

Uncertainty and Predictability of Real Housing Returns in the United Kingdom: A Regional Analysis*

Afees A. Salisu

Centre for Econometrics and Applied Research (CEAR), Ibadan, Nigeria and Department of Economics, University of Pretoria, Pretoria, South Africa

Email: adebare1@yahoo.com

Rangan Gupta

Department of Economics, University of Pretoria, Pretoria, South Africa.

Email: rangan.gupta@up.ac.za

Ahamuefula E. Ogbonna

Centre for Econometrics and Applied Research (CEAR), Ibadan, Nigeria & Department of Statistics, University of Ibadan, Nigeria.

Email: ogbonnaephraim@yahoo.com.

Mark E. Wohar

Corresponding author. University of Nebraska at Omaha, Omaha, NE 68182, USA.

Email: mwohar@unomaha.edu

Abstract: The predictability of uncertainty for real housing returns in the United Kingdom is examined using regional data covering twelve (12) regions namely East Midlands, East of England, London, North East, North West, Northern Ireland, Scotland, South East, South West, Wales, West Midlands, Yorkshire and the Humber. We utilize both housing price uncertainty (HPU) and economic policy uncertainty (EPU) data while we render analyses for three data samples – full sample and two sub-samples covering the periods before and after the emergence of global financial crisis (GFC). Relying on a predictive model that accounts for the salient characteristics of the data, we find a negative relationship between HPU and real housing returns, on the average, regardless of the region analysed. Also, the model that accounts for HPU outperforms the benchmark model that ignores it while controlling for relevant covariates further improves the forecast performance. Additional analyses involving the EPU measure depict lower predictive contents for house price movements relative to the HPU measure and therefore using sector-specific uncertainty measure is crucial for more precise forecasts of real housing returns.

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1. Introduction

In the wake of the global financial crisis, which, as pointed out by Leamer (2007, 2015), had its roots in the turmoil surrounding the housing market of the United States (US), before engulfing the world economy (Hirata et al., 2013), a burgeoning number of studies (see for example, Antonakakis et al., 2015, 2016; El Montasser et al., 2016; Su et al., 2016; André et al., 2017; Christou et al., 2017, 2019; Aye, 2018; Chow et al., 2018; Christidou and Fountas, 2018; Aye et al., 2019; Aye and Gupta, 2019; Choudhry, 2020; Nguyen Thanh et al., 2020; Strobel et al., 2020; Gupta et al., forthcoming) have highlighted the effect of uncertainty on international house price movements.

These studies outline multiple channels through which uncertainty can affect the housing market: First, increased uncertainty about the demand for housing or the cost of financing can cause developers to postpone new construction, thus reducing supply, due to concerns surrounding the irreversibility of investment decisions. Second, increased uncertainty about future employment, income and wealth might cause households to postpone the home-buying decision, and instead increase precautionary savings. Third, when uncertainty about employment and income raises the probability of default on the mortgage, lenders might reduce or deny mortgages to riskier borrowers. Taken together, these decisions in response to uncertainty can cause a decline in demand and prices in the housing markets, unless demand for other assets is more sensitive to uncertainty. Fourth, given that the user cost of housing is equal to the sum of the depreciation rate of the dwelling, g the maintenance and repair costs as a fraction of the current value, the marginal income tax rate, the nominal interest rate, the property tax rate, and the expected nominal housing price inflation rate, the last component is likely to be influenced by uncertainty surrounding any determinant of housing price, including income, interest and tax rates, and housing market regulations, among others. Therefore, it is not surprising to expect an empirical link between uncertainty and housing returns, and as depicted by the above-mentioned works, the effect is generally negative, with uncertainty being characterized as an adverse demand shock.

While these studies are of tremendous importance in deducing the uncertainty-housing returns link empirically, these primarily being in-sample analyses (barring André et al., (2017), Christou et al., (2017), Gupta et al., (forthcoming), which forecasts aggregate and state-level housing returns of the US, and that of a panel of Organisation for Economic Co-operation and Development (OECD) countries based on aggregate uncertainty), is to some degree of limited value to

policymakers and investors looking to make real-time decisions, for which they require out-of-sample forecasts. Furthermore, in-sample predictability does not guarantee out-of-sample forecasting gains, and at the same time, the best evaluation of predictors and econometric frameworks is obtained from out-of-sample, rather than in-sample exercises (Campbell & Thompson, 2008). In light of this, the objective of our current study is to analyse the role of uncertainty, and in particular the same associated with the housing market, in forecasting real housing returns of the overall and 12 regions of the United Kingdom (UK), after controlling for other standard macroeconomic and financial predictors, as well as aggregate economic uncertainty. The decision to choose the UK, is primarily driven by the availability of recent data on housing price uncertainty (HPU) in the public domain.¹ Besides, our sample period primarily focusses on 1998Q1 to 2019Q2 (with an extended analysis also delving into 1983Q1 to 2019Q2), which not only includes several business cycles, the global financial and European sovereign debt crises, but also (the recently concluded) Brexit process, and hence studying the role of uncertainty in forecasting housing returns of the UK, which has been shown to be a leading indicator historically for the country (Plakandaras et al., 2020), is an interesting case study on its own. This is because, the Brexit process could potentially affect the UK housing market by reducing foreign investment in the housing market and deferred buying leading to heightened housing market and overall uncertainty.

Thus, we offer the following contributions to the literature associated with uncertainty and house price movements. First, we utilize quarterly data for twelve of UK's regions, over and above the overall housing returns. Our choice of regional data helps to circumvent any possible aggregation bias and therefore avoid any generalization issues about the relationship under consideration, especially given the well-established heterogeneity across the regions (Ashworth and Parker, 1997; Cameron et al., 2006; Hamnett 2009). Second, we distinctly accommodate housing price uncertainty (HPU) in the predictive model of UK house price movements contrary to the practice in the literature which limits the uncertainty proxy to economic (aggregate) policy uncertainty (EPU) (examples of such studies include Antonakakis et al., 2015; El Montasser et al., 2016; Su et al. 2016; André et al, 2017; Aye et al., 2018; Chow et al., 2018; Christidou and Fountas, 2018; Huang et al., 2018; Aye et al., 2019; Christou et al., 2019; Choudhr, 2020; Gupta

¹ Nguyen Thanh et al., (2020) has also developed a real estate-based uncertainty index for the US, but that data only runs till 2017, and is no longer updated.

et al., forthcoming).² Consequently, the predictive contents of both sector-specific and overall policy uncertainties for house price movements in the UK are distinctly examined. We consider three predictive models of real housing returns that account for HPU: a single predictive model with HPU being the only predictor; an extended predictive model that controls for important macroeconomic and financial predictors of real housing returns in addition to HPU; and a predictive model that accounts for any probable asymmetric effect of HPU on real housing returns, with the role of such asymmetries stressed by Bahmani-Oskooee and Maki-Nayeri (2019), while relating uncertainty and investment decisions due to the possibility of both positive and negative effects. These variants of HPU-based model offer robust results that enable us make some generalizations about the predictability of HPU. Third, we use both recent and long data samples as well as sub-samples that account for the role of global financial crisis owing to its adverse effects on the housing market. Fourth, we utilise both the housing price uncertainty and overall economic policy uncertainty in order to check if the outcome will be sensitive to the coverage of uncertainty. And finally, we consider multiple out-of-sample forecast horizons and the outcomes are compared with a benchmark model that ignores the role of HPU in the predictive model of real housing returns.

Our empirical analyses rely on a technique that accounts for the inherent statistical features of the variables of interest (see Westerlund and Narayan (2012, 2015) for technical details).³ To the best of our knowledge. This is the first paper to forecast aggregate and regional real housing returns based on sector-specific and aggregate measures of economic uncertainty. At this stage, we must emphasize that our paper can be considered to be an out-of-sample extension of the work of Choudhry (2020). The author of this paper empirically investigated the effect of the economic policy related uncertainty on house prices across 10 different geographical regions of England and Wales, based on the Autoregressive Distributed Lag (ARDL) bounds cointegration test. Results showed a stable long-run relationship (cointegration) between house prices and its determinants

² For instance, Leahy and Whited (1996) argue that any test of the relationship between investment and uncertainty must distinguish between the effects of industry-wide and firm-specific shocks. Similarly, Choi and Loungani (2015) show that, despite the high correlation between the aggregate and sector-specific uncertainty measures (see also Bloom, 2009), they have distinct impacts on unemployment.

³ Several studies have employed this methodology to analyze return predictability although not from the perspective of housing return predictability (see for example, Narayan and Gupta (2015), Narayan et al., (2018), Salisu et al., (2019a,b,c,d,e)).

(including economic policy uncertainty) in nine of the regions, and more importantly, uncertainty was found to have negative effect on house prices both in the short- and long-runs.

Our results show that on the average, there exists an inverse relationship between HPU and real housing returns for all the regions examined in the United Kingdom. We equally find that the model that accounts for HPU outperforms the benchmark model that ignores it. We also demonstrate the role of other important determinants of real housing returns and sound a note of caution as regards accounting for the role of asymmetry in the HPU data. Finally, we are able to establish that sector-specific uncertainty measure (HPU) contains higher predictive contents for house price movements than the aggregate economic policy uncertainty measure.

Following this introduction, the rest of this paper is structured as follows. Section 2 captures the adopted methodology. Section 3 presents the issues surrounding the data. Empirical analyses and results are provided in section 4, followed by section 5 which concludes the paper.

2. Methodology

In a bid to forecast housing price returns of the different regions in the United Kingdom, we construct a predictive model that accounts for the inherent statistical features (such as endogeneity, conditional heteroscedasticity and persistence) that typically characterize high frequency time series data (see Westerlund and Narayan (2012, 2015) hereafter referred to as WN). The WN-type model was designed to circumvent parameter proliferation by isolating predictor(s) in the estimation and predictability analyses, a major attraction of the model. In essence, the technique helps to limit the predictability analyses to the predictor(s) of interest, while it also simultaneously resolves any inherent bias (see Westerlund and Narayan (2012, 2015) for the theoretical expositions; and also Narayan and Gupta (2015), Narayan et al., (2018), Salisu et al., (2019a,b,c,d,e) among others for recent applications). Our model is therefore a distributed lag model that incorporates the observed statistical features within a single model framework. It does not include an autoregressive part since the model is often used for return series which are typically stationary and therefore allowing for additional lags may increase redundancy and by implication introduce bias in the estimation process.

We briefly highlight the estimation process as follows. First, we test for the presence of conditional heteroscedasticity, endogeneity and persistence, to be adequately guided while making a choice on the predictive model (Bannigadmath and Narayan 2015; Narayan and Gupta, 2015;

Phan et al., 2015; Narayan et al., 2016, 2018; Devpura et al., 2018; Salisu et al., 2018, 2019a,b,c,d,e; among others). Second, a distributed lag model, with one period lag and a first difference of the predictor that accounts for persistence, is specified. Third, the comprising variables of our model are pre-weighted with the inverse of the standard deviation of the residuals ($1/\hat{\sigma}_\varepsilon$) that is obtained from an autoregressive conditional heteroscedastic (ARCH) structure -

$$\hat{\sigma}_{\varepsilon,t}^2 = \varpi + \sum_{j=1}^q \hat{\varepsilon}_{t-j}^2, \text{ to exploit the additional information of the conditional heteroscedasticity}$$

effect and improve predictability. We specify three different variants of the model for HPU (and also replicate the same for EPU): the first relates housing returns with HPU (hpu) (see equation 1); the second incorporates some control variables ($rgdp$, fsi and $intr$) to extend the first model construct (see equation 2), while the last incorporates positively and negatively decomposed partial sums of the economic policy uncertainty, to ascertain asymmetry effect (see equation 3).

$$r_t = \alpha + \beta_1 hpu_{t-1} + \beta_2 \Delta hpu_t + \varepsilon_t, \quad (1)$$

$$r_t = \alpha + \beta_1 hpu_{t-1} + \beta_2 \Delta hpu_t + \beta_3 rgdp_{t-1} + \beta_4 \Delta rgdp_t + \beta_5 fsi_{t-1} + \beta_6 \Delta fsi_t + \beta_7 intr_{t-1} + \beta_8 \Delta intr_t + \varepsilon_t, \quad (2)$$

$$r_t = \alpha + \beta_1 hpu_{t-1}^{(+)} + \beta_2 \Delta hpu_t^{(+)} + \beta_3 hpu_{t-1}^{(-)} + \beta_4 \Delta hpu_t^{(-)} + \varepsilon_t, \quad (3)$$

where $r_t = \ln(P_t/P_{t-1})$ measures the returns on housing prices - P_t at time t ; α is the intercept; the subscript - $t - 1$ for the predictor and control variables indicates the one period lag of the variable of interest; β_i 's are the slope parameters associated with the variables in the model; while ε_t is the error term. The differenced terms (Δhpu_t , $\Delta rgdp_t$, Δfsi_t and $\Delta intr_t$) correct for plausible endogeneity bias that may result from the correlation between each of the variables and the residual (ε_t), as well as plausible unit root in the predictors.

On the asymmetry effect, the hpu_t is decomposed into positive and negative partial sums, respectively defined as $hpu_t^{(+)} = \sum_{i=1}^T \Delta hpu_t^{(+)} = \sum_{i=1}^T \max(\Delta hpu_t, 0)$ and

$$hpu_t^{(-)} = \sum_{t=1}^T \Delta hpu_t^{(-)} = \sum_{t=1}^T \min(\Delta hpu_t, 0) \quad (\text{see also, Narayan and Gupta (2015); Salisu et al.,$$

(2019a,b,c,d,e, 2020)). In all cases, we examine the statistical significance of the one period lag of the predictor variables of interest, under the null hypothesis of no predictability using the conventional t-test statistic. As previously espoused, we expect a priori the relationship between housing returns and economic policy uncertainty to be negative.

We estimate the regression models in a rolling- rather than a fixed-window, to forecast regional housing returns. We consider a historical average model that regresses regional housing returns on constant only, as a benchmark model; and compare the model fitness and forecast errors of our predictive model with those of the benchmark historical average model using the conventional likelihood ratio [LR] test and relative RMSE, respectively. The LR-test is often used to ascertain the goodness of fit of nested contending models using their estimated log-likelihood functions. The test statistic is given by:

$$LR-test = -2 \log_e \left(\frac{L_{HA\ model}(\hat{\theta})}{L_{WN-Type\ DL\ model}(\hat{\theta})} \right), \quad (4)$$

where the numerator and the denominator correspond to the likelihood of the historical average (restricted) and the WN-Type DL (unrestricted) models, respectively. The test statistic is approximates a Chi-Squared random variable, with the difference in the number of parameters from both contending models as the number of degrees of freedom. The null hypothesis asserts preference of the restricted (historical average) model, such that a rejection of the null would indicate that the unrestricted (WN-Type DL) model is preferred. Also, on the basis of forecast errors, the relative RMSE is obtained as the ratio of the RMSE of the unrestricted model to the restricted model. Given that smaller RMSE are indicative of better forecast performance, we expect the relative RMSE value to be less than one for our WN-type DL model to be preferred over the benchmark historical average model. Relative RMSE values greater than one indicates preference in favour of the historical average model; while relative RMSE value 1 indicates no difference between the forecast errors of the contending models.

We also formally compare our predictive model with the benchmark historical average model, using Clark and West [CW] (2007) statistic. CW, which is a pairwise comparison test that

is suited for nested models, tests the statistical significance of the difference between the forecast errors of a pair of contending models. The CW estimation equation is given in (5):

$$\hat{f}_{t+h} = (r_{t+h} - \hat{r}_{1,t,t+h})^2 - \left[(r_{t+h} - \hat{r}_{2,t,t+h})^2 - (\hat{r}_{1,t,t+h} - \hat{r}_{2,t,t+h})^2 \right] \quad (5)$$

where h is the forecast period; $(r_{t+h} - \hat{r}_{1,t,t+h})^2$ and $(r_{t+h} - \hat{r}_{2,t,t+h})^2$ are respectively the squared residuals from the historical average (restricted) and our distributed lag predictive (unrestricted) models; while $(\hat{r}_{1,t,t+h} - \hat{r}_{2,t,t+h})^2$ is a CW test incorporated term - adjusted squared residual, that serve as a corrective measure for the noise associated with the forecasts of the larger model. Furthermore, \hat{f}_{t+h} is defined as $MSE_1 - (MSE_2 - adj.)$, where $MSE_1 = P^{-1} \sum (r_{t+h} - \hat{r}_{1,t,t+h})^2$, $MSE_2 = P^{-1} \sum (r_{t+h} - \hat{r}_{2,t,t+h})^2$, $adj. = P^{-1} \sum (\hat{r}_{1,t,t+h} - \hat{r}_{2,t,t+h})^2$ and P is the number of averaged forecasts. We subsequently regress \hat{f}_{t+h} on a constant and adjudge the equality, or otherwise, of the forecast errors of the paired contending models using the t-statistic of the estimated constant. Significance of the t-statistic would imply that the unrestricted model outperforms the restricted model.

We compare our HPU-based predictive model with the EPU-based model, which constitutes comparison of non-nested models, using a modified Diebold-Mariano (DM) test (see Harvey, Leybourne, and Newbold, 1997). The modified DM test extends the Diebold and Mariano (1995) test by taking cognizance of potential autocorrelation and heavy-tailed distributions, and accounting for same accordingly. The DM test statistic for comparing the forecast errors of our predictive model with those of the benchmark models is defined in equation (6) as:

$$DM = \frac{\bar{d}}{\sqrt{V(d)/T}} \sim N(0,1), \quad (6)$$

where $\bar{d} = \frac{1}{T} \sum_{t=1}^T d_t$ is the average loss differential between the paired contending models, $V(d_t)$ is the unconditional variance of the loss differential where $d_t \equiv l(\varepsilon_{wn}) - l(\varepsilon_{bench})$, $l(\varepsilon_{wn})$ is the loss function of the forecast error of our WN-type model and $l(\varepsilon_{bench})$ is the loss function of the

forecast error of the benchmark model. The modified DM test statistic as per Harvey, Leybourne, and Newbold (1997) is given as:

$$DM^* = \left(\sqrt{\frac{T+1-2h+T^{-1}h(h-1)}{T}} \right) DM, \quad (7)$$

where DM^* denotes the modified DM statistic and h is the forecast horizon. The null hypothesis ($H_0 : E(d_t) = 0$) that the precision of both forecasts are equal, is tested against an alternative ($H_1 : E(d_t) \neq 0$) that the forecasts of our HPU-based predictive model differ markedly from the forecasts of our EPU-based predictive model variant, with negative (positive) DM statistics indicating preference (model having lower forecast errors) for HPU- (EPU-) based predictive model. We employ the formula given in Harvey et al., (1997) to empirically examine the out-of-sample forecast performance of our predictive model variants for 1-quarter, 2- quarters and 4- quarters -ahead forecast horizons using 50% of the full data under a rolling window framework.

3. Data Issues

We employed quarterly frequency data on UK regional housing returns, housing related economic policy uncertainty (HPU), regional and overall real output growth, financial stress index (FSI), mortgage rate and aggregate economic policy uncertainty (EPU), spanning a period between 1998Q1 and 2019Q2, based on data availability. Although, HPU data is available from 1982, however, the overall EPU data only begins from 1998. Thus, for the purpose of comparing the results of the two EPU proxies, we use data covering 1998Q1 to 2019Q2. Nonetheless, we also perform additional analysis using a long range data of the HPU from 1982Q1 to 2019Q2. Total seasonally-adjusted house prices for each region and the overall UK were obtained from Land Registry data of the Office for National Statistics. The nominal house price is deflated by the seasonally-adjusted overall Consumer Price Index of the UK, with the latter derived from the Main Economic Database of the OECD. We work with log-returns of the real house price. Our data cover twelve regions in the UK namely East Midlands, East of England, London, North East, North West, Northern Ireland, Scotland, South East, South West, Wales, West Midlands, Yorkshire and the Humber.

The study aims to ascertain the predictability of housing returns using housing related uncertainty. We also considered model without and with control variables. In this regard, the

mortgage rate data comes from the Bank of England, while the FSI is derived from the Statistical Data Warehouse of the European Central Bank. The index includes six market-based financial stress measures that capture returns and (realized) volatility of three financial market segments, i.e., equity, bond and foreign exchange. In addition, when aggregating the sub-indices, the FSI takes the co-movement across market segments into account. For further details, the reader is referred to Duprey et al., (2017). The measure for economic (gross value added) growth of the regions is obtained from the nowcasting project of Koop et al., (2020) associated with the Economic Statistics of the Centre of Excellence,⁴ while that for the overall UK is from the Main Indicators database of the OECD. In the paper, Koop et al., (2020) develop a mixed frequency Vector Autoregressive (MF-VAR) model and use it to produce estimates of quarterly regional output growth. Temporal and cross-sectional restrictions are imposed in the model to ensure that the quarterly regional estimates are consistent with the annual regional observations and the observed quarterly UK totals. Koop et al., (2020) use a machine learning method based on the hierarchical Dirichlet-Laplace prior to ensure optimal shrinkage and parsimony in the over-parameterised MF-VAR.

Turning now to the main predictor of uncertainty related to the housing market. We gather the quarterly housing economic policy uncertainty (HPU) series from the United Kingdom Housing Observatory.⁵ The HPU index is constructed by Yusupova et al., (2020) using the methodology suggested by Baker et al., (2016). The HPU is an index of search results from five large newspapers in the UK: The Guardian, The Independent, The Times, Financial Times and Daily Mail. In particular, the authors use LexisNexis digital archives of these newspapers to obtain a quarterly 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’ (including variants like ‘uncertainties’, ‘housing market’ or ‘regulatory’). To meet the search criteria an article must contain terms in all three categories. The resulting series of search counts is then scaled by the total number of articles in the given newspaper and in the given quarter. Finally, to obtain the HPU index, Yusupova et al., (2020) average across the five newspapers by quarter and normalise the index to a mean of 100. As far as the overall EPU of the UK is concerned, we utilize

⁴ See: <https://www.escoe.ac.uk/regionalnowcasting/>.

⁵ <https://uk.housing-observatory.com/dashboard.html>.

the index of Baker et al., (2016), which is based on the number of news articles containing the terms uncertain or uncertainty, economic or economy, as well as policy relevant terms: ‘policy’, ‘tax’, ‘spending’, ‘regulation’, ‘Bank of England’, ‘budget’, and ‘deficit’.⁶

The statistical summary, as well as preliminary analyses of the variables to be used in this study are presented in Table 1. The intuition is to understand the data characteristics, so as to be guided in the choice of model to be adopted. An appropriate model would be one that accounts for most of the observed salient data features.

Regional real housing returns are found to range between 0.728 and 1.453, which corresponds to Northern Ireland and London; with Northern Ireland housing returns over time having the highest deviation from the estimated mean, while others in the range of 2.165 and 2.610. The regional housing returns are partly negatively (positively) skewed, while all the regions’ real housing returns are found to be leptokurtic. While most of the regions’ real housing returns showed the presence of ARCH effect and/or autocorrelation up to the 10th lag, North West and Yorkshire and the Humber do not show any evidence of ARCH effect and/or autocorrelation at the highest specified lag. However, there are evidence of high persistence in all but Scotland that exhibited persistence of about 0.5. On the other hand, the average real output growth for the twelve regions and the aggregate is observed to range between 1.578 and 3.364, corresponding to North East and London, respectively; with the least and highest dispersions found in South West and London, respectively. Output growth is negatively skewed and leptokurtic (exhibiting excess kurtosis values greater than 3) in all the regions except in the North East. We also find evidence of ARCH effect, autocorrelation and higher order autocorrelation, as well as high level of persistence in the output growth series. While the predictor variables (housing related economic policy uncertainty and UK aggregate economic policy uncertainty) only showed evidence of persistence, the other control variables showed evidence of ARCH, autocorrelation as well as persistence (see Table 1).

Few evidences of endogeneity were found in the cases of UK aggregate economic policy uncertainty, regional output growth and mortgage rate (see results in Table 2). Given these data characteristics, it is pertinent to adopt a model that capture most, if not all, of the observed salient features; and to this effect, the WN-type distributed lag model that accounts for conditional heteroscedasticity as well as persistence is employed.

⁶ The data is downloadable from: http://policyuncertainty.com/uk_monthly.html.

Table 1: Summary Statistics and Preliminary Analysis

| | Mean | Std. Dev. | Skewness | Kurtosis | ARCH (1) | ARCH (5) | ARCH (10) | Q(1) | Q(5) | Q(10) | Q ² (1) | Q ² (5) | Q ² (10) | Persistence |
|---|-------|-----------|----------|----------|-----------|-----------|-----------|-----------|------------|------------|--------------------|--------------------|---------------------|-------------|
| Real Housing Returns | | | | | | | | | | | | | | |
| East Midlands | 1.165 | 2.361 | -0.182 | 5.130 | 0.105 | 8.410 | 16.990* | 0.149 | 5.39 | 9.11 | 0.11 | 12.560*** | 20.008*** | 0.850*** |
| East of England | 1.330 | 2.349 | -0.826 | 5.706 | 2.081 | 11.046* | 12.695 | 5.336** | 17.791*** | 26.392*** | 2.17 | 14.925** | 16.562* | 0.844*** |
| London | 1.453 | 2.424 | -0.715 | 4.852 | 0.104 | 3.007 | 7.051 | 1.346 | 13.822** | 19.264** | 0.109 | 2.872 | 6.884 | 0.780*** |
| North East | 0.854 | 2.610 | 0.492 | 5.093 | 0.001 | 2.820 | 4.403 | 4.254** | 12.656** | 17.883* | 0.001 | 3.557 | 6.503 | 0.746*** |
| North West | 1.076 | 2.350 | 0.101 | 4.442 | 0.118 | 4.722 | 13.982 | 0.043 | 3.746 | 6.539 | 0.123 | 5.606 | 14.346 | 0.852*** |
| Northern Ireland | 0.728 | 4.459 | -0.184 | 3.796 | 22.580*** | 33.959*** | 34.333*** | 2.267 | 15.377*** | 17.948* | 23.238*** | 57.642*** | 57.956*** | 0.607*** |
| Scotland | 0.966 | 2.609 | 0.039 | 3.292 | 4.139** | 7.346 | 11.618 | 0.391 | 2.629 | 15.452 | 4.317* | 6.008 | 11.62 | 0.499*** |
| South East | 1.231 | 2.355 | -0.874 | 5.540 | 1.158 | 16.595*** | 21.729** | 4.100** | 18.059*** | 23.602*** | 1.209 | 21.212*** | 26.118*** | 0.806*** |
| South West | 1.225 | 2.388 | -0.556 | 5.054 | 0.075 | 9.252* | 11.193 | 2.577 | 12.559** | 19.133** | 0.079 | 10.193* | 11.868 | 0.838*** |
| Wales | 1.068 | 2.386 | 0.290 | 4.357 | 0.463 | 8.068 | 13.182 | 3.438 | 15.029 | 17.355* | 0.482 | 8.803 | 15.423 | 0.821*** |
| West Midlands | 1.096 | 2.213 | -0.385 | 5.029 | 0.001 | 10.957* | 14.299 | 0.216 | 6.414 | 10.856 | 0.001 | 13.417** | 19.123** | 0.840*** |
| Yorkshire and the Humber | 1.062 | 2.411 | 0.187 | 4.731 | 2.520 | 4.453 | 6.179 | 0.596 | 6.902 | 8.991 | 2.623 | 4.961 | 6.249 | 0.825*** |
| Aggregate | 1.083 | 2.165 | -0.744 | 5.652 | 7.549*** | 10.629* | 10.729 | 0.094 | 11.019* | 13.645 | 7.888*** | 13.318** | 16.062* | 0.730*** |
| Output Growth | | | | | | | | | | | | | | |
| East Midlands | 1.638 | 1.601 | -2.274 | 9.909 | 39.722*** | 64.840*** | 62.525*** | 52.351*** | 93.330*** | 102.330*** | 41.574*** | 85.962*** | 88.347*** | 0.909*** |
| East of England | 2.065 | 1.940 | -1.669 | 6.611 | 32.211*** | 48.550*** | 47.761*** | 49.849*** | 122.520*** | 166.440*** | 33.681*** | 45.801*** | 48.205*** | 0.925*** |
| London | 3.364 | 2.768 | -1.176 | 5.929 | 42.853*** | 49.663*** | 51.156*** | 51.938*** | 110.390*** | 131.780*** | 44.779*** | 74.907*** | 79.111*** | 0.910*** |
| North East | 1.578 | 2.040 | 0.244 | 2.985 | 25.987*** | 35.504*** | 34.481*** | 49.082*** | 85.383*** | 93.054*** | 27.006*** | 42.885*** | 43.666*** | 0.955*** |
| North West | 2.046 | 1.628 | -0.752 | 3.333 | 24.302*** | 39.290*** | 48.664*** | 49.716*** | 100.840*** | 108.640*** | 25.112*** | 38.313*** | 52.348*** | 0.938*** |
| Northern Ireland | 1.661 | 2.315 | -0.674 | 3.356 | 8.343*** | 20.701*** | 26.084*** | 32.518*** | 47.295*** | 53.642*** | 8.679*** | 21.894*** | 25.800*** | 0.945*** |
| Scotland | 1.885 | 1.629 | -1.201 | 5.386 | 15.544*** | 27.618*** | 28.173*** | 35.785*** | 88.728*** | 107.500*** | 16.247*** | 27.749*** | 28.743*** | 0.880*** |
| South East | 2.023 | 1.726 | -1.175 | 5.910 | 40.836*** | 63.079*** | 62.598*** | 51.247*** | 150.060*** | 204.010*** | 42.631*** | 77.097*** | 81.425*** | 0.871*** |
| South West | 1.745 | 1.583 | -0.989 | 5.044 | 22.251*** | 34.272*** | 37.323*** | 40.491*** | 114.860*** | 154.130*** | 22.933*** | 51.170*** | 60.446*** | 0.877*** |
| Wales | 1.644 | 2.015 | -1.584 | 7.133 | 32.094*** | 35.639*** | 39.553*** | 41.651*** | 77.647*** | 83.278*** | 33.438*** | 41.308*** | 58.562*** | 0.901*** |
| West Midlands | 1.740 | 1.976 | -2.835 | 11.852 | 42.749*** | 64.648*** | 62.033*** | 52.437*** | 101.770*** | 115.180*** | 44.722*** | 87.494*** | 90.851*** | 0.911*** |
| Yorkshire and the Humber | 1.694 | 2.033 | -1.223 | 4.863 | 0.367 | 17.471*** | 20.692** | 20.103** | 34.377*** | 45.894** | 0.383 | 21.877*** | 28.277*** | 0.946*** |
| Aggregate | 1.986 | 1.845 | -2.485 | 10.596 | 36.975*** | 45.973*** | 44.268*** | 31.800*** | 79.177*** | 94.644*** | 38.656*** | 57.821*** | 59.945*** | 0.897*** |
| Main Predictor and Other Control Variables | | | | | | | | | | | | | | |
| Housing EPU | 4.600 | 0.545 | -0.090 | 2.285 | 2.446 | 3.784 | 5.324 | 0.148 | 3.27 | 9.024 | 2.491 | 3.856 | 5.903 | 0.845*** |
| UK Aggregate EPU | 4.673 | 0.490 | -0.042 | 2.559 | 1.081 | 4.656 | 8.785 | 0.108 | 1.371 | 10.043 | 1.121 | 5.094 | 13.848 | 0.823*** |
| Financial Stress Index | 0.125 | 0.095 | 2.078 | 7.437 | 2.152 | 9.460* | 11.842 | 0.007 | 5.142 | 7.741 | 2.252 | 13.910** | 16.200* | 0.824*** |
| Mortgage Rate | 4.535 | 1.688 | 0.375 | 2.188 | 0.205 | 0.200 | 0.411 | 18.009*** | 23.446*** | 26.859*** | 0.214 | 0.238 | 0.308 | 0.963*** |

Note: ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively. ARCH effect, autocorrelation and higher autocorrelation is tested at lags 1, 5 and 10, under the null hypothesis of no presence of the corresponding statistical feature; with significance (non-significance) indicating the presence (absence) of the corresponding statistical features. In the case of persistence test, the null hypothesis asserts the absence of persistence; such that a rejection of the null will indicate the plausibility of the presence of unit root in the series.

Table 2: Endogeneity Results

| | HPU | EPU | Real Output Growth | Financial Stress Index | Mortgage Rate |
|--------------------------|---------|------------|--------------------------|------------------------------|------------------|
| East Midlands | 0.0010 | -0.0070 | 0.0052 | -0.0633 | 0.0089 |
| East of England | 0.0045 | 0.0001 | 0.0060* | -0.0659 | 0.0122 |
| London | 0.0005 | -0.0004 | 0.0034 | -0.0508 | 0.0151* |
| North East | -0.0082 | -0.0203** | 0.0098** | -0.0664 | 0.0125 |
| North West | -0.0034 | -0.0130 | 0.0089** | -0.0649 | 0.0150* |
| Northern Ireland | -0.0099 | -0.0237 | 0.0008 | -0.1099 | 0.0483*** |
| Scotland | -0.0060 | -0.0243*** | 0.0016 | -0.0357 | 0.0183* |
| South East | 0.0022 | 0.0019 | 0.0032 | -0.0620 | 0.0154* |
| South West | 0.0000 | -0.0057 | 0.0057* | -0.0681 | 0.0118 |
| Wales | -0.0027 | -0.0123 | 0.0076*** | -0.0518 | 0.0147* |
| West Midlands | 0.0001 | -0.0060 | 0.0040 | -0.0664 | 0.0110 |
| Yorkshire and the Humber | -0.0035 | -0.0136 | 0.0077** | -0.0773 | 0.0151* |
| Aggregate | -0.0052 | -0.0048 | 1.1387*** | -0.0674 | 0.0189** |

Note: HPU = Housing price uncertainty; EPU = Economic Policy Uncertainty; ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively. Significant estimates would imply that the corresponding predictor variables listed on each column exhibit some form of endogeneity bias, such that the variable is correlated with the model residual.

4. Empirical Results

4.1 Main Results

Following from the observed data characteristics, we adopted the WN-type distributed lag model that accounts for conditional heteroscedasticity and persistence within a single model framework, to ascertain the predictive capacity of housing price uncertainty for housing returns in twelve UK regions as well as the aggregate housing returns. We considered three different constructs of the WN-type distributed lag model: First, is a model with no included control variables that is estimated to ascertain the predictability of regional housing returns using only HPU as the predictor; second, the initial model is extended to include some control variables (regional output growth, financial stress index and mortgage rate), in a bid to ascertain if their inclusion would improve forecast performance; and third, a model construct that incorporates both positively and negatively decomposed partial sums of the uncertainty measures, to view plausible impact of asymmetry effect on the predictability of housing returns. The estimation process is conducted with respect to each of the twelve regions in the UK, as well as the aggregated data, under three different sub-sample intervals: Full sample (1998Q1 – 2019Q2), Pre-GFC sample (1998Q1 – 2007Q4) and Post-GFC sample (2008Q1 – 2019Q2). While the HPU measure is considered for the main estimation (see results in Tables 3 - 5), we consider the aggregate EPU as additional analysis for robustness purpose (see results in Tables 6 - 8). Furthermore, in addition to the in-sample evaluation of the model performance(s), we also evaluate the models' out-of-sample forecast performance for three different forecasts horizons as previously explained. The forecast

performance of our HPU-based model is also compared with those of the EPU-based model, using the modified Diebold and Mariano test (see results in Table 9), under a two-sided hypothesis.

Table 3: Predictability of housing price uncertainty (HPU) for housing returns

| | Without Control | With Control | Asymmetry Effect | |
|--|-------------------|-------------------|-------------------|-------------------|
| | | | Positive | Negative |
| <i>Full Sample</i> | | | | |
| East Midlands | -1.614*** [0.074] | -1.659*** [0.152] | 0.101 [0.137] | 0.236 [0.160] |
| East of England | -0.998*** [0.123] | -2.261*** [0.131] | -1.094*** [0.156] | -0.837*** [0.169] |
| London | -1.605*** [0.043] | -4.169*** [0.186] | -2.020*** [0.065] | -2.054*** [0.096] |
| North East | -0.661*** [0.069] | -1.140*** [0.174] | -0.105*** [0.022] | 0.095*** [0.027] |
| North West | -0.250*** [0.073] | -0.951*** [0.096] | 0.323** [0.126] | 0.550*** [0.137] |
| Northern Ireland | -2.036*** [0.173] | -1.651*** [0.197] | -0.783*** [0.139] | -0.513*** [0.168] |
| Scotland | -1.714*** [0.079] | -2.020*** [0.399] | -1.059*** [0.125] | -0.930*** [0.147] |
| South East | -0.999*** [0.054] | -2.701*** [0.248] | -1.853*** [0.071] | -2.019*** [0.081] |
| South West | -2.161*** [0.073] | -2.455*** [0.293] | -0.186 [0.148] | 0.169 [0.171] |
| Wales | -0.934*** [0.099] | -1.029*** [0.121] | -0.537* [0.269] | -0.374 [0.323] |
| West Midlands | -0.307*** [0.061] | -0.898*** [0.281] | 0.658*** [0.201] | 0.903*** [0.244] |
| Yorkshire and the Humber | -0.318*** [0.060] | -0.711*** [0.132] | 0.443 [0.267] | 0.698** [0.304] |
| Aggregate | -1.425*** [0.079] | -2.722*** [0.221] | -1.565*** [0.099] | -1.546*** [0.106] |
| <i>Pre-GFC Sample (1998Q1 – 2007Q4)</i> | | | | |
| East Midlands | 2.950*** [0.124] | 0.349 [0.300] | 3.187*** [0.766] | 4.164*** [0.878] |
| East of England | -1.437*** [0.068] | -2.502 [1.554] | 0.311 [0.179] | 1.455*** [0.140] |
| London | -1.805*** [0.243] | -6.533*** [0.413] | -0.722 [0.475] | 0.193 [0.539] |
| North East | 4.288*** [0.241] | -0.843 [0.599] | 3.440*** [0.396] | 4.238*** [0.412] |
| North West | 2.670*** [0.089] | 2.159*** [0.165] | 1.927*** [0.559] | 2.243*** [0.554] |
| Northern Ireland | 0.157 [0.149] | 1.427* [0.785] | -4.541*** [0.491] | -5.078*** [0.617] |
| Scotland | 1.051*** [0.297] | -1.073 [0.662] | 0.712* [0.402] | 0.161 [0.534] |
| South East | -1.482*** [0.013] | 0.689* [0.348] | -0.259* [0.132] | 0.967*** [0.114] |
| South West | 0.932** [0.354] | -1.767** [0.723] | 0.337 [0.223] | 1.356*** [0.185] |
| Wales | 3.122*** [0.221] | 0.921** [0.312] | 3.718*** [0.513] | 4.274*** [0.685] |
| West Midlands | 1.731*** [0.135] | 0.615 [0.532] | 2.279*** [0.253] | 2.804*** [0.316] |
| Yorkshire and the Humber | 0.481*** [0.147] | -0.400** [0.129] | 2.841*** [0.080] | 3.067*** [0.170] |
| Aggregate | -0.652* [0.327] | -1.686 [1.067] | -1.682*** [0.199] | -1.716*** [0.124] |
| <i>Post-GFC Sample (2008Q1 – 2019Q2)</i> | | | | |
| East Midlands | -0.200** [0.070] | -1.446*** [0.211] | -0.409*** [0.089] | -1.166*** [0.057] |
| East of England | -0.493*** [0.065] | -2.939*** [0.234] | -1.140*** [0.183] | -2.728*** [0.236] |
| London | -3.445*** [0.134] | -4.600*** [0.469] | -3.505*** [0.081] | -3.784*** [0.118] |
| North East | -0.715*** [0.069] | -1.452*** [0.158] | -0.824*** [0.056] | -1.524*** [0.088] |
| North West | 0.230*** [0.060] | -2.098*** [0.123] | -0.821*** [0.187] | -1.598*** [0.212] |
| Northern Ireland | -0.220*** [0.031] | -2.825*** [0.153] | -2.937*** [0.531] | -4.953*** [0.496] |
| Scotland | 0.108** [0.043] | -1.241*** [0.127] | -0.238*** [0.080] | -0.761*** [0.138] |
| South East | -1.668*** [0.189] | -3.279*** [0.523] | -1.883*** [0.316] | -3.400*** [0.546] |
| South West | -0.560*** [0.107] | -2.157*** [0.542] | -0.714*** [0.107] | -1.397*** [0.068] |
| Wales | 0.335*** [0.068] | -0.890*** [0.222] | -0.501*** [0.092] | -1.063*** [0.141] |
| West Midlands | 0.386** [0.136] | -0.488** [0.204] | 0.277*** [0.051] | 0.192*** [0.061] |
| Yorkshire and the Humber | 0.332** [0.130] | -1.386*** [0.334] | -0.843*** [0.015] | -1.569*** [0.012] |
| Aggregate | -0.502*** [0.139] | -1.658*** [0.064] | -0.919*** [0.222] | -2.199*** [0.411] |

Note: The reported estimates are the slope coefficients and the corresponding standard error in square brackets associated with the one period lag of HPU-based models. The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed HPU, as well as their first differences. The ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively, where significance indicates a stance of predictability with respect to our HPU-based model is confirmed; otherwise, it's a case of no predictability.

On the in-sample predictability, Table 3 presents the estimated coefficients of one period lag of HPU, under the three specified sample intervals – Full sample (top panel), Pre-GFC sample (middle panel) and Post-GFC (bottom panel); and under three different constructs of the WN-type distributed lag models (without control variables, with control variables and with the incorporation

of positively and negatively decomposed partial sums of HPU). Under the full sample interval, we find the nexus between housing returns and HPU to be negative and statistically significant. This stance is consistent across all the regions as well as in the case of the aggregated housing data. The magnitude of the negative impact of HPU on housing returns is further increased and still statistically significant when control variables are included in the HPU-based model. With respect to the third model construct, there appears to be some similarities between the estimated coefficients associated with the positively and negatively decomposed HPU, across the UK regions and which is suggestive of little or no difference between the decomposed partial sums. Imperatively, while the inclusion of control variables may seem to have some supportive influence on the predictive capability of HPU, accounting for asymmetry effect may not matter. The observed negative relationship aligns with our a priori expectation that low housing returns are associated with high risks. Our confirmation of a significant predictive capacity of HPU aligns with the extant studies that also find overall uncertainty to be a good predictor for real housing returns (see, Choudhry (2020) in particular as it deals with regional UK data).

The stance is however different under the Pre- and Post-GFC sample periods, especially when model without control variables is considered. However, the results for the model with control variables under the Post-GFC sample period align reasonably well with the results under the full sample period, and further confirms our a priori expectation of a significantly negative relationship. The results in the Pre-GFC sample period are mixed, with high risk – low returns and high risks – high returns relationship, and more of the latter being observed. Again, there appears to be great similarities in the estimated coefficients associated with the decomposed partial sums. However, across the sample periods and under the model constructs, the negative relationship between housing returns and HPU is quite evident.

On the model fitness, based on the likelihoods of the contending models, we find statistically significant likelihood ratio statistics across the UK regions and the aggregated data (see results in Table 4). The results emanate from the fact that maximization of the likelihood function is higher in our HPU-based predictive model than the historical average model. This is indicative of the goodness of fit of our predictive model for UK regions' housing returns and by extension, HPU data is said to contain predictive contents for housing returns. The result is consistent across model constructs and sample periods. One striking feature here is the improvement in the model fitness when control variables are introduced. This is indicative of the

additional significant information the inclusion of control variables provides. Evidently, with respect to model fitness, HPU-based predictive models fit the data better than the benchmark model.

Table 4: Likelihood Ratio test for HPU-based models relative to the benchmark model

| | Without Control Variables | | | With Control Variables | | | Asymmetry Effect Incorporated | | |
|--------------------------|---------------------------|--------------|------------|------------------------|--------------|------------|-------------------------------|--------------|------------|
| | Restricted | Unrestricted | LR-Test | Restricted | Unrestricted | LR-Test | Restricted | Unrestricted | LR-Test |
| <i>Full Sample</i> | | | | | | | | | |
| East Midlands | 67.829 | 122.327 | 108.995*** | -50.852 | 42.605 | 186.915*** | -28.653 | 8.713 | 74.732*** |
| East of England | -30.424 | -5.861 | 49.127*** | 75.159 | 132.451 | 114.583*** | -59.637 | 8.075 | 135.424*** |
| London | -21.597 | 45.439 | 134.072*** | -68.865 | 58.954 | 255.638*** | -55.458 | 32.124 | 175.164*** |
| North East | -18.868 | 5.407 | 48.551*** | -62.738 | 14.432 | 154.340*** | -25.852 | 43.886 | 139.475*** |
| North West | 22.35 | 28.593 | 12.486*** | -47.985 | 118.719 | 333.409*** | -21.646 | 18.373 | 80.038*** |
| Northern Ireland | -51.716 | -23.629 | 56.175*** | -6.243 | 89.836 | 192.158*** | -46.095 | 13.508 | 119.205*** |
| Scotland | -37.102 | -1.496 | 71.212*** | -66.427 | 88.218 | 309.290*** | 0.245 | 55.4 | 110.311*** |
| South East | -36.336 | 20.629 | 113.931*** | 29.701 | 121.075 | 182.747*** | -47.088 | -2.51 | 89.155*** |
| South West | -69.647 | -11.007 | 117.281*** | -31.03 | 31.329 | 124.719*** | -41.334 | 42.553 | 167.775*** |
| Wales | -13.43 | 13.353 | 53.567*** | 22.783 | 117.744 | 189.922*** | 56.486 | 93.747 | 74.522*** |
| West Midlands | 20.612 | 42.701 | 44.177*** | 140.094 | 226.624 | 173.060*** | 20.446 | 47.952 | 55.013*** |
| Yorkshire and the Humber | -7.8 | 1.916 | 19.433*** | -27.682 | 16.032 | 87.428*** | 84.158 | 117.44 | 66.564*** |
| Aggregate | -20.513 | 19.733 | 80.492*** | 13.538 | 71.608 | 116.142*** | -23.54 | 15.202 | 77.485*** |
| <i>Pre-GFC Sample</i> | | | | | | | | | |
| East Midlands | 19.76 | 36.087 | 32.653*** | -22.815 | 21.683 | 88.996*** | -14.467 | 40.256 | 109.445*** |
| East of England | -13.138 | 19.315 | 64.905*** | -19.285 | 18.84 | 76.249*** | -35.176 | -0.882 | 68.589*** |
| London | -24.254 | -12.843 | 22.823*** | -13.901 | 34.696 | 97.194*** | 5.574 | 47.266 | 83.383*** |
| North East | -5.106 | 17.52 | 45.252*** | -42.144 | 20.534 | 125.356*** | -20.176 | -4.986 | 30.379*** |
| North West | -21.842 | 5.413 | 54.510*** | 49.531 | 85.016 | 70.969*** | -23.003 | 0.903 | 47.811*** |
| Northern Ireland | 26.374 | 28.733 | 4.718* | 16.09 | 58.544 | 84.908*** | -24.607 | -10.517 | 28.180*** |
| Scotland | 10.756 | 15.187 | 8.861** | -25.978 | -0.576 | 50.805*** | -34.154 | -14.597 | 39.116*** |
| South East | 14.664 | 52.336 | 75.346*** | 4.456 | 65.505 | 122.099*** | -7.16 | 32.455 | 79.230*** |
| South West | 9.932 | 24.184 | 28.504*** | -0.875 | 31.21 | 64.170*** | 22.788 | 64.157 | 82.738*** |
| Wales | 15.159 | 59.213 | 88.108*** | -25.22 | 8.255 | 66.950*** | -35.904 | -3.326 | 65.156*** |
| West Midlands | -12.703 | 4.733 | 34.871*** | -0.023 | 37.579 | 75.204*** | -11.448 | 12.642 | 48.179*** |
| Yorkshire and the Humber | 122.088 | 137.477 | 30.777*** | -16.568 | 50.307 | 133.751*** | -25.726 | 6.957 | 65.367*** |
| Aggregate | -14.878 | -13.095 | 3.566 | -12.254 | 6.883 | 38.275*** | 31.155 | 51.793 | 41.275*** |
| <i>Post-GFC Sample</i> | | | | | | | | | |
| East Midlands | -1.929 | 22.034 | 47.927*** | -24.05 | 37.428 | 122.955*** | 48.805 | 96.708 | 95.805*** |
| East of England | 62.743 | 79.125 | 32.764*** | -47.616 | 5.07 | 105.372*** | -16.551 | 14.565 | 62.232*** |
| London | 8.906 | 39.161 | 60.510*** | -10.908 | 39.771 | 101.358*** | -9.197 | 40.668 | 99.730*** |
| North East | 74.646 | 86.968 | 24.643*** | -29.841 | 20.515 | 100.713*** | 42.764 | 109.825 | 134.121*** |
| North West | 12.604 | 23.274 | 21.341*** | 2.832 | 55.017 | 104.369*** | -28.291 | 10.481 | 77.545*** |
| Northern Ireland | 53.15 | 71.366 | 36.434*** | 0.871 | 49.556 | 97.369*** | -28.182 | 15.506 | 87.377*** |
| Scotland | 11.922 | 14.543 | 5.243* | -41.561 | 4.405 | 91.932*** | -17.065 | -3.866 | 26.398*** |
| South East | -19.889 | -3.062 | 33.654*** | -23.294 | 8.505 | 63.599*** | -29.241 | -4.287 | 49.908*** |
| South West | -7.254 | -1.061 | 12.385*** | -3.987 | 40.996 | 89.968*** | 2.331 | 43.134 | 81.606*** |
| Wales | 7.433 | 10.538 | 6.210** | -22.793 | 32.495 | 110.576*** | 5.746 | 29.772 | 48.051*** |
| West Midlands | -2.285 | 13.726 | 32.022*** | -31.555 | 30.527 | 124.164*** | 1.035 | 24.831 | 47.592*** |
| Yorkshire and the Humber | 6.427 | 7.868 | 2.883 | -20.151 | 14.084 | 68.471*** | 2.208 | 61.117 | 117.818*** |
| Aggregate | 3.73 | 7.846 | 8.231** | 0.0003 | 62.891 | 125.783*** | -3.575 | 18.668 | 44.485*** |

Note: The reported estimates are the log likelihood of the restricted (historical average) and the unrestricted (HPU-based) models, as well as the likelihood ratio test statistics, which is based on the Chi-Square statistics. The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed HPU data, as well as their first differences. The ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively, where significance indicates preference of the HPU-based model over the restricted benchmark model; otherwise, the latter is preferred over the former.

On the forecast performance using the relative RMSE (see the superscripted label in Table 5 and the detailed statistics in Table A1 in the appendix), we find all three constructs of HPU-based framework to mostly outperform the benchmark (historical average) model when the full sample period is considered except in the case of East Midlands and Northern Ireland (model with decomposed partial sums of HPU), and Wales (model with control variables and model with decomposed partial sums of HPU). This stance is consistent across the in-sample and the three out-of-sample forecast horizons. The relative RMSE results under the Pre-GFC sample period differ from the stance under the full sample, as there are more cases where the benchmark model outperforms the HPU-based model, especially when the model with no control variables is considered. The inclusion of control variables is found to improve the forecast performance of our predictive model, in confirmation of the predictability results earlier reported in Table 3. In the Post-GFC sample period, all the HPU-based models, with the exception of model without control variables, consistently outperform the benchmark model across the UK regions. In other words, our proposed HPU-based models predict housing returns more precisely than the benchmark model, especially when the model incorporates relevant control variables. To formally confirm this stance by determining the significance of the out-performance stance, we employ the Clark and West (2007) test, comparing each of the HPU-based constructs with the benchmark model. The stance of outperformance of the former over the latter across the UK regions and forecast horizons observed in Table 5, judging by the reported relative RMSE values, is reaffirmed by the Clark and West test results (see Table 5). The HPU-based models are evidently mostly preferred to the benchmark model, which is not only indicative of the predictive power of HPU and the included control variables but also, the important role that accounting for salient data features plays in predicting housing returns (see also studies on return predictability although not from the perspective of housing return predictability, Bannigidamath and Narayan (2015), Narayan and Gupta (2015), Phan et al., (2015), Narayan et al., (2016, 2018), Devpura et al., (2018), Salisu et al., (2018, 2019a,b,c,d,e) among others).

Table 5: Clark and West test for HPU-based models relative to the benchmark model

| | Without Control Variables | | | With Control Variables | | | Asymmetry Effect | | |
|--|-----------------------------|-----------------------------|-----------------------------|------------------------------|------------------------------|-------------------------------|------------------------------|------------------------------|------------------------------|
| | <i>h</i> = 1 | <i>h</i> = 2 | <i>h</i> = 4 | <i>h</i> = 1 | <i>h</i> = 2 | <i>h</i> = 4 | <i>h</i> = 1 | <i>h</i> = 2 | <i>h</i> = 4 |
| <i>Full Sample (1998Q1 – 2019Q2)</i> | | | | | | | | | |
| East Midlands | 1.585*** [0.518] | 1.592*** [0.511] | 1.631*** [0.500] | 2.500*** [0.955] | 2.473** [0.943] | 2.447*** [0.921] | 0.552 [0.459] ^a | 0.548 [0.453] ^a | 0.523 [0.443] ^a |
| East of England | 1.397*** [0.334] | 1.374*** [0.330] | 1.367*** [0.323] | 2.162*** [0.542] | 2.114*** [0.538] | 2.081*** [0.526] | 3.232*** [0.768] | 3.218*** [0.759] | 3.262*** [0.741] |
| London | 2.550*** [0.539] | 2.536*** [0.533] | 2.624*** [0.525] | 6.456*** [1.458] | 6.386*** [1.442] | 6.512*** [1.411] | 3.546*** [0.770] | 3.494*** [0.763] | 3.533*** [0.745] |
| North East | 0.656* [0.309] | 0.666** [0.305] | 0.697** [0.300] | 6.001*** [1.311] | 5.927*** [1.298] | 5.838*** [1.269] | 1.389*** [0.202] | 1.399*** [0.200] | 1.432*** [0.199] |
| North West | 0.351* [0.202] | 0.345* [0.200] | 0.335* [0.195] | 4.003*** [0.950] | 3.956*** [0.939] | 3.896*** [0.918] | 1.044** [0.496] | 1.032** [0.490] | 1.027** [0.478] |
| Northern Ireland | 4.981*** [1.802] | 4.941*** [1.781] | 4.822*** [1.741] | 14.191*** [2.889] | 13.984*** [2.862] | 13.744*** [2.799] | 2.917 [2.657] ^a | 2.883 [2.625] ^a | 2.834 [2.562] ^a |
| Scotland | 1.634** [0.782] | 1.611** [0.773] | 1.591** [0.755] | 2.521*** [0.813] | 2.501*** [0.803] | 2.485*** [0.784] | 1.936** [0.763] | 1.915** [0.754] | 1.903** [0.736] |
| South East | 1.457*** [0.321] | 1.440*** [0.318] | 1.443*** [0.310] | 3.192*** [0.774] | 3.138*** [0.766] | 3.143*** [0.748] | 1.661*** [0.485] | 1.621*** [0.481] | 1.585*** [0.470] |
| South West | 3.082*** [0.661] | 3.064*** [0.654] | 3.116*** [0.639] | 3.162*** [0.776] | 3.130*** [0.767] | 3.120*** [0.749] | 2.393*** [0.781] | 2.383*** [0.772] | 2.405*** [0.753] |
| Wales | 1.011*** [0.276] | 1.002*** [0.273] | 1.001*** [0.267] | 1.501*** [0.382] | 1.485*** [0.378] | 1.472*** [0.369] | 1.534*** [0.318] | 1.521*** [0.315] | 1.511*** [0.308] |
| West Midlands | 0.421*** [0.132] | 0.416*** [0.130] | 0.428*** [0.127] | 0.125 [0.349] ^a | 0.124 [0.345] ^a | 0.104 [0.337] ^a | 1.976** [0.877] ^a | 1.954** [0.866] ^a | 1.954** [0.846] ^a |
| Yorkshire and the Humber | 0.288*** [0.108] | 0.286*** [0.107] | 0.280*** [0.104] | 3.162*** [0.677] | 3.147*** [0.669] | 3.087*** [0.654] | 1.033** [0.474] | 1.037** [0.469] | 1.034** [0.457] |
| Aggregate | 1.804*** [0.401] | 1.785*** [0.397] | 1.778*** [0.388] | 4.379*** [1.188] | 4.335*** [1.174] | 4.268*** [1.147] | 1.870*** [0.447] | 1.845*** [0.442] | 1.839*** [0.431] |
| <i>Pre-GFC Sample (1998Q1 – 2007Q4)</i> | | | | | | | | | |
| East Midlands | 1.621 [1.851] ^a | 1.077 [1.880] ^a | -0.423 [2.106] ^a | 5.914*** [1.258] | 5.838*** [1.226] | 5.024*** [1.359] | 3.759** [1.752] ^a | 3.710** [1.703] ^a | 2.992* [1.705] ^a |
| East of England | 0.649 [0.428] | 0.674 [0.417] | 0.930** [0.449] | 2.457*** [0.807] | 2.461*** [0.785] | 1.982** [0.827] | 4.047*** [1.086] | 4.031*** [1.056] | 4.089*** [1.004] |
| London | 1.396** [0.542] | 1.331** [0.531] | 1.422** [0.535] | 4.995*** [1.314] | 4.841*** [1.287] | 5.220*** [1.388] ^a | 3.766*** [1.127] | 3.605** [1.107] | 3.614*** [1.089] |
| North East | 4.334*** [1.307] | 3.953*** [1.327] | 2.340 [1.716] ^a | 8.119*** [2.100] | 8.311*** [2.052] | 8.984*** [2.002] | 3.684** [1.885] ^a | 3.507** [1.841] ^a | 2.040 [2.023] ^a |
| North West | 1.906*** [0.570] | 1.674*** [0.601] | 0.769 [0.873] ^a | 4.476** [1.763] ^a | 4.033** [1.771] ^a | 3.299* [1.760] ^a | 1.146* [0.536] | 1.070** [0.526] | 0.525 [0.635] ^a |
| Northern Ireland | 0.117 [0.431] ^a | 0.170 [0.423] ^a | 0.002 [0.431] ^a | 4.262 [2.743] | 4.101 [2.673] | 5.887* [3.109] | 4.834 [3.692] ^a | 4.764 [3.589] ^a | 5.528 [3.522] ^a |
| Scotland | 0.901 [0.625] ^a | 0.982 [0.613] ^a | 0.424 [0.729] ^a | 4.788*** [1.497] | 4.753*** [1.457] | 4.467*** [1.397] | 4.369*** [1.632] | 4.363*** [1.586] | 3.368** [1.661] ^a |
| South East | 0.692** [0.265] | 0.679** [0.258] | 0.719*** [0.252] | 2.470** [0.925] | 2.486** [0.900] | 2.766*** [0.876] | 4.691*** [1.219] | 4.608*** [1.188] | 4.694*** [1.131] |
| South West | 1.001 [1.139] ^a | 0.845 [1.119] ^a | 0.152 [1.166] ^a | 3.030*** [0.872] | 3.170*** [0.859] | 3.196*** [0.818] | 3.256*** [0.927] | 3.295*** [0.901] | 3.447*** [0.866] |
| Wales | 2.633** [0.967] | 2.401** [0.969] | 0.992 [1.375] ^a | 4.674** [1.829] ^a | 4.467** [1.791] ^a | 4.091** [1.718] ^a | 3.046** [1.246] | 2.931** [1.216] | 1.711 [1.449] ^a |
| West Midlands | 0.875 [0.943] ^a | 0.672 [0.940] ^a | -0.295 [1.125] ^a | 3.321*** [0.673] | 3.512*** [0.681] | 3.708*** [0.703] | 1.671* [0.881] | 1.526* [0.868] | 0.898 [0.963] ^a |
| Yorkshire and the Humber | 0.395 [0.650] ^a | 0.432 [0.633] ^a | 0.587 [0.611] ^a | 6.201*** [1.300] | 6.149*** [1.265] | 6.132*** [1.204] | 2.116** [0.842] | 2.055** [0.821] | 1.437 [0.894] |
| Aggregate | 0.061 [0.268] ^a | 0.055 [0.261] ^a | 0.120 [0.253] ^a | 1.408 [0.964] ^a | 1.384 [0.938] ^a | 1.336 [0.890] ^a | 0.126 [0.376] ^a | 0.156 [0.367] ^a | 0.319 [0.409] ^a |
| <i>Post-GFC Sample (2008Q1 – 2019Q2)</i> | | | | | | | | | |
| East Midlands | 0.232 [0.564] ^a | 0.239 [0.551] ^a | 0.220 [0.527] ^a | 6.004*** [2.155] | 5.881*** [2.109] | 5.608*** [2.025] | 2.430*** [0.751] | 2.396*** [0.734] | 2.269*** [0.708] |
| East of England | 1.063 [1.278] ^a | 1.010 [1.250] ^a | 0.906 [1.198] ^a | 9.435*** [3.582] | 9.207*** [3.507] | 8.686** [3.372] | 4.909** [1.898] | 4.751** [1.861] | 4.210** [1.819] ^a |
| London | 3.704*** [0.997] | 3.608*** [0.978] | 3.558*** [0.936] | 8.605*** [3.116] | 8.402*** [3.051] | 7.993*** [2.931] | 6.476*** [2.214] | 6.310*** [2.170] | 5.978*** [2.089] |
| North East | 0.348 [0.624] ^a | 0.376 [0.611] ^a | 0.359 [0.585] ^a | 3.209*** [1.061] | 3.168*** [1.037] | 3.037*** [0.996] | 2.328** [1.067] | 2.298** [1.043] | 2.230** [1.004] |
| North West | 0.095 [0.799] ^a | 0.192 [0.787] ^a | 0.227 [0.753] ^a | 4.770*** [1.595] | 4.729*** [1.559] | 4.549*** [1.495] | 2.373*** [0.565] | 2.472*** [0.561] | 2.431*** [0.537] |
| Northern Ireland | 0.512 [2.155] ^a | 0.853 [2.133] ^a | 1.060 [2.044] ^a | 18.869*** [5.522] | 18.779*** [5.396] | 18.167*** [5.176] | 15.964*** [4.069] | 16.333*** [3.992] | 16.130*** [3.820] |
| Scotland | -0.035 [0.344] ^a | -0.020 [0.336] ^a | 0.013 [0.322] ^a | 2.830** [1.221] | 2.802** [1.193] | 2.724** [1.142] | 1.006*** [0.371] | 1.022*** [0.363] | 1.051*** [0.348] |
| South East | 1.604* [0.829] ^a | 1.506* [0.815] ^a | 1.403* [0.783] ^a | 9.522*** [3.384] | 9.223*** [3.320] | 8.760*** [3.191] | 4.808** [1.844] | 4.523** [1.824] ^a | 4.061** [1.774] ^a |
| South West | 0.426 [0.628] ^a | 0.432 [0.613] ^a | 0.368 [0.588] ^a | 7.936** [2.963] | 7.772** [2.899] | 7.371** [2.786] | 2.405*** [0.740] | 2.385*** [0.723] | 2.175*** [0.708] |
| Wales | -0.073 [0.481] ^a | -0.031 [0.472] ^a | 0.029 [0.454] ^a | 4.497*** [1.539] | 4.461*** [1.504] | 4.297*** [1.443] | 1.737*** [0.432] | 1.791*** [0.426] | 1.794*** [0.407] |
| West Midlands | 0.008 [0.816] ^a | 0.065 [0.799] ^a | 0.046 [0.764] ^a | 6.246*** [2.018] | 6.153*** [1.974] | 5.860*** [1.898] | 1.272*** [0.395] | 1.323*** [0.389] | 1.237*** [0.378] |
| Yorkshire and the Humber | -0.133 [0.751] ^a | -0.116 [0.734] ^a | -0.061 [0.704] ^a | 3.749*** [1.257] | 3.678*** [1.230] | 3.536*** [1.180] | 2.059*** [0.685] | 2.036*** [0.670] | 2.002*** [0.642] |
| Aggregate | 0.390 [0.510] ^a | 0.393 [0.498] ^a | 0.352 [0.477] ^a | 7.438** [2.876] | 7.280** [2.814] | 6.926** [2.702] | 3.636*** [1.258] | 3.593*** [1.230] | 3.345*** [1.189] |

Note: The values reported are the Clark and West results that compares the HPU-based models with the benchmark model. The ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively. Positive and significant values indicate that the HPU-based model is preferred to the benchmark model. The superscripted “a” denotes cases where the relative RMSE comparison of our predictive model variants with the benchmark is greater than one; denoting that the forecast errors of our predictive model variants are not less than those of the benchmark model (detailed statistics are presented in Table A1, under the appendix). The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed HPU, as well as their first differences.

4.2 Additional Results

We consider some additional analyses herein, by way of robustness check on the main estimation results presented in Tables 3 – 5. In the light of the foregoing, we replicate the main analysis for the Economic Policy Uncertainty (EPU) data which is not sector-specific unlike the HPU. The intuition is to ascertain if the coverage of uncertainty measure matters for the predictability and forecast outcomes. We proceed in much the same way as in the main estimation, using three data samples and three variants of the EPU-based framework across the twelve UK regions as well as the aggregated data. The results on predictability, model fitness and forecast performance using relative RMSE and the Clark and West statistics are presented in Tables 6 – 8, respectively. Interestingly, we find the estimated coefficients of the uncertainty measure in the three different constructs to be mostly negative and statistically significant across the UK regions and the aggregated data under the full sample and Post-GFC sample intervals (see results in Table 6). The Pre-GFC sample period has more of positive and statistically significant coefficients, a similitude of the results obtained in the case in the main estimation. This high risk – high returns relationship seems to be associated with period of relative stability (pre-GFC), while the high risk – low returns relationship could be said to be associated with more tensed (Post-GFC and consequently, Full Sample) periods. In other words, in terms of the direction of predictability (see Table 6) and the model fitness of EPU-based models (see results in Table 7), the conclusions are similar to those of the main analysis involving HPU. Similarly, the EPU-based model outperforms the benchmark (historical average) more prominently for the post-GFC period (see Table 8).

We further evaluate the comparative performance of both the HPU- and EPU-based models in order to provide more justification for the role of the former when modelling and forecasting housing returns. A cursory look at the forecast performance of the two uncertainty measures, HPU and EPU (see Tables 5 and 8 respectively) suggests that the sector-specific uncertainty (HPU) measure seems to offer better forecast outcomes than the aggregate uncertainty (EPU) measure. This aligns with our hypothesis on the need to reflect some specific information about the sector in question in the computation of uncertainty measure. However, following a more scientific method to ascertain the data supported uncertainty measure, we employ the modified Diebold and Mariano test, and find that the results of outperformance between the sector-specific HPU and the aggregate EPU measures are mixed (see Table 9). On average, there are approximately 42% (32%) cases where our predictive HPU-based model (EPU-based model) outperforms the EPU-based

model (HPU-based model), especially for the pre-GFC sample period as well as in the presence of asymmetry. There are approximately 26% cases where the forecast performance of our HPU-based and EPU-based predictive models are statistically equal, which implies that the former does equally as good as the latter. The significance of asymmetry in the outperformance of HPU over EPU suggests stronger nonlinear connections between HPU and housing returns. The increased uncertainties in the regional housing sector in the U.K. have resulted in dwindling housing returns causing investments in the sector to be more chaotic. The stance is different for the post-GFC sample period, wherein the EPU-based model dominates the HPU-based model in about 59% cases. This is understandable as several policy options pursued during the global financial crisis, and the Brexit, seem experimental which consequently engendered policy uncertainties with greater implications on the economy including the housing sector, which has by then stabilized after the initial crash.

More results, using a longer range of data for HPU from 1982Q1 to 2019Q2, are presented in the appendix (see Tables A1 – A4), and these correspond to the predictability, likelihood ratio test, relative RMSE and the Clark and West statistics. The results are similar to the short range (full) data as virtually all the predictive models outperform the benchmark model judging by the forecast measures. Thus, we confirm again a high risk – low returns relationship, and also, the importance of considering a sample data that includes the post-GFC period.

Table 6: Predictability of economic policy uncertainty (EPU) for housing returns

| | Without Control | With Control | Asymmetry Effect | |
|--|-------------------|-------------------|-------------------|-------------------|
| | | | Positive | Negative |
| <i>Full Sample (1998Q1 – 2019Q2)</i> | | | | |
| East Midlands | -0.274*** [0.024] | -0.125 [0.227] | -0.103 [0.209] | 0.024 [0.241] |
| East of England | -0.421*** [0.094] | -0.369*** [0.125] | -0.027 [0.058] | 0.036 [0.067] |
| London | -1.521*** [0.147] | -0.901*** [0.049] | -1.253*** [0.105] | -1.070*** [0.150] |
| North East | -0.618*** [0.081] | -1.335*** [0.170] | -1.025*** [0.233] | -1.018*** [0.266] |
| North West | -1.516*** [0.037] | -0.678*** [0.159] | 0.300** [0.133] | 0.611*** [0.166] |
| Northern Ireland | -2.108*** [0.102] | -1.051*** [0.222] | -1.663*** [0.047] | -1.674*** [0.081] |
| Scotland | -2.919*** [0.069] | -2.764*** [0.312] | -2.763*** [0.160] | -2.775*** [0.195] |
| South East | -0.617*** [0.061] | -0.451*** [0.059] | -0.858*** [0.106] | -0.781*** [0.126] |
| South West | -0.998*** [0.046] | -0.997*** [0.158] | -0.442*** [0.112] | -0.282** [0.123] |
| Wales | -0.541*** [0.045] | -0.805*** [0.182] | -0.401*** [0.105] | -0.271* [0.134] |
| West Midlands | 0.003 [0.109] | -0.090 [0.129] | 0.153* [0.076] | 0.239*** [0.086] |
| Yorkshire and the Humber | -1.000*** [0.212] | -1.256*** [0.096] | -0.571* [0.291] | -0.498 [0.317] |
| Aggregate | -1.164*** [0.031] | -0.698*** [0.095] | -0.861*** [0.072] | -0.749*** [0.079] |
| <i>Pre-GFC Sample (1998Q1 – 2007Q4)</i> | | | | |
| East Midlands | 2.530*** [0.448] | 0.483 [0.286] | 3.368*** [0.203] | 3.655*** [0.188] |
| East of England | 2.604*** [0.290] | 2.724* [1.266] | 1.270*** [0.367] | 2.085*** [0.265] |
| London | 0.034 [0.146] | 2.262 [1.783] | -0.237 [0.195] | 0.983*** [0.125] |
| North East | -1.660*** [0.227] | 1.123** [0.359] | 3.073*** [0.411] | 2.724*** [0.413] |
| North West | -0.543** [0.203] | 1.771*** [0.457] | 1.982*** [0.322] | 1.811*** [0.269] |
| Northern Ireland | -2.111*** [0.074] | 6.880*** [1.496] | 0.425 [0.473] | -0.564 [0.456] |
| Scotland | -2.520*** [0.215] | -0.703 [0.699] | -1.178* [0.580] | -1.452*** [0.371] |
| South East | 1.825*** [0.038] | 0.785** [0.330] | 0.610* [0.283] | 1.540*** [0.228] |
| South West | 1.583*** [0.036] | 2.440*** [0.536] | 1.380*** [0.313] | 2.194*** [0.276] |
| Wales | -0.348 [0.362] | 0.263 [0.298] | 1.377*** [0.229] | 1.143*** [0.243] |
| West Midlands | 0.993* [0.553] | 0.819* [0.361] | 1.242** [0.568] | 1.922*** [0.507] |
| Yorkshire and the Humber | 1.610*** [0.520] | 1.228*** [0.294] | 1.416** [0.552] | 1.140** [0.480] |
| Aggregate | 0.419* [0.233] | 2.428*** [0.390] | 0.436 [0.593] | 1.249** [0.536] |
| <i>Post-GFC Sample (2008Q1 – 2019Q2)</i> | | | | |
| East Midlands | 0.031 [0.310] | -0.844 [0.503] | -0.804*** [0.175] | -1.509*** [0.182] |
| East of England | -0.482*** [0.137] | -2.184*** [0.203] | -1.469*** [0.064] | -2.580*** [0.086] |
| London | -2.907*** [0.352] | -5.027*** [0.246] | -3.246*** [0.557] | -3.754*** [0.636] |
| North East | 0.542*** [0.120] | -1.084 [0.630] | -0.909*** [0.193] | -1.112*** [0.286] |
| North West | 0.350*** [0.048] | -1.280*** [0.279] | -0.567*** [0.114] | -1.323*** [0.169] |
| Northern Ireland | -0.375** [0.146] | -2.973*** [0.200] | -2.436*** [0.142] | -5.052*** [0.174] |
| Scotland | 0.241*** [0.026] | -1.650*** [0.314] | -0.066 [0.199] | -0.455** [0.214] |
| South East | -1.203*** [0.234] | -2.850*** [0.148] | -1.717*** [0.107] | -2.861*** [0.117] |
| South West | -0.621*** [0.056] | -2.308*** [0.242] | -0.997*** [0.153] | -1.586*** [0.185] |
| Wales | 0.079 [0.049] | -0.777*** [0.102] | -0.323 [0.209] | -0.947*** [0.233] |
| West Midlands | 0.462*** [0.111] | -0.693*** [0.170] | -0.188* [0.093] | -0.754*** [0.110] |
| Yorkshire and the Humber | 0.243 [0.191] | -1.397*** [0.296] | -0.355*** [0.064] | -0.900*** [0.060] |
| Aggregate | -0.837*** [0.035] | -1.597*** [0.265] | -1.378*** [0.215] | -2.343*** [0.193] |

Note: The reported estimates are the slope coefficients and the corresponding standard error in square brackets associated with the one period lag of EPU-based model. The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed EPU data, as well as their first differences. The ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively, where significance indicates a stance of predictability with respect to the EPU-based model is confirmed; otherwise, it's a case of no predictability

Table 7: Likelihood Ratio test for EPU-based models relative to the benchmark model

| | Without Control Variables | | | With Control Variables | | | Asymmetry Effect Incorporated | | |
|--------------------------|---------------------------|--------------|------------|------------------------|--------------|------------|-------------------------------|--------------|------------|
| | Restricted | Unrestricted | LR-Test | Restricted | Unrestricted | LR-Test | Restricted | Unrestricted | LR-Test |
| <i>Full Sample</i> | | | | | | | | | |
| East Midlands | 18.283 | 32.113 | 27.660*** | 39.338 | 62.672 | 46.667*** | -23.016 | 4.284 | 54.601*** |
| East of England | -12.341 | -3.406 | 17.868*** | -17.055 | 45.72 | 125.550*** | 94.035 | 102.842 | 17.613*** |
| London | -15.858 | 3.031 | 37.780*** | 46.643 | 132.949 | 172.614*** | 15.269 | 94.379 | 158.220*** |
| North East | 2.069 | 64.166 | 124.195*** | -23.6 | 37.758 | 122.717*** | -52.297 | 29.394 | 163.383*** |
| North West | -7.037 | 160.88 | 335.834*** | -55.576 | 72.137 | 255.427*** | -16.283 | 9.758 | 52.081*** |
| Northern Ireland | -28.255 | 15.172 | 86.854*** | -59.1 | 13.716 | 145.631*** | 37.669 | 110.692 | 146.047*** |
| Scotland | -27.026 | 46.668 | 147.388*** | -60.261 | 23.084 | 166.690*** | -59.33 | -5.544 | 107.573*** |
| South East | -1.208 | 20.929 | 44.273*** | -2.885 | 50.91 | 107.591*** | 53.32 | 120.077 | 133.515*** |
| South West | -38.082 | -3.492 | 69.181*** | -32.658 | 67.778 | 200.873*** | -26.722 | 8.282 | 70.008*** |
| Wales | 7.544 | 32.044 | 49.000*** | -19.777 | 9.418 | 58.390*** | -23.901 | 2.519 | 52.841*** |
| West Midlands | -1.727 | 23.352 | 50.159*** | -19.538 | 11.001 | 61.077*** | -9.461 | 5.387 | 29.696*** |
| Yorkshire and the Humber | 2.554 | 17.323 | 29.538*** | -68.76 | 59.163 | 255.846*** | -25.847 | -6.668 | 38.359*** |
| Aggregate | -24.385 | 20.527 | 89.826*** | -0.483 | 39.251 | 79.469*** | -15.957 | 10.484 | 52.883*** |
| <i>Pre-GFC Sample</i> | | | | | | | | | |
| East Midlands | -14.622 | -7.138 | 14.967*** | -34.029 | 11.1 | 90.258*** | -25.719 | 70.07 | 191.577*** |
| East of England | 7.354 | 17.19 | 19.672*** | -18.262 | 45.663 | 127.850*** | -28.475 | 40.189 | 137.327*** |
| London | 10.353 | 13.213 | 5.719* | 1.132 | 19.615 | 36.966*** | -22.622 | 32.003 | 109.251*** |
| North East | 17.904 | 39.495 | 43.182*** | 0.363 | 46.44 | 92.154*** | -14.12 | 1.053 | 30.346*** |
| North West | 62.181 | 67.361 | 10.361*** | -37.695 | 38.972 | 153.334*** | 23.176 | 34.831 | 23.310*** |
| Northern Ireland | -15.672 | 11.67 | 54.683*** | -27.584 | -1.766 | 51.636*** | -43.348 | 3.632 | 93.960*** |
| Scotland | 21.261 | 56.12 | 69.718*** | 64.346 | 90.224 | 51.757*** | -22.242 | 42.256 | 128.997*** |
| South East | 5.878 | 28.958 | 46.159*** | 11.836 | 57.863 | 92.053*** | -25.565 | 3.332 | 57.794*** |
| South West | -11.687 | 26.4 | 76.174*** | -20.719 | 11.96 | 65.357*** | -27.982 | -2.64 | 50.684*** |
| Wales | 43.994 | 46.832 | 5.677* | -25.2 | 18.696 | 87.792*** | -11.392 | -0.678 | 21.428*** |
| West Midlands | -9.974 | -2.184 | 15.579*** | -30.654 | 46.275 | 153.858*** | -36.658 | -10.399 | 52.517*** |
| Yorkshire and the Humber | 7.834 | 12.313 | 8.959** | -23.763 | 57.681 | 162.887*** | 44.933 | 64.906 | 39.947*** |
| Aggregate | -1.904 | 0.539 | 4.887* | -21.351 | 2.655 | 48.013*** | -11.546 | 17.013 | 57.117*** |
| <i>Post-GFC Sample</i> | | | | | | | | | |
| East Midlands | 49.598 | 52.977 | 6.758** | -29.514 | 13.036 | 85.100*** | -23.559 | 19.316 | 85.749*** |
| East of England | -12.572 | -1.072 | 23.000*** | -15.244 | 46.37 | 123.229*** | 86.311 | 149.082 | 125.541*** |
| London | -26.533 | 1.778 | 56.621*** | -31.483 | 12.56 | 88.086*** | -6.979 | 24.444 | 62.847*** |
| North East | 2.988 | 9.674 | 13.372*** | -4.3 | 46.459 | 101.518*** | -4.531 | 2.225 | 13.512*** |
| North West | 2.447 | 23.687 | 42.482*** | 28.45 | 53.38 | 49.861*** | -17.671 | 9.524 | 54.389*** |
| Northern Ireland | 147.281 | 150.926 | 7.291** | -71.278 | 59.715 | 261.986*** | -39.329 | -1.55 | 75.558*** |
| Scotland | 5.458 | 10.188 | 9.461*** | 13.491 | 79.226 | 131.470*** | 16.007 | 43.058 | 54.102*** |
| South East | 24.74 | 42.529 | 35.579*** | -25.067 | 29.805 | 109.744*** | -38.752 | 16.579 | 110.662*** |
| South West | 14.227 | 29.673 | 30.892*** | -41.612 | 16.477 | 116.178*** | -16.014 | 11.581 | 55.190*** |
| Wales | 3.819 | 18.472 | 29.306*** | 32.914 | 75.114 | 84.399*** | 61.277 | 99.275 | 75.996*** |
| West Midlands | 3.471 | 8.449 | 9.955*** | -45.819 | 35.91 | 163.458*** | 1.648 | 22.496 | 41.696*** |
| Yorkshire and the Humber | 14.727 | 28.15 | 26.847*** | -20.301 | 12.206 | 65.014*** | -17.641 | 16.387 | 68.056*** |
| Aggregate | -3.639 | 22.18 | 51.637*** | -19.077 | 29.78 | 97.715*** | -27.343 | 33.102 | 120.889*** |

Note: The reported estimates are the log likelihood of the restricted (historical average) and the unrestricted (EPU-based) models, as well as the likelihood ratio test statistics, which is based on the Chi-Square statistics. The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed EPU data, as well as their first differences. The ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively, where significance indicates preference of the EPU-based model over the restricted benchmark model; otherwise, the latter is preferred over the former.

Table 8: Clark and West test for EPU-based models relative to the benchmark model

| | Without Control Variables | | | With Control Variables | | | Asymmetry Effect | | |
|--------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|------------------------------|-----------------------------|------------------------------|-------------------------------|-------------------------------|
| | $h = 1$ | $h = 2$ | $h = 4$ | $h = 1$ | $h = 2$ | $h = 4$ | $h = 1$ | $h = 2$ | $h = 4$ |
| <i>Full Sample</i> | | | | | | | | | |
| East Midlands | 0.160** [0.064] | 0.158** [0.064] | 0.161** [0.062] | 0.119 [0.527] ^a | 0.110 [0.520] ^a | 0.071 [0.509] ^a | 0.621 [0.454] ^a | 0.614 [0.448] ^a | 0.587 [0.438] ^a |
| East of England | 0.254 [0.276] ^a | 0.230 [0.274] ^a | 0.212 [0.269] ^a | 0.218 [1.092] ^a | 0.178 [1.079] ^a | 0.155 [1.055] ^a | 0.445 [0.355] ^a | 0.413 [0.352] ^a | 0.401 [0.344] ^a |
| London | 1.155*** [0.350] | 1.142*** [0.346] | 1.190*** [0.340] | 1.879 [1.228] ^a | 1.827 [1.215] ^a | 1.944 [1.189] ^a | 1.740*** [0.435] | 1.745*** [0.430] | 1.884*** [0.431] |
| North East | 0.533*** [0.170] | 0.530*** [0.168] | 0.549*** [0.166] | 4.465*** [1.157] | 4.418*** [1.144] | 4.326*** [1.119] | 1.162*** [0.286] | 1.168*** [0.282] | 1.194*** [0.277] |
| North West | 1.427*** [0.406] | 1.412*** [0.401] | 1.458*** [0.393] | 4.012*** [0.926] | 3.966*** [0.916] | 3.890*** [0.896] | 0.672** [0.276] | 0.664** [0.273] | 0.664** [0.266] |
| Northern Ireland | 4.304*** [1.561] | 4.253*** [1.543] | 4.164*** [1.508] | 10.503*** [2.140] | 10.323*** [2.122] | 10.149*** [2.075] | 3.982** [1.709] | 3.935** [1.688] | 3.848** [1.649] |
| Scotland | 3.686*** [0.784] | 3.661*** [0.775] | 3.631*** [0.757] | 3.917*** [0.793] | 3.888*** [0.783] | 3.853*** [0.765] | 3.783*** [0.738] | 3.763*** [0.729] | 3.726*** [0.712] |
| South East | 0.459 [0.332] ^a | 0.427 [0.329] ^a | 0.410 [0.322] ^a | 0.083 [0.841] ^a | 0.062 [0.831] ^a | 0.061 [0.812] ^a | 1.091** [0.535] | 1.037* [0.531] ^a | 1.056** [0.518] ^a |
| South West | 0.693** [0.346] | 0.678* [0.342] | 0.673** [0.334] | 0.482 [1.254] ^a | 0.472 [1.239] ^a | 0.496 [1.210] ^a | 1.151** [0.474] | 1.139** [0.468] | 1.148** [0.457] |
| Wales | 0.478*** [0.118] | 0.474*** [0.117] | 0.477*** [0.114] | 1.085*** [0.316] | 1.073*** [0.312] | 1.060*** [0.305] | 0.949*** [0.246] | 0.942*** [0.243] | 0.939*** [0.237] |
| West Midlands | 0.007 [0.069] ^a | 0.005 [0.069] ^a | 0.012 [0.068] ^a | -0.983 [0.721] ^a | -0.976 [0.712] ^a | -0.958 [0.695] ^a | 0.289 [0.258] ^a | 0.283 [0.255] ^a | 0.290 [0.249] ^a |
| Yorkshire and the Humber | 0.874*** [0.226] | 0.866*** [0.223] | 0.884*** [0.219] | 3.422*** [0.717] | 3.396*** [0.709] | 3.334*** [0.694] | 0.825*** [0.220] | 0.815*** [0.218] | 0.822*** [0.213] |
| Aggregate | 0.836** [0.353] | 0.822** [0.349] | 0.809** [0.341] | 0.497** [0.575] ^a | 0.483 [0.568] ^a | 0.471 [0.555] ^a | 0.971** [0.486] ^a | 0.957** [0.480] ^a | 0.949** [0.468] ^a |
| <i>Pre-GFC Sample</i> | | | | | | | | | |
| East Midlands | 1.389 [1.085] ^a | 1.310 [1.059] ^a | 0.767 [1.091] ^a | 6.821*** [1.538] | 6.748*** [1.498] | 5.783*** [1.643] | 2.298* [1.202] ^a | 2.432** [1.176] ^a | 2.281* [1.126] ^a |
| East of England | 1.292* [0.677] | 1.267* [0.659] | 0.967 [0.668] ^a | 2.777*** [0.885] | 2.757*** [0.861] | 2.295** [0.911] | 2.909*** [1.048] | 2.874*** [1.019] ^a | 2.951*** [0.966] |
| London | 0.342 [0.221] | 0.335 [0.216] | 0.287 [0.212] | 1.386* [0.780] ^a | 1.303* [0.763] ^a | 1.211 [0.730] ^a | 3.725*** [1.268] | 3.611*** [1.237] | 3.501*** [1.179] |
| North East | -0.197 [1.408] ^a | -0.072 [1.375] ^a | 0.332 [1.338] ^a | 7.681*** [1.813] | 7.667*** [1.763] | 7.482*** [1.684] | 0.951 [0.935] ^a | 0.951 [0.908] ^a | 0.608 [0.906] ^a |
| North West | -0.095 [0.787] ^a | 0.040 [0.777] ^a | 0.332 [0.767] ^a | 2.485** [0.930] | 2.495** [0.905] | 2.184** [0.890] | 0.071 [0.556] ^a | 0.055 [0.541] ^a | -0.318 [0.587] ^a |
| Northern Ireland | 1.988* [1.003] | 2.012** [0.976] | 2.478** [1.051] | 9.341** [3.949] | 8.931** [3.863] | 12.609** [5.275] | 7.524*** [2.516] | 7.795*** [2.460] | 7.001*** [2.405] |
| Scotland | 2.106** [0.883] | 2.105** [0.859] | 2.168** [0.822] | 2.436* [1.214] | 2.504** [1.182] | 2.063* [1.173] ^a | 4.065** [1.771] ^a | 4.223** [1.729] ^a | 3.623** [1.692] ^a |
| South East | 0.877* [0.434] | 0.855* [0.423] | 0.663 [0.429] ^a | 2.961** [1.160] | 2.952** [1.129] | 2.729** [1.098] | 4.103*** [1.217] | 4.003*** [1.187] | 3.857*** [1.128] |
| South West | 1.107 [0.798] ^a | 1.048 [0.778] ^a | 0.497 [0.850] ^a | 2.775*** [0.749] | 2.777*** [0.728] | 1.880* [1.021] ^a | 2.813** [1.111] ^a | 2.796** [1.080] ^a | 2.836*** [1.022] ^a |
| Wales | -0.062 [0.523] ^a | -0.004 [0.512] ^a | 0.219 [0.512] ^a | 4.851** [1.818] | 4.752** [1.771] | 5.042** [1.697] | 0.640* [0.334] | 0.571* [0.332] | 0.385 [0.349] ^a |
| West Midlands | 0.698 [0.835] ^a | 0.624 [0.816] ^a | -0.007 [0.896] ^a | 3.051** [1.465] ^a | 2.957** [1.428] ^a | 2.658* [1.370] ^a | 1.519* [0.888] ^a | 1.558* [0.864] ^a | 1.757** [0.830] ^a |
| Yorkshire and the Humber | 0.020 [0.515] ^a | 0.063 [0.503] ^a | 0.026 [0.479] ^a | 6.657*** [1.288] | 6.582*** [1.255] | 6.464*** [1.216] | 0.546 [0.333] | 0.505 [0.326] | 0.251 [0.359] |
| Aggregate | -0.321 [0.341] ^a | -0.321 [0.331] ^a | -0.252 [0.318] ^a | 0.569 [0.820] ^a | 0.606 [0.798] ^a | -0.190 [0.990] ^a | 1.952** [0.953] ^a | 1.912** [0.927] ^a | 2.071** [0.886] ^a |
| <i>Post-GFC Sample</i> | | | | | | | | | |
| East Midlands | 0.033 [0.739] ^a | 0.045 [0.723] ^a | 0.025 [0.691] ^a | 6.002*** [1.775] | 5.882*** [1.739] | 5.608*** [1.673] | 2.082*** [0.456] | 2.057*** [0.446] | 1.939*** [0.435] |
| East of England | 0.195 [1.065] ^a | 0.166 [1.041] ^a | 0.077 [0.999] ^a | 7.958*** [2.741] | 7.754*** [2.686] | 7.271*** [2.590] | 3.423*** [1.034] | 3.303*** [1.017] | 2.867*** [1.019] ^a |
| London | 1.466 [1.186] ^a | 1.408 [1.161] ^a | 1.396 [1.110] ^a | 7.541*** [2.629] | 7.336*** [2.577] | 6.854*** [2.487] | 2.529** [1.053] | 2.433** [1.034] | 2.172** [1.005] |
| North East | -0.069 [0.553] ^a | -0.034 [0.541] ^a | -0.037 [0.520] ^a | 4.536** [1.639] | 4.448** [1.604] | 4.29*** [1.538] | 0.475 [0.547] ^a | 0.509 [0.536] ^a | 0.461 [0.515] ^a |
| North West | 0.099 [0.618] ^a | 0.185 [0.610] ^a | 0.206 [0.583] ^a | 4.101*** [1.139] | 4.121*** [1.113] | 3.982*** [1.069] | 2.202*** [0.445] | 2.319*** [0.450] | 2.299*** [0.431] |
| Northern Ireland | 0.292 [2.551] ^a | 0.742 [2.533] ^a | 1.008 [2.429] ^a | 18.462*** [5.152] | 18.372*** [5.034] | 17.645*** [4.840] | 18.788*** [3.015] | 19.570*** [3.048] | 19.656*** [2.920] |
| Scotland | -0.024 [0.328] ^a | -0.009 [0.321] ^a | 0.026 [0.308] ^a | 3.228** [1.174] | 3.210** [1.147] | 3.110** [1.099] | 1.204*** [0.402] | 1.224*** [0.393] | 1.250*** [0.377] |
| South East | 0.423 [1.154] ^a | 0.348 [1.130] ^a | 0.281 [1.082] ^a | 9.114*** [2.911] | 8.797*** [2.862] | 8.270*** [2.761] | 3.322*** [1.107] | 3.098*** [1.105] ^a | 2.703*** [1.092] ^a |
| South West | 0.117 [0.891] ^a | 0.132 [0.871] ^a | 0.078 [0.834] ^a | 8.539*** [3.041] | 8.362*** [2.976] | 7.918*** [2.863] | 1.690*** [0.368] | 1.681*** [0.360] | 1.493*** [0.370] |
| Wales | 0.134 [0.396] ^a | 0.178 [0.389] ^a | 0.198 [0.373] ^a | 4.007*** [1.273] | 3.992*** [1.244] | 3.857*** [1.193] | 1.825*** [0.353] | 1.889*** [0.350] | 1.933*** [0.338] |
| West Midlands | 0.051 [0.726] ^a | 0.103 [0.711] ^a | 0.081 [0.680] ^a | 7.026*** [2.383] | 6.911*** [2.331] | 6.584*** [2.240] | 1.649*** [0.318] | 1.702*** [0.315] | 1.597*** [0.311] |
| Yorkshire and the Humber | 0.073 [0.674] ^a | 0.089 [0.658] ^a | 0.123 [0.630] ^a | 4.153*** [1.193] | 4.081*** [1.168] | 3.942*** [1.121] | 1.458*** [0.302] | 1.451*** [0.295] | 1.456*** [0.285] |
| Aggregate | 0.135 [0.870] ^a | 0.147 [0.850] ^a | 0.107 [0.813] ^a | 5.231*** [1.845] | 5.131*** [1.805] | 4.872*** [1.736] | 2.803*** [0.790] | 2.773*** [0.772] | 2.573*** [0.751] |

Note: The values reported are the Clark and West results that compares the EPU-based models with the benchmark model. The ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively. Positive and significant values indicate that the EPU-based model is preferred to the benchmark model. The superscripted "a" denote cases where the relative RMSE comparison of our predictive model variants with the benchmark is greater than one; denoting that the forecast errors of our predictive model variants are not less than those of the benchmark model (detailed statistics are presented in Table A2, under the appendix) The model with control variables includes one period lag and first differences of output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed EPU, as well as their first differences.

Table 9: Modified Diebold and Mariano test for HPU-based model relative to EPU-based model

| | Without Control Variables | | | With Control Variables | | | Asymmetry Effect | | |
|--------------------------|---------------------------|--------------|--------------|------------------------|--------------|--------------|------------------|--------------|--------------|
| | <i>h</i> = 1 | <i>h</i> = 2 | <i>h</i> = 4 | <i>h</i> = 1 | <i>h</i> = 2 | <i>h</i> = 4 | <i>h</i> = 1 | <i>h</i> = 2 | <i>h</i> = 4 |
| <i>Full Sample</i> | | | | | | | | | |
| East Midlands | 2.666*** | 2.768*** | 2.949*** | 5.360*** | 5.308*** | 5.283*** | 3.462*** | 3.454*** | 3.313*** |
| East of England | 1.028 | 1.136 | 1.234 | 2.416** | 2.432** | 2.438** | -2.008** | -1.805* | -1.487 |
| London | 6.918*** | 6.922*** | 6.933*** | 1.858* | 1.901* | 1.955** | -1.220 | -1.374 | -1.488 |
| North East | 4.204*** | 4.292*** | 4.200*** | 3.566*** | 3.489*** | 3.502*** | 0.161 | 0.220 | 0.313 |
| North West | -8.227*** | -8.227*** | -8.292*** | 2.949*** | 2.822*** | 2.870*** | 6.723*** | 6.359*** | 6.046*** |
| Northern Ireland | -3.535*** | -3.581*** | -3.541*** | 1.046 | 0.968 | 1.054 | -3.830*** | -3.775*** | -3.694*** |
| Scotland | -2.979*** | -3.055*** | -3.176*** | 0.289 | 0.233 | 0.136 | -2.217** | -2.307** | -2.367** |
| South East | 5.613*** | 5.671*** | 5.742*** | -0.690 | -0.673 | -0.516 | 1.521 | 1.558 | 1.401 |
| South West | 4.691*** | 4.748*** | 4.883*** | 4.436*** | 4.410*** | 4.333*** | -4.658*** | -4.377*** | -3.994*** |
| Wales | -0.165 | -0.138 | 0.023 | 3.376 | 3.360 | 3.365 | -2.158** | -2.077** | -1.845* |
| West Midlands | 2.382*** | 2.455*** | 2.591*** | 4.032*** | 4.023*** | 3.823*** | -5.756*** | -5.474*** | -5.299*** |
| Yorkshire and the Humber | -2.526** | -2.500** | -2.709** | 0.505 | 0.537 | 0.518 | -2.465** | -2.270** | -2.225** |
| Aggregate | 3.432*** | 3.456*** | 3.520*** | -0.283 | -0.221 | -0.142 | 3.186*** | 3.155*** | 3.202*** |
| <i>Pre-GFC Sample</i> | | | | | | | | | |
| East Midlands | -4.180*** | -4.286*** | -4.448*** | 3.158*** | 2.955*** | 2.976*** | -5.801*** | -5.778*** | -5.877*** |
| East of England | 2.739*** | 2.746*** | 2.948*** | 1.774* | 1.755* | 1.429 | 0.297 | 0.424 | 0.390 |
| London | 1.805 | 1.947** | 2.306** | -2.468*** | -2.509*** | -1.274 | 4.133*** | 4.130*** | 4.302*** |
| North East | -4.067*** | -4.163*** | -4.245*** | 0.978 | 1.178 | 1.622 | -9.827*** | -9.565*** | -9.545*** |
| North West | -6.187*** | -6.254*** | -6.039*** | -5.055*** | -5.132*** | -5.194*** | -0.144 | -0.195 | -0.422 |
| Northern Ireland | -1.703** | -1.630 | -1.834** | 5.162*** | 4.969*** | 3.120*** | -6.986*** | -6.267*** | -5.290*** |
| Scotland | -2.856*** | -2.856*** | -3.103*** | 2.678*** | 2.730*** | 2.941*** | 1.131 | 1.239 | 0.398 |
| South East | 2.162*** | 2.197** | 2.440*** | 2.009** | 1.961** | 2.121** | 0.153 | 0.339 | 0.705 |
| South West | -5.066*** | -5.152*** | -5.252*** | 3.365*** | 3.433*** | 3.628*** | 1.808* | 1.924* | 1.942* |
| Wales | -3.782*** | -3.893*** | -3.977*** | -1.882* | -2.103*** | -2.436*** | -1.649** | -1.577* | -1.955** |
| West Midlands | -1.169 | -1.314 | -1.524 | 2.821*** | 2.979*** | 3.023*** | -2.688*** | -2.811*** | -3.091*** |
| Yorkshire and the Humber | 5.990*** | 5.779*** | 5.395*** | -1.303 | -1.191 | -1.102 | -2.895*** | -2.925*** | -3.182*** |
| Aggregate | -0.735 | -0.681 | -0.619 | -3.807*** | -3.847*** | -3.754*** | -0.665 | -0.597 | -0.679 |
| <i>Post-GFC Sample</i> | | | | | | | | | |
| East Midlands | 7.006*** | 6.723*** | 6.769*** | 0.160 | 0.236 | 0.304 | 3.669*** | 3.644*** | 3.541*** |
| East of England | 3.895*** | 3.668*** | 3.670*** | 3.024*** | 3.127*** | 3.099*** | 4.079*** | 3.882*** | 3.423*** |
| London | 2.929*** | 2.914*** | 2.898*** | 2.465** | 2.589*** | 2.694*** | 1.691* | 1.831* | 1.933* |
| North East | -1.230 | -1.222 | -0.934 | 0.705 | 0.563 | 0.502 | 2.059** | 2.108** | 1.591 |
| North West | -6.283*** | -6.245*** | -6.178*** | 3.598*** | 3.665*** | 3.602*** | 1.259 | 1.317 | 1.496 |
| Northern Ireland | 6.798*** | 6.600*** | 6.471*** | -5.464*** | -5.386*** | -5.392*** | 2.747*** | 2.888*** | 3.119*** |
| Scotland | -0.286 | -0.204 | 0.027 | 2.616*** | 2.751*** | 2.532** | -2.639*** | -2.696*** | -2.876*** |
| South East | -0.005 | -0.074 | 0.011 | 1.436 | 1.497 | 1.699* | 2.609*** | 2.371** | 2.228** |
| South West | -1.124 | -0.927 | -1.069 | 0.003 | 0.036 | 0.274 | 6.377*** | 6.097*** | 5.956*** |
| Wales | 6.447*** | 6.509*** | 5.944*** | 4.416*** | 4.480*** | 4.452*** | 6.269*** | 6.236*** | 6.332*** |
| West Midlands | 2.278*** | 2.134*** | 2.148** | -2.002** | -2.019** | -1.878* | -3.670*** | -3.304*** | -2.785*** |
| Yorkshire and the Humber | 0.320 | 0.521 | 0.314 | 4.741*** | 4.810*** | 4.883*** | 5.925*** | 5.792*** | 5.674*** |
| Aggregate | 14.115*** | 13.915*** | 13.485*** | 0.142 | 0.238 | 0.276 | 2.903*** | 2.624*** | 2.287** |

Note: For the modified DM test, the null hypothesis of equal forecast accuracy between the HPU- and EPU- based predictive models is rejected if the computed statistic is greater than (in absolute terms) 1.645 (for a two-sided 0.10 test), 1.96 (for a two-sided 0.05 test), and 2.58 (for a two-sided 0.01 test), and are denoted by *, **, and ***, respectively. A rejection of the null hypothesis implies the superior out-of-sample forecast performance of HPU-based predictive model over the stated benchmark model (negative DM statistic) or superior out-of-sample forecast performance of EPU-based predictive model over the stated benchmark model (positive DM statistic), while a non-rejection implies equal forecast accuracy between the paired models.

5. Conclusion

In this study, we test whether uncertainty has predictive contents for real housing returns in the United Kingdom. We utilize both housing price uncertainty (HPU) and economic policy uncertainty (EPU) data and our analyses cover twelve (12) regions namely East Midlands, East of England, London, North East, North West, Northern Ireland, Scotland, South East, South West, Wales, West Midlands, Yorkshire and the Humber. Unlike the aggregate data, the use of regional data and sector-specific uncertainty helps to circumvent any possible aggregation bias and by extension enables us to offer meaningful generalizations about the relationship being examined. We offer a number of scenarios to validate our results. First, for our main analysis involving HPU, we consider three predictive models of real housing returns: (i) the main model with HPU as the only predictor; (ii) an extended model that accounts for relevant covariates in addition to HPU; and (iii) an asymmetric (nonlinear) variant of the main model that accounts for asymmetries in HPU (positive and negative changes in HPU). Second, we consider three data samples namely the full sample (that utilizes all the available data), the pre-GFC sample which predates the global financial crisis and the post-GFC sample which captures its aftermath. Third, we replicate all the analyses for the economic (overall) policy uncertainty (EPU) in order to check the sensitivity of the results to uncertainty coverage and compare the stance of outperformance with the sector-specific policy uncertainty (HPU). Forth, we consider multiple out-of-sample forecast horizons and the outcomes are compared with a benchmark model that ignores the role of uncertainty in the predictive model of real housing returns.

Our results are summarized as follows. First, on the average (i.e. using the full data sample), we find a negative relationship between HPU and real housing returns in the United Kingdom for virtually all the regions examined. In other words, increased uncertainties in the housing market may lower trading in the market and by implication lower housing returns. Second, we find that the model that accounts for HPU outperforms the benchmark model that ignores it. Third, when we controlled for relevant covariates such as real gross domestic product, financial stress index, and mortgage rate, the forecast performance of the HPU-based models improves. Fourth, the outcome of our distinct analyses for the sub-samples, i.e. pre- and post-GFC periods suggests that the out-of-sample predictability of HPU only becomes evident after using recent HPU data (i.e. the post-GFC period) albeit with relevant control variables. Fifth, the outcome of the HPU further reinforces the need to use recent data for improved predictability of HPU for real housing returns.

Put differently, a longer data span that accommodates recent HPU data is encouraged for better forecast outcomes. Finally, we are able to establish that sector-specific uncertainty measure may contain higher predictive contents for house price movements than the aggregate economic policy uncertainty measure.

A possible extension of this paper would be to examine the role of HPU in forecasting housing price volatility, and comparing its performance with EPU, as outlined in Bouri et al., (forthcoming).

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Appendix

Table A1: Relative RMSE results for the HPU-based models

| | Without Control Variables | | | With Control Variables | | | | Asymmetry Effect | | | | |
|--------------------------|---------------------------|---------------|-------|------------------------|-----------|---------------|-------|------------------|-----------|---------------|-------|-------|
| | In-Sample | Out-of-Sample | | | In-Sample | Out-of-Sample | | | In-Sample | Out-of-Sample | | |
| | | $h=1$ | $h=2$ | $h=4$ | | $h=1$ | $h=2$ | $h=4$ | | $h=1$ | $h=2$ | $h=4$ |
| <i>Full Sample</i> | | | | | | | | | | | | |
| East Midlands | 0.926 | 0.926 | 0.925 | 0.921 | 0.911 | 0.912 | 0.912 | 0.910 | 1.013 | 1.013 | 1.013 | 1.014 |
| East of England | 0.920 | 0.922 | 0.923 | 0.922 | 0.895 | 0.900 | 0.904 | 0.904 | 0.899 | 0.899 | 0.897 | 0.891 |
| London | 0.830 | 0.832 | 0.831 | 0.826 | 0.730 | 0.743 | 0.743 | 0.734 | 0.812 | 0.820 | 0.822 | 0.819 |
| North East | 0.973 | 0.972 | 0.971 | 0.969 | 0.811 | 0.811 | 0.811 | 0.810 | 0.932 | 0.932 | 0.931 | 0.928 |
| North West | 0.987 | 0.988 | 0.988 | 0.988 | 0.776 | 0.776 | 0.776 | 0.774 | 0.974 | 0.974 | 0.974 | 0.972 |
| Northern Ireland | 0.967 | 0.967 | 0.967 | 0.967 | 0.804 | 0.804 | 0.806 | 0.807 | 1.073 | 1.072 | 1.072 | 1.072 |
| Scotland | 0.985 | 0.987 | 0.987 | 0.986 | 0.935 | 0.935 | 0.934 | 0.934 | 0.964 | 0.964 | 0.964 | 0.962 |
| South East | 0.902 | 0.903 | 0.904 | 0.903 | 0.887 | 0.892 | 0.894 | 0.890 | 0.921 | 0.926 | 0.929 | 0.930 |
| South West | 0.832 | 0.832 | 0.831 | 0.825 | 0.850 | 0.851 | 0.851 | 0.848 | 0.968 | 0.967 | 0.966 | 0.960 |
| Wales | 0.939 | 0.940 | 0.939 | 0.939 | 0.917 | 0.917 | 0.916 | 0.916 | 0.922 | 0.923 | 0.923 | 0.922 |
| West Midlands | 0.968 | 0.968 | 0.968 | 0.966 | 1.045 | 1.046 | 1.045 | 1.047 | 1.038 | 1.037 | 1.037 | 1.033 |
| Yorkshire and the Humber | 0.986 | 0.986 | 0.986 | 0.986 | 0.844 | 0.844 | 0.842 | 0.842 | 0.965 | 0.964 | 0.963 | 0.962 |
| Aggregate | 0.884 | 0.885 | 0.885 | 0.883 | 0.844 | 0.847 | 0.847 | 0.845 | 0.921 | 0.922 | 0.922 | 0.919 |
| <i>Pre-GFC Sample</i> | | | | | | | | | | | | |
| East Midlands | 1.297 | 1.315 | 1.371 | 1.534 | 0.638 | 0.638 | 0.650 | 0.809 | 1.048 | 1.051 | 1.043 | 1.110 |
| East of England | 0.986 | 0.987 | 0.983 | 0.954 | 0.916 | 0.915 | 0.913 | 0.996 | 0.962 | 0.961 | 0.960 | 0.933 |
| London | 0.892 | 0.894 | 0.903 | 0.905 | 0.872 | 0.868 | 0.874 | 1.081 | 0.813 | 0.868 | 0.897 | 0.956 |
| North East | 0.860 | 0.870 | 0.912 | 1.125 | 0.651 | 0.664 | 0.660 | 0.647 | 1.056 | 1.074 | 1.079 | 1.234 |
| North West | 0.885 | 0.888 | 0.926 | 1.086 | 1.081 | 1.085 | 1.139 | 1.201 | 0.947 | 0.947 | 0.956 | 1.040 |
| Northern Ireland | 1.008 | 1.008 | 1.006 | 1.011 | 0.938 | 0.962 | 0.964 | 0.927 | 1.112 | 1.069 | 1.066 | 1.037 |
| Scotland | 1.009 | 1.007 | 1.004 | 1.057 | 0.871 | 0.876 | 0.873 | 0.885 | 0.936 | 0.966 | 0.962 | 1.081 |
| South East | 0.941 | 0.941 | 0.941 | 0.932 | 0.947 | 0.953 | 0.991 | 0.999 | 0.977 | 0.991 | 0.999 | 0.979 |
| South West | 1.275 | 1.315 | 1.333 | 1.394 | 0.884 | 0.884 | 0.886 | 0.881 | 0.937 | 0.937 | 0.929 | 0.901 |
| Wales | 0.885 | 0.904 | 0.936 | 1.148 | 0.996 | 1.010 | 1.021 | 1.036 | 0.934 | 0.938 | 0.943 | 1.111 |
| West Midlands | 1.067 | 1.095 | 1.132 | 1.289 | 0.823 | 0.822 | 0.817 | 0.813 | 0.930 | 0.925 | 0.949 | 1.065 |
| Yorkshire and the Humber | 1.074 | 1.071 | 1.066 | 1.043 | 0.589 | 0.588 | 0.587 | 0.602 | 0.905 | 0.901 | 0.902 | 0.992 |
| Aggregate | 1.044 | 1.043 | 1.044 | 1.029 | 1.142 | 1.144 | 1.141 | 1.125 | 1.118 | 1.128 | 1.124 | 1.095 |
| <i>Post-GFC Sample</i> | | | | | | | | | | | | |
| East Midlands | 1.073 | 1.072 | 1.075 | 1.079 | 0.633 | 0.639 | 0.644 | 0.659 | 0.775 | 0.784 | 0.797 | 0.823 |
| East of England | 1.068 | 1.076 | 1.090 | 1.098 | 0.481 | 0.498 | 0.507 | 0.552 | 0.867 | 0.916 | 0.955 | 1.050 |
| London | 0.817 | 0.835 | 0.837 | 0.834 | 0.612 | 0.659 | 0.660 | 0.679 | 0.742 | 0.787 | 0.792 | 0.808 |
| North East | 1.109 | 1.109 | 1.110 | 1.112 | 0.768 | 0.770 | 0.771 | 0.775 | 0.862 | 0.871 | 0.870 | 0.898 |
| North West | 1.231 | 1.231 | 1.225 | 1.228 | 0.563 | 0.571 | 0.568 | 0.569 | 0.797 | 0.812 | 0.817 | 0.837 |
| Northern Ireland | 1.143 | 1.137 | 1.126 | 1.121 | 0.507 | 0.504 | 0.502 | 0.500 | 0.578 | 0.596 | 0.592 | 0.609 |
| Scotland | 1.069 | 1.070 | 1.069 | 1.067 | 0.793 | 0.799 | 0.801 | 0.801 | 0.922 | 0.933 | 0.935 | 0.944 |
| South East | 1.015 | 1.026 | 1.036 | 1.040 | 0.462 | 0.506 | 0.540 | 0.560 | 0.911 | 0.966 | 1.023 | 1.087 |
| South West | 1.071 | 1.072 | 1.075 | 1.083 | 0.448 | 0.459 | 0.466 | 0.499 | 0.877 | 0.893 | 0.916 | 0.950 |
| Wales | 1.127 | 1.115 | 1.111 | 1.106 | 0.463 | 0.460 | 0.461 | 0.463 | 0.827 | 0.815 | 0.818 | 0.819 |
| West Midlands | 1.167 | 1.165 | 1.165 | 1.175 | 0.577 | 0.580 | 0.581 | 0.609 | 0.959 | 0.963 | 0.969 | 0.994 |
| Yorkshire and the Humber | 1.229 | 1.226 | 1.228 | 1.232 | 0.671 | 0.671 | 0.675 | 0.676 | 0.803 | 0.806 | 0.819 | 0.825 |
| Aggregate | 1.061 | 1.063 | 1.064 | 1.070 | 0.505 | 0.519 | 0.522 | 0.547 | 0.842 | 0.876 | 0.908 | 0.972 |

Note: The values reported are the relative RMSE results that compares the HPU-based models with the benchmark (restricted) model. Hence, we expect values to be less than one for the HPU-based model to be preferred over the benchmark model. Values greater than one lend support to the benchmark model, while a ratio value of one indicates no relative difference between the two competing (nested) models. The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed HPU data, as well as their first differences.

Table A2: Relative RMSE results for the EPU-based models

| | Without Control Variables | | | | With Control Variables | | | | Asymmetry Effect | | | |
|--------------------------|---------------------------|---------------|---------|---------|------------------------|---------------|---------|---------|------------------|---------------|---------|---------|
| | In-Sample | Out-of-Sample | | | In-Sample | Out-of-Sample | | | In-Sample | Out-of-Sample | | |
| | | $h = 1$ | $h = 2$ | $h = 4$ | | $h = 1$ | $h = 2$ | $h = 4$ | | $h = 1$ | $h = 2$ | $h = 4$ |
| <i>Full Sample</i> | | | | | | | | | | | | |
| East Midlands | 0.994 | 0.994 | 0.994 | 0.993 | 1.116 | 1.118 | 1.118 | 1.120 | 1.016 | 1.016 | 1.016 | 1.017 |
| East of England | 1.004 | 1.006 | 1.008 | 1.009 | 1.140 | 1.144 | 1.148 | 1.147 | 1.006 | 1.008 | 1.011 | 1.011 |
| London | 0.968 | 0.971 | 0.971 | 0.966 | 1.102 | 1.105 | 1.108 | 1.096 | 0.942 | 0.941 | 0.939 | 0.930 |
| North East | 0.975 | 0.975 | 0.975 | 0.973 | 0.811 | 0.812 | 0.812 | 0.812 | 0.945 | 0.944 | 0.944 | 0.941 |
| North West | 0.955 | 0.955 | 0.955 | 0.954 | 0.765 | 0.766 | 0.766 | 0.766 | 0.974 | 0.974 | 0.974 | 0.973 |
| Northern Ireland | 0.957 | 0.958 | 0.958 | 0.957 | 0.843 | 0.843 | 0.846 | 0.847 | 0.954 | 0.954 | 0.954 | 0.954 |
| Scotland | 0.874 | 0.874 | 0.874 | 0.874 | 0.867 | 0.868 | 0.868 | 0.868 | 0.863 | 0.863 | 0.863 | 0.863 |
| South East | 1.002 | 1.005 | 1.007 | 1.008 | 1.106 | 1.105 | 1.106 | 1.105 | 0.997 | 0.999 | 1.004 | 1.000 |
| South West | 0.994 | 0.995 | 0.995 | 0.995 | 1.180 | 1.180 | 1.180 | 1.175 | 0.973 | 0.973 | 0.972 | 0.970 |
| Wales | 0.971 | 0.971 | 0.971 | 0.970 | 0.936 | 0.936 | 0.936 | 0.935 | 0.952 | 0.952 | 0.952 | 0.951 |
| West Midlands | 1.008 | 1.008 | 1.008 | 1.007 | 1.178 | 1.178 | 1.179 | 1.177 | 1.001 | 1.001 | 1.001 | 1.000 |
| Yorkshire and the Humber | 0.954 | 0.954 | 0.954 | 0.951 | 0.805 | 0.805 | 0.804 | 0.804 | 0.960 | 0.960 | 0.960 | 0.958 |
| Aggregate | 0.992 | 0.993 | 0.994 | 0.993 | 1.061 | 1.062 | 1.062 | 1.062 | 1.012 | 1.012 | 1.012 | 1.011 |
| <i>Pre-GFC Sample</i> | | | | | | | | | | | | |
| East Midlands | 1.040 | 1.041 | 1.044 | 1.103 | 0.705 | 0.705 | 0.708 | 0.874 | 1.041 | 1.043 | 1.023 | 1.027 |
| East of England | 0.999 | 0.998 | 0.997 | 1.041 | 0.922 | 0.920 | 0.917 | 0.999 | 1.027 | 1.025 | 1.021 | 0.996 |
| London | 0.983 | 0.983 | 0.983 | 0.990 | 1.014 | 1.025 | 1.042 | 1.060 | 0.963 | 0.971 | 0.972 | 0.970 |
| North East | 1.219 | 1.215 | 1.203 | 1.165 | 0.611 | 0.611 | 0.605 | 0.628 | 1.022 | 1.020 | 1.017 | 1.046 |
| North West | 1.178 | 1.181 | 1.162 | 1.122 | 0.910 | 0.910 | 0.905 | 0.943 | 1.067 | 1.067 | 1.066 | 1.113 |
| Northern Ireland | 0.979 | 0.976 | 0.974 | 0.962 | 0.995 | 0.972 | 0.978 | 0.929 | 0.958 | 0.937 | 0.929 | 0.950 |
| Scotland | 0.945 | 0.943 | 0.940 | 0.932 | 0.990 | 0.989 | 0.986 | 1.015 | 1.129 | 1.138 | 1.143 | 1.173 |
| South East | 0.977 | 0.976 | 0.976 | 1.007 | 0.882 | 0.912 | 0.941 | 0.981 | 0.978 | 0.982 | 0.981 | 0.973 |
| South West | 1.046 | 1.047 | 1.051 | 1.125 | 0.865 | 0.864 | 0.858 | 1.031 | 1.039 | 1.037 | 1.030 | 1.008 |
| Wales | 1.073 | 1.070 | 1.064 | 1.037 | 0.991 | 0.993 | 0.989 | 0.948 | 0.975 | 0.979 | 0.986 | 1.007 |
| West Midlands | 1.118 | 1.121 | 1.127 | 1.213 | 1.094 | 1.100 | 1.099 | 1.109 | 1.058 | 1.053 | 1.042 | 1.005 |
| Yorkshire and the Humber | 1.071 | 1.068 | 1.063 | 1.061 | 0.581 | 0.579 | 0.577 | 0.611 | 0.959 | 0.961 | 0.965 | 0.999 |
| Aggregate | 1.144 | 1.143 | 1.143 | 1.123 | 1.340 | 1.343 | 1.340 | 1.485 | 1.123 | 1.126 | 1.122 | 1.080 |
| <i>Post-GFC Sample</i> | | | | | | | | | | | | |
| East Midlands | 1.164 | 1.163 | 1.166 | 1.175 | 0.643 | 0.653 | 0.662 | 0.681 | 0.836 | 0.844 | 0.858 | 0.887 |
| East of England | 1.130 | 1.137 | 1.148 | 1.158 | 0.547 | 0.572 | 0.590 | 0.637 | 0.913 | 0.951 | 0.984 | 1.062 |
| London | 1.014 | 1.034 | 1.039 | 1.037 | 0.775 | 0.838 | 0.850 | 0.875 | 0.928 | 0.966 | 0.979 | 0.998 |
| North East | 1.133 | 1.132 | 1.133 | 1.138 | 0.831 | 0.835 | 0.834 | 0.836 | 1.085 | 1.088 | 1.091 | 1.100 |
| North West | 1.153 | 1.152 | 1.146 | 1.148 | 0.671 | 0.683 | 0.682 | 0.691 | 0.855 | 0.873 | 0.880 | 0.908 |
| Northern Ireland | 1.206 | 1.200 | 1.187 | 1.184 | 0.476 | 0.475 | 0.473 | 0.476 | 0.709 | 0.755 | 0.771 | 0.838 |
| Scotland | 1.067 | 1.068 | 1.067 | 1.066 | 0.834 | 0.845 | 0.856 | 0.854 | 0.951 | 0.972 | 0.977 | 0.985 |
| South East | 1.134 | 1.145 | 1.154 | 1.159 | 0.589 | 0.647 | 0.687 | 0.727 | 0.929 | 0.975 | 1.018 | 1.081 |
| South West | 1.161 | 1.164 | 1.168 | 1.175 | 0.483 | 0.500 | 0.508 | 0.551 | 0.956 | 0.971 | 0.984 | 1.020 |
| Wales | 1.071 | 1.060 | 1.056 | 1.053 | 0.513 | 0.508 | 0.510 | 0.512 | 0.881 | 0.870 | 0.876 | 0.888 |
| West Midlands | 1.173 | 1.171 | 1.170 | 1.181 | 0.641 | 0.644 | 0.644 | 0.671 | 0.930 | 0.939 | 0.948 | 0.980 |
| Yorkshire and the Humber | 1.171 | 1.169 | 1.172 | 1.171 | 0.748 | 0.753 | 0.764 | 0.767 | 0.902 | 0.905 | 0.919 | 0.932 |
| Aggregate | 1.196 | 1.200 | 1.202 | 1.210 | 0.591 | 0.608 | 0.616 | 0.634 | 0.865 | 0.893 | 0.915 | 0.968 |

Note: The values reported are the relative RMSE results that compares the EPU-based models with the benchmark (restricted) model. Hence, we expect values to be less than one for the EPU-based model to be preferred over the benchmark model. Values greater than one lend support to the benchmark model, while a ratio value of one indicates no relative difference between the two competing (nested) models. The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed EPU data, as well as their first differences.

Table A3: Predictability of HPU for housing returns [Long range Sample (1982Q1 – 2019Q2)]

| | Without Control | With Control | Asymmetry Effect | |
|--------------------------|-------------------|-------------------|-------------------|-------------------|
| | | | Positive | Negative |
| East Midlands | -0.690*** [0.023] | -1.329*** [0.051] | -1.502*** [0.042] | -1.621*** [0.048] |
| East of England | -0.780*** [0.159] | -2.689*** [0.215] | -1.810*** [0.045] | -2.133*** [0.047] |
| London | -2.469*** [0.048] | -3.816*** [0.188] | -2.906*** [0.095] | -2.920*** [0.100] |
| North East | -0.512*** [0.059] | -0.549*** [0.162] | -0.747*** [0.107] | -0.778*** [0.119] |
| North West | -0.313*** [0.045] | 0.041 [0.043] | -0.822*** [0.010] | -0.875*** [0.016] |
| Northern Ireland | -0.774*** [0.124] | -1.136*** [0.065] | -2.104*** [0.118] | -2.223*** [0.122] |
| Scotland | -0.361*** [0.085] | -0.472** [0.215] | -0.945*** [0.111] | -1.005*** [0.116] |
| South East | -1.444*** [0.102] | -1.438*** [0.204] | -1.912*** [0.109] | -2.078*** [0.135] |
| South West | -1.284*** [0.088] | -2.864*** [0.069] | -2.765*** [0.164] | -2.933*** [0.175] |
| Wales | -0.807*** [0.009] | -0.894*** [0.065] | -0.857*** [0.126] | -0.832*** [0.136] |
| West Midlands | -0.433*** [0.023] | -1.016*** [0.142] | -0.306*** [0.062] | -0.315*** [0.062] |
| Yorkshire and the Humber | -0.744*** [0.076] | -1.159*** [0.162] | -2.016*** [0.054] | -2.166*** [0.052] |
| Aggregate | -2.221*** [0.091] | -1.907*** [0.058] | -3.047*** [0.092] | -3.258*** [0.093] |

Note: The reported estimates are the slope coefficients and the corresponding standard error in square brackets associated with the one period lag of HPU-based models. The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed HPU, as well as their first differences. The ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively, where significance indicates a stance of predictability with respect to our HPU-based model is confirmed; otherwise, it's a case of no predictability.

Table A4: Likelihood Ratio Test Results [Long range Sample (1982Q1 – 2019Q2)]

| | Without Control Variables | | | With Control Variables | | | Asymmetry Effect Incorporated | | |
|--------------------------|---------------------------|--------------|------------|------------------------|--------------|-------------|-------------------------------|--------------|------------|
| | Restricted | Unrestricted | LR-Test | Restricted | Unrestricted | LR-Test | Restricted | Unrestricted | LR-Test |
| <i>Full Sample</i> | | | | | | | | | |
| East Midlands | -41.221 | 45.139 | 172.720*** | -60.837 | 77.579 | 276.833*** | -18.162 | 133.473 | 303.268*** |
| East of England | 63.559 | 81.914 | 36.709*** | -48.900 | 27.059 | 151.917*** | -71.778 | 32.718 | 208.992*** |
| London | -101.211 | 3.126 | 208.674*** | -99.054 | 51.394 | 300.896*** | -96.411 | -13.885 | 165.053*** |
| North East | -30.942 | -16.332 | 29.220*** | 37.646 | 105.361 | 135.431*** | -32.982 | -19.123 | 27.717*** |
| North West | -9.504 | 21.014 | 61.037*** | 57.37334 | 115.483 | 116.2194*** | -15.092 | 38.656 | 107.497*** |
| Northern Ireland | -93.090 | -77.557 | 31.066*** | 24.222 | 192.640 | 336.836*** | -82.5466 | -22.19061 | 120.712*** |
| Scotland | -25.812 | -3.998 | 43.628*** | -39.629 | 26.881 | 133.019*** | -45.844 | -13.554 | 64.580*** |
| South East | -54.655 | -19.291 | 70.729*** | -64.151 | 12.048 | 152.398*** | -4.444 | 52.754 | 114.395*** |
| South West | -57.801 | -17.614 | 80.374*** | -164.339 | 7.532 | 343.742*** | -30.053 | 57.276 | 174.658*** |
| Wales | -47.338 | 151.890 | 398.456*** | 74.909 | 223.764 | 297.710*** | -8.762 | 38.993 | 95.510*** |
| West Midlands | 124.808 | 234.990 | 220.364*** | -64.829 | 26.120 | 181.896*** | -1.465 | 60.857 | 124.642*** |
| Yorkshire and the Humber | 59.676 | 87.671 | 55.989*** | -147.172 | 51.155 | 396.655*** | -58.998 | 154.806 | 427.607*** |
| Aggregate | 10.421 | 92.810 | 164.779*** | -41.515 | 100.718 | 284.466*** | -45.000 | 104.090 | 298.181*** |

Note: The reported estimates are the log likelihood of the restricted (historical average) and the unrestricted (HPU-based) models, as well as the likelihood ratio test statistics, which is based on the Chi-Square statistics. The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed HPU data, as well as their first differences. The ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively, where significance indicates preference of the HPU-based model over the restricted benchmark model; otherwise, the latter is preferred over the former.

Table A5: Relative RMSE Results [Long range Sample (1982Q1 – 2019Q2)]

| | Without Control Variables | | | | With Control Variables | | | | Asymmetry Effect | | | |
|--------------------------|---------------------------|---------------|-------|-------|------------------------|---------------|-------|-------|------------------|---------------|-------|-------|
| | In-Sample | Out-of-Sample | | | In-Sample | Out-of-Sample | | | In-Sample | Out-of-Sample | | |
| | | $h=1$ | $h=2$ | $h=4$ | | $h=1$ | $h=2$ | $h=4$ | | $h=1$ | $h=2$ | $h=4$ |
| East Midlands | 0.953 | 0.953 | 0.953 | 0.952 | 0.976 | 0.976 | 0.976 | 0.976 | 0.957 | 0.957 | 0.957 | 0.957 |
| East of England | 0.980 | 0.981 | 0.982 | 0.983 | 0.828 | 0.832 | 0.834 | 0.835 | 0.958 | 0.964 | 0.968 | 0.974 |
| London | 0.871 | 0.872 | 0.871 | 0.867 | 0.759 | 0.763 | 0.762 | 0.759 | 0.891 | 0.892 | 0.892 | 0.889 |
| North East | 0.977 | 0.977 | 0.976 | 0.976 | 0.933 | 0.933 | 0.933 | 0.933 | 0.966 | 0.966 | 0.966 | 0.965 |
| North West | 0.990 | 0.990 | 0.991 | 0.991 | 0.885 | 0.885 | 0.885 | 0.885 | 0.943 | 0.943 | 0.943 | 0.942 |
| Northern Ireland | 0.993 | 0.993 | 0.993 | 0.993 | 0.950 | 0.950 | 0.951 | 0.951 | 0.971 | 0.971 | 0.971 | 0.971 |
| Scotland | 0.993 | 0.994 | 0.994 | 0.993 | 0.989 | 0.989 | 0.989 | 0.989 | 0.981 | 0.981 | 0.982 | 0.981 |
| South East | 0.931 | 0.933 | 0.934 | 0.932 | 0.934 | 0.937 | 0.938 | 0.942 | 0.897 | 0.902 | 0.904 | 0.905 |
| South West | 0.957 | 0.957 | 0.957 | 0.956 | 0.846 | 0.846 | 0.846 | 0.845 | 0.895 | 0.896 | 0.896 | 0.895 |
| Wales | 0.983 | 0.983 | 0.983 | 0.983 | 0.962 | 0.962 | 0.962 | 0.962 | 0.999 | 1.000 | 1.000 | 0.999 |
| West Midlands | 0.979 | 0.979 | 0.979 | 0.978 | 0.899 | 0.899 | 0.899 | 0.899 | 0.993 | 0.993 | 0.993 | 0.992 |
| Yorkshire and the Humber | 0.988 | 0.988 | 0.988 | 0.988 | 0.936 | 0.936 | 0.936 | 0.936 | 1.020 | 1.020 | 1.020 | 1.020 |
| Aggregate | 0.871 | 0.871 | 0.871 | 0.869 | 0.819 | 0.820 | 0.820 | 0.821 | 0.881 | 0.883 | 0.883 | 0.881 |

Note: The values reported are the relative RMSE results that compares the WN-type distributed lag (unrestricted) model with the historical average (restricted) model. Hence, we expect values to be less than one for the WN-type distributed lag model to be preferred over the historical average model. Values greater than one lend support to the historical average model, while a ratio value of one indicates no relative difference between the historical average model and our WN-type distributed lag model. The model with control variables include one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed aggregate economic policy uncertainty, as well as their first differences.

Table A6: Clark and West Results [Long range Sample (1982Q1 – 2019Q2)]

| | Without Control Variables | | | With Control Variables | | | Asymmetry Effect | | |
|--------------------------|---------------------------|------------------|------------------|------------------------|------------------|------------------|------------------|------------------|------------------|
| | $h = 1$ | $h = 2$ | $h = 4$ | $h = 1$ | $h = 2$ | $h = 4$ | $h = 1$ | $h = 2$ | $h = 4$ |
| East Midlands | 0.717*** [0.177] | 0.713*** [0.175] | 0.720*** [0.173] | 1.087** [0.525] | 1.074** [0.521] | 1.070** [0.514] | 1.055** [0.411] | 1.050** [0.408] | 1.039** [0.402] |
| East of England | 0.812** [0.323] | 0.797** [0.320] | 0.775** [0.315] | 3.813*** [0.828] | 3.764*** [0.821] | 3.702*** [0.807] | 1.416*** [0.405] | 1.379*** [0.403] | 1.303*** [0.399] |
| London | 3.594*** [0.615] | 3.581*** [0.611] | 3.643*** [0.605] | 7.196*** [1.403] | 7.150*** [1.394] | 7.174*** [1.375] | 4.330*** [0.781] | 4.309*** [0.776] | 4.346*** [0.766] |
| North East | 0.440** [0.174] | 0.441** [0.173] | 0.445** [0.170] | 1.398*** [0.449] | 1.387*** [0.445] | 1.363*** [0.437] | 0.664*** [0.239] | 0.661*** [0.237] | 0.665*** [0.233] |
| North West | 0.391 [0.270] | 0.387 [0.267] | 0.376 [0.262] | 1.580*** [0.354] | 1.564*** [0.351] | 1.540*** [0.344] | 0.795*** [0.200] | 0.786*** [0.198] | 0.780*** [0.194] |
| Northern Ireland | 1.361 [0.824] | 1.348 [0.818] | 1.325 [0.807] | 5.093*** [1.573] | 5.039*** [1.563] | 5.006*** [1.542] | 2.595*** [0.960] | 2.594*** [0.953] | 2.564*** [0.940] |
| Scotland | 0.245* [0.148] | 0.242 [0.147] | 0.241* [0.145] | 0.597** [0.282] | 0.591** [0.280] | 0.586** [0.276] | 0.588** [0.250] | 0.580** [0.248] | 0.575** [0.245] |
| South East | 1.691*** [0.443] | 1.672*** [0.439] | 1.667*** [0.431] | 2.368*** [0.663] | 2.334*** [0.658] | 2.261*** [0.647] | 1.896*** [0.432] | 1.862*** [0.429] | 1.824*** [0.422] |
| South West | 1.604*** [0.414] | 1.592*** [0.411] | 1.590*** [0.405] | 5.080*** [0.959] | 5.050*** [0.953] | 5.006*** [0.940] | 3.235*** [0.648] | 3.214*** [0.643] | 3.205*** [0.634] |
| Wales | 0.566*** [0.194] | 0.563*** [0.193] | 0.563*** [0.190] | 1.167*** [0.373] | 1.159*** [0.371] | 1.146*** [0.366] | 0.534* [0.283] | 0.531* [0.281] | 0.533* [0.277] |
| West Midlands | 0.448*** [0.129] | 0.445*** [0.128] | 0.450*** [0.126] | 2.273*** [0.556] | 2.255*** [0.552] | 2.228*** [0.545] | 0.280** [0.114] | 0.277** [0.113] | 0.277** [0.112] |
| Yorkshire and the Humber | 0.518** [0.207] | 0.516** [0.206] | 0.515** [0.203] | 3.035*** [0.775] | 3.030*** [0.769] | 2.990*** [0.759] | 0.870 [0.732] | 0.871 [0.727] | 0.878 [0.717] |
| Aggregate | 2.426*** [0.455] | 2.424*** [0.452] | 2.457*** [0.446] | 3.317*** [0.579] | 3.294*** [0.576] | 3.250*** [0.569] | 2.833*** [0.566] | 2.813*** [0.563] | 2.799*** [0.555] |

Note: The values reported are the Clark and West results that compares the HPU-based models with the benchmark model. The ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively. Positive and significant values indicate that the HPU-based model is preferred to the benchmark model. The model with control variables includes one period lag and first differences of real output growth, Financial Stress Index and mortgage rate; while the model with asymmetry effect incorporates one lag each of the positively and negatively decomposed HPU, as well as their first differences.