substitute LHPU with consumer sentiment and use this variable in the TVP-VAR, rolling, and recursive-rolling tests. The test results using the consumer sentiment variable are presented in "Appendix". Figure 9 shows the Wald tests for Granger causality in the TVP-VAR model, whereas Fig. 10 shows the rolling and recursive-rolling tests. In both Figures, we can see that the null hypothesis of Granger causality from consumer sentiment to real housing prices is not rejected for long periods of time. For multivariate models, including Models 2–4, the non-rejection is more obvious. Furthermore, significant causation is only found in a few cases in the rolling and recursive-rolling models. As a result, we find that the consumer sentiment variable does not have significant predictive ability for housing prices. Housing market uncertainty variable we use is exclusive to the housing market and does not represent broader economic sentiment.[8]

It is also interest to determine the sign of the effect of the uncertainty variables on housing prices. Since the models have time-varying parameters, the sign of the effect should also be assessed in a time-varying manner. For VAR models, one can assess the sign of the effect with the sum of the coefficients of lagged uncertainty variables in the housing price equation (see, e.g., Sims 1972). Although impulse response functions can also be used, they measure effects for future periods and their shape might be nonlinear. Moreover, impulse response functions do not represent the isolated effect of a variable for horizons greater than one in VAR models with a dimension greater than two. Thus, the sum of the coefficients on the lags of a variable offers a practical measure for assigning the sign and magnitude of the effect of a variable on another one in a VAR model (Sims 1972).[9]

As a preliminary indicator, we first report rolling Pearson correlation coefficient estimates: (1) between the real house price and real house price uncertainty variables; and (2) between the real house price and economic policy uncertainty variables. We use a fixed rolling window size of 40 quarters. The rolling correlation coefficient estimates and their 95% confidence bands are given in Fig. 6a, b, respectively, for house price uncertainty and economic policy uncertainty. The correlation estimates are all negative, with values around − 0.40 and − 0.60, and significant except for a few quarters in 2008 and 2018–2019 where the confidence bands cover zero.

Figure 6b, c display the rolling VAR coefficient sums for house price uncertainty and economic policy uncertainty as well as their 95% confidence bands. We report

[8] We have also estimated lag augmented VAR (LA-VAR) based Wald Granger causality tests of Shi et al. (2020), which employs the method proposed by Toda and Yamamoto (1995), per the recommendation of an anonymous referee. The LA-VAR method is robust to the presence of potentially integrated variables in estimated models. The results of the LA-VAR method do not alter any of our key findings. Although test results are somewhat weaker during certain time periods, this can be attributed to the LA-VAR model's inclusion of additional lag. Our most important findings are qualitatively robust to the possibility of nonstationary series in the models we estimate. To conserve space, the results for the LA-VAR models are not reported but are available upon request from the authors.

[9] Indeed, we do not take the sum of the coefficients in our case since the lag order is 1 and there is a single coefficient for the first lags of LHPU and LEPU.

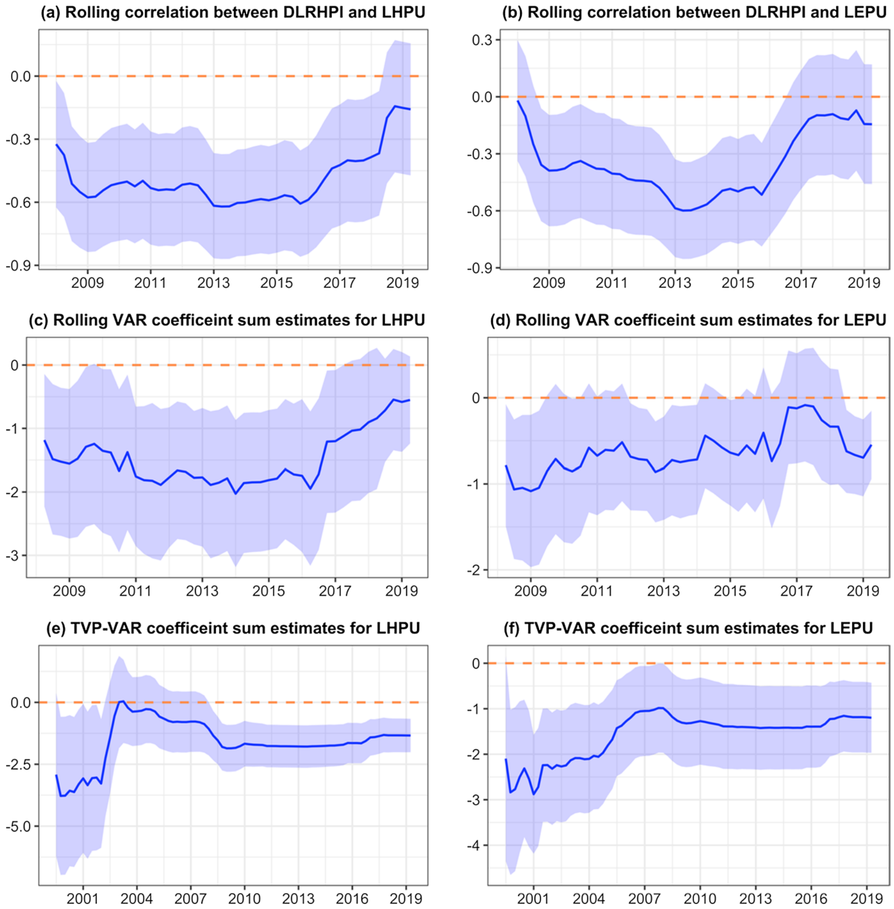

Fig. 6 Sign of the effect of house price uncertainty and economic policy uncertainty on real house prices. *Note* Rolling Pearson correlation coefficients and rolling VARs are estimated with a window size of 40 quarters. Confidence bands for the rolling VAR is obtained with 2000 bootstrap replicates. TVP-VARs are estimated using a Bayesian Monte Carlo Markov Chain simulation, with a burn-in draws of 5000 and posterior draws of 20,000. The rolling VAR and TVP-VAR coefficient estimates are based on the benchmark model specification

the coefficient estimates only for the benchmark model. The rolling VAR coefficient estimates display a similar patter to rolling correlation estimates—negative all over the estimation period. The coefficient estimates for the house price uncertainty have some insignificant estimates on the edges in the 2008 and 2018–2019 periods. However, the coefficient estimates for economic policy uncertainty are less negative than the estimates for house price uncertainty—an average of − 1.48 versus − 0.63—and they also have some insignificant estimates in the mid periods.

The time-varying coefficient estimates, which are estimated from a Bayesian TVP-VAR with random walk parameters, measuring the effects for house price uncertainty and economic policy uncertainty on the real house prices are given in Fig. 6c, d. The TVP-VAR estimate complements the rolling correlation and rolling VAR coefficient estimates because they are all negative for the whole estimation period and mostly significant at the 5% significance level. Similar to rolling correlation and rolling VAR coefficient, the TVP-VAR coefficient estimates become only insignificant around 2007–2008. We note that the TVP-VAR coefficient estimates are more negative and more significant—measured by the distance of the confidence limit to zero line—than the rolling VAR estimates. Overall, all three alternative estimation approaches for the sign of the effect of uncertainty variables on real house prices show that the uncertainty impacts real house prices negatively.

4 Conclusion and policy insights

The challenge of housing market has become a discourse across several quarters by public and private government officials in both developing and developed economies. This study focuses on the UK on which has become obvious that her urban population has stretched demand for housing is overwhelming with abnormal prices after several housing bubbles and bursts. This study is conducted to provide an answer to the question of "whether housing market uncertainty has any effect on housing prices between 1998Q1 to 2019Q2". This study adds to the housing literature by accounting for other covariate ignored in previous studies that can better explain housing price in UK. To do this, economic policy uncertainty, population interest rate, and economic growth were incorporated into the time-varying model environment to explore this causality relationship and present a more robust policy direction to all key players in the housing market.

Empirical outcomes from the time-varying analysis concludes that housing price uncertainty is a key predictor for real housing price index in the UK. Given the predictive power of housing price uncertainty on real housing price index. This suggests that in an uncertainty prone environment, it imposes a negative effect on the economy and decrease macroeconomic indicators like the ones accounted for in our study such as interest rate employment, population, and real output (GDP). This will, in turn, have a ripple effect on real house prices as real estate developers can delay future construction activities thereby decreasing housing supplies and increases housing demand and real house prices.

These highlights, undoubtedly the pertinent role of housing rice uncertainty in predicting real housing price determination of UK house prices and demand too. Our estimates show that both house price uncertainty and economic policy uncertainties negatively impact real housing prices, implying periods with increasing uncertainty will lead to declines in real housing prices. This is insightful for policymakers that housing price uncertainty should be considered in terms of real housing investment decisions.

In conclusion, as a guide for an extension, other studies can be conducted to account for other co-variates not modeled in this current study because housing price uncertainty and housing prices effect on macro-economic indicators can be ambiguous, which is worthy of re-investigation for other EU housing markets. Secondly, future studies could consider the use of the world EPU index as a representation of global EPU for the UK housing price modelling in a time-varying framework.

Table 3 List of variables, definitions and sources

Variables	Definition	Source
RHPI	Real House Price Index	Nationwide Building Society Website[a]
HPU	House Price Uncertainty Index	United Kingdom Housing Observatory[b]
EPU	Economic Policy Uncertainty Index	Baker et al. (2016)[c]
POP	Population	OECD
IRATE	Short-term Interest Rate	OECD
GDP	Real Gross Domestic Period	OECD

[a] Seehttps://www.nationwide.co.uk/about/house-price-index

[b] See https://uk.housing-observatory.com/resources.html

cSee https://www.policyuncertainty.com

Table 4 Unit root test results

Variables	DF-GLS unit root test			Zivot–Andrews unit root test			
	Statistic	Critical value		Statistic	SB date	Critical value	
		5%	1%			5%	1%
IRATE	−2.947	−3.081	−2.788	−3.194	2016Q1	−5.08	−4.82
ΔIRATE	−4.421**	−3.081	−2.788	−5.004***	2008Q4	−5.08	−4.82
GDP	−1.307	−3.087	−2.794	−2.719	2003Q3	−5.08	−4.82
ΔGDP	−4.461**	−3.087	−2.794	−5.637**	2008Q2	−5.08	−4.82
POP	−1.873	−3.081	−2.788	−3.252	2006Q3	−5.08	−4.82
ΔPOP	−2.951***	−3.081	−2.788	−4.888***	2004Q3	−5.08	−4.82
EPU	−3.253**	−3.078	−2.785	−4.921***	2007Q3	−5.08	−4.82
ΔEPU	−9.180**	−3.081	−2.788	−9.413**	2002Q1	−5.08	−4.82
HPU	−3.576**	−3.078	−2.785	−4.925***	2010Q4	−5.08	−4.82
ΔHPU	−8.011**	−3.081	−2.788	−7.499**	2003Q2	−5.08	−4.82
RHPI	−1.158	−3.081	−2.788	−4.117	2008Q2	−5.08	−4.82
ΔRHPI	−3.896**	−3.081	−2.788	−5.180**	2008Q4	−5.08	−4.82

** and *** denote the significance levels at 5 and 10 percent. "Δ" represents the first difference of the related variable. *SB* date is estimated structural break date

Appendix

See Tables 3, 4 and Figs. 7, 8, 9, 10.

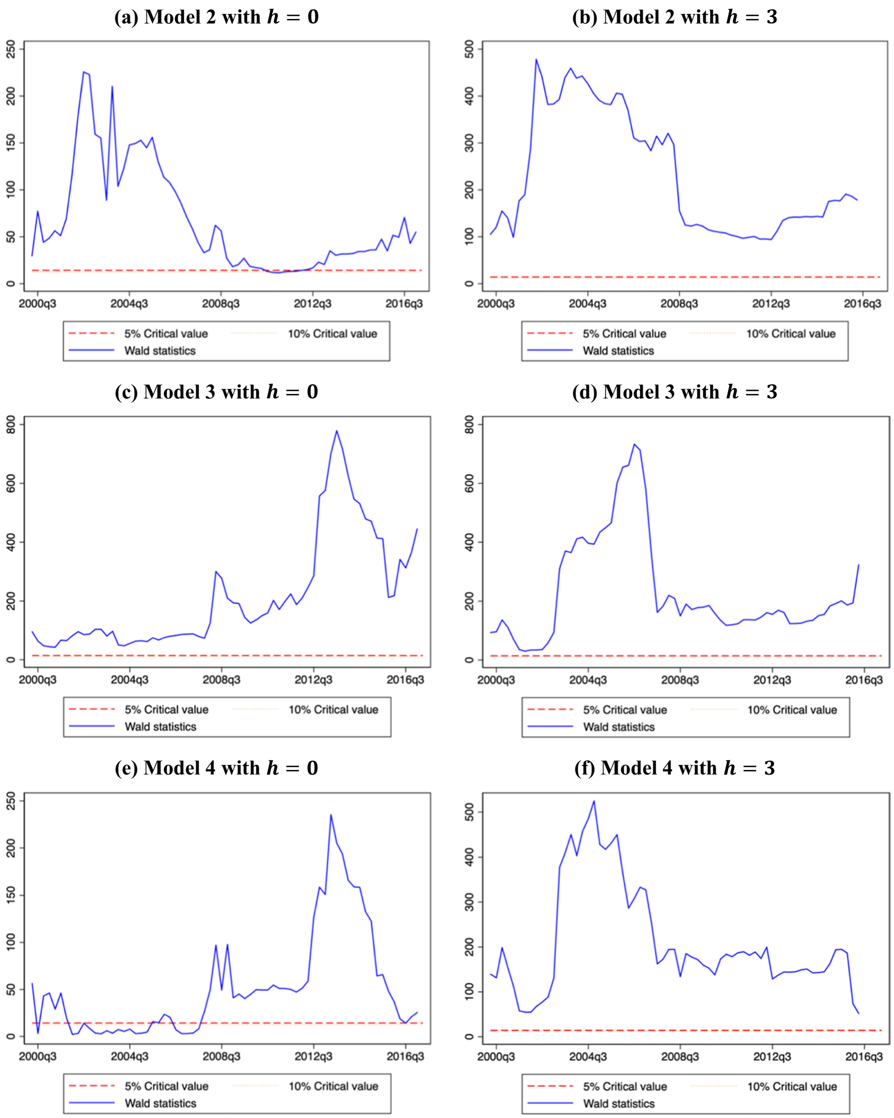

Fig. 7 Time-varying Wald statistics for the Granger causality from housing price uncertainty to housing price for the extended models. *Note* Critical values are taken from Rossi (2005)

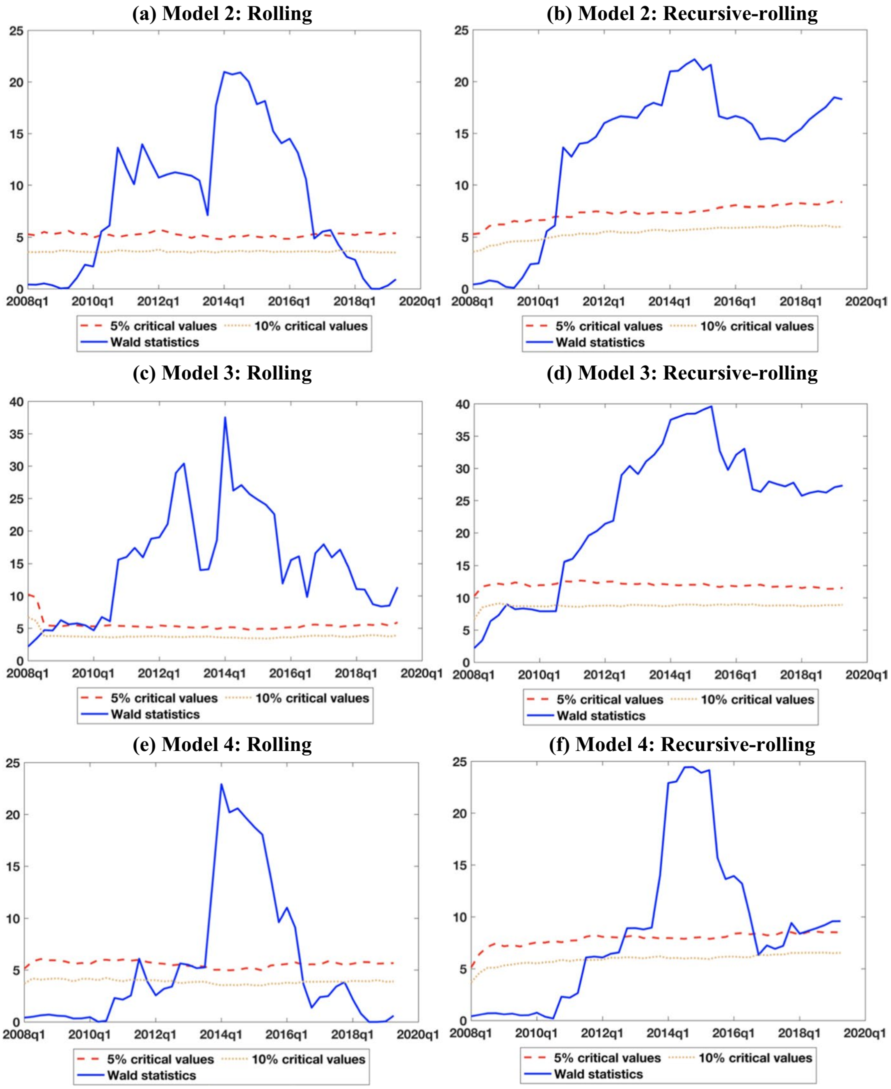

Fig. 8 Rolling and recursive-rolling Wald statistics for the Granger causality from housing price uncertainty to housing price for the extended models. *Note* Critical values are obtained with 2000 bootstrap replications

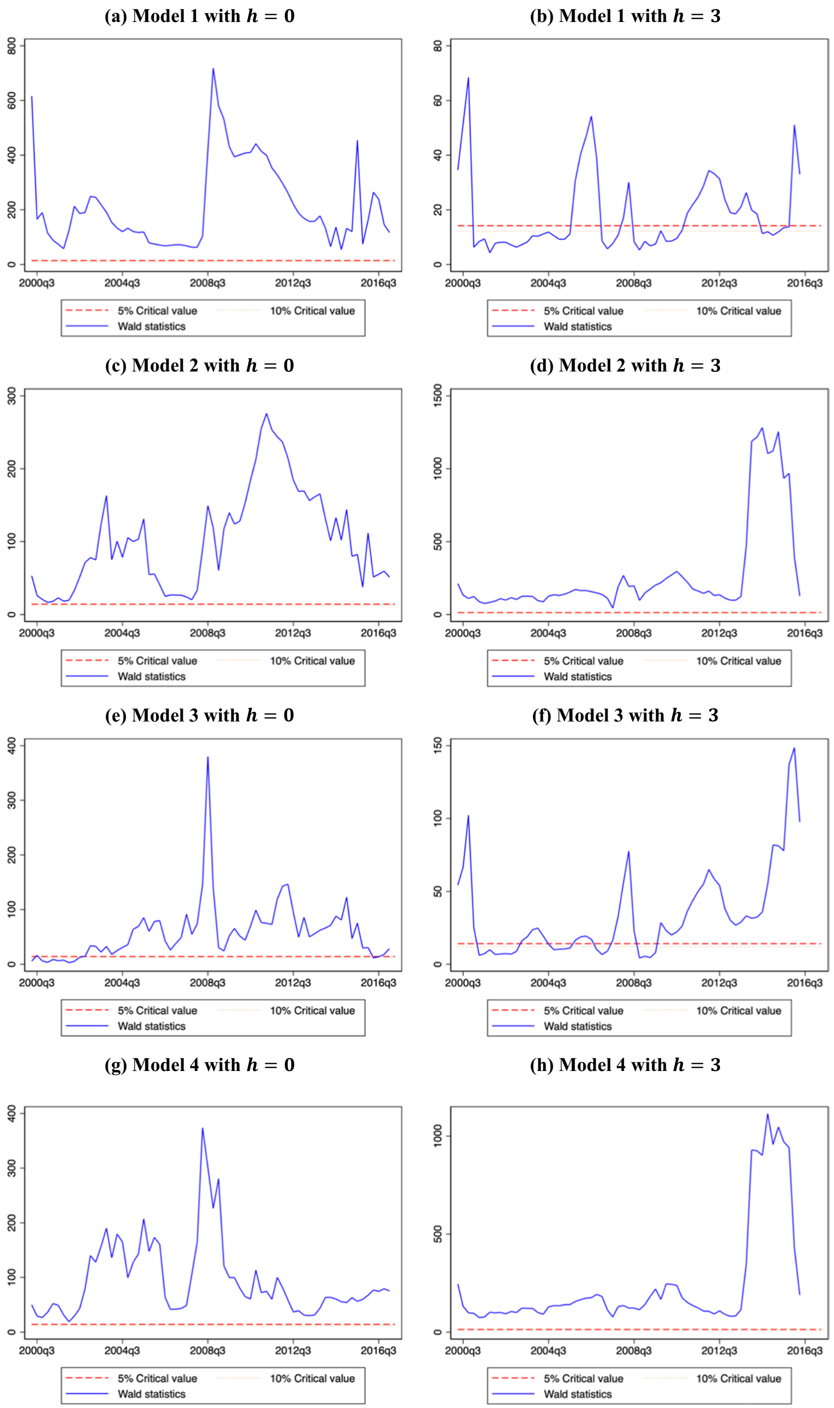

Fig. 9 Time-varying Wald statistics for the Granger causality from consumer sentiment to housing price

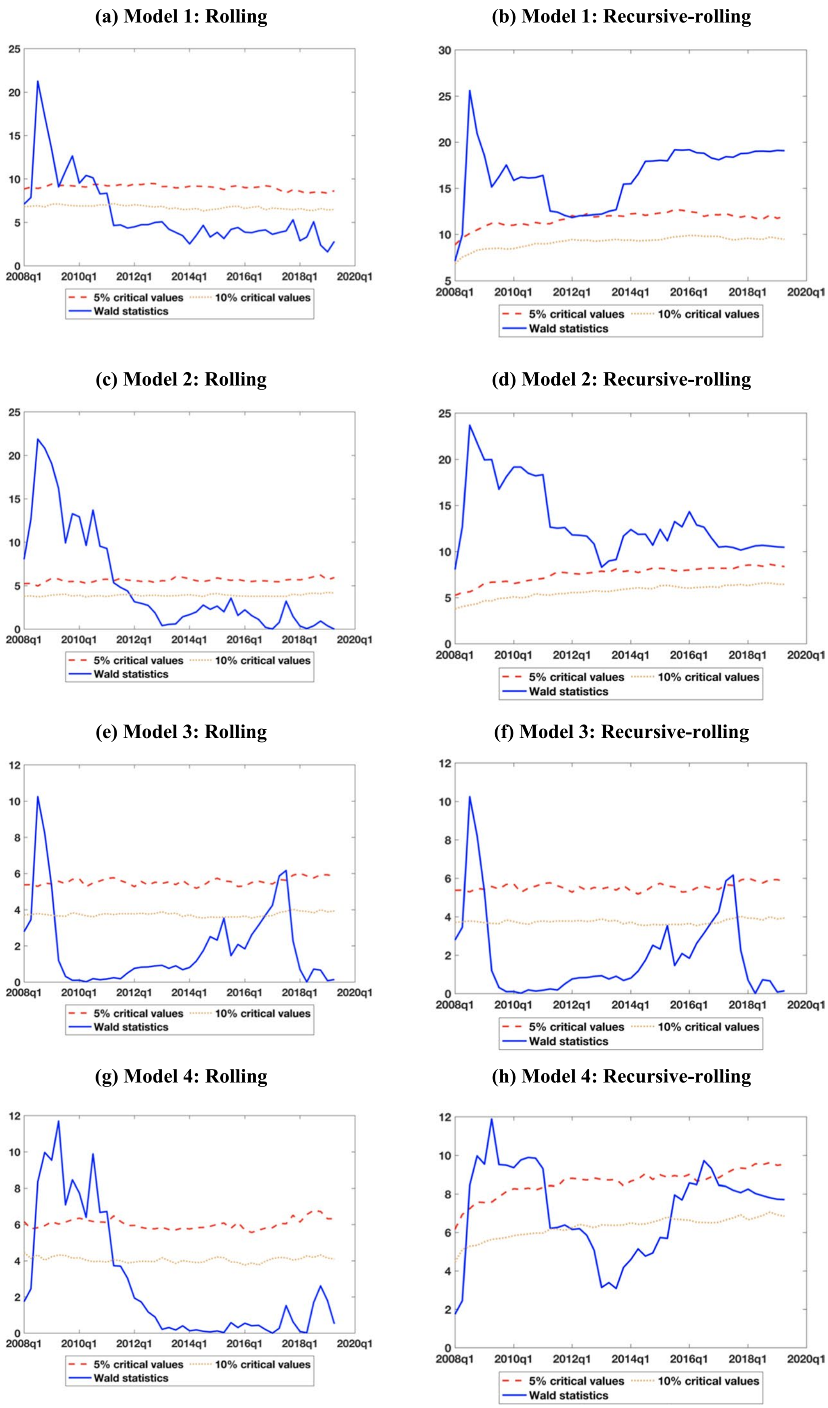

Fig. 10 Rolling and recursive-rolling Wald statistics for the Granger causality from consumer sentiment to housing price

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