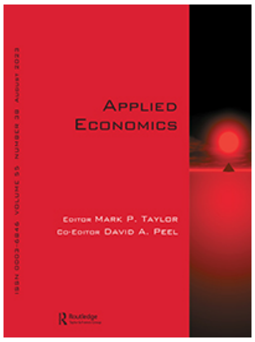

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Daniel Lo, Michael James McCord & Graham Squires

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Regional spillover of housing (un)affordability: an empirical study on the residential housing markets for first-time buyers in the U.K

Daniel Lo[a], Michael James McCord[a] and Graham Squires[b]

[a]Faculty of Computing, Engineering and the Built Environment, Ulster University, Belfast, UK; [b]Department of Property, Lincoln University, Lincoln, New Zealand

ABSTRACT

This study examines the lead–lag relationships between the levels of housing affordability of different regions of the U.K. By utilizing government data, a number of housing affordability indicators are constructed to explore whether spatial diffusion exists between different regional submarkets of first-time homebuyers over the period of 2000 – 2021. The results reveal that during periods of economic expansion, housing unaffordability tended to diffuse from regions of slower economic growth to regions of higher economic development. It is further evident that in the aftermath of the GFC, the London housing market Granger-caused other regional markets in terms of housing (un)affordability. Lastly, the U.K'.s decision to leave the EU in 2016 seems to have led to more divergence between the submarket regions, which in a Granger causal sense, have become less causally correlated in terms of pricing. We conjecture that the causal interactions between the different regional housing submarkets exist with the lead–lag relationships governed primarily by their underlying macroeconomic fundamentals.

KEYWORDS

Affordability; housing market; cointegration; causality; U.K.

JEL CLASSIFICATION

R30

I. Introduction

Housing affordability is now an entrenched global problem that is problematized across geography and concentrated for certain groups of people (Malpezzi 2022). As a concept, housing affordability can be contextualized with changes in housing markets, and in particular, price signals that demonstrate concerns such as house price bubbles which are influenced by housing market behaviours (McMillan and Speight 2010). These occurrences of market 'overheating' can result in differences in terms of regional pricing effects, with some regions overheating in a very different way to other regions and at different rates of change due to their underpinning market structures (Cook 2006; Holmes and Grimes 2008). Further, evidence has suggested that the convergence of housing markets back to equilibrium has tended to be slower in regions that have had some marked overheating (Cook 2003). Indeed, the way in which spatial diffusion of house prices takes place differs across property markets which is governed by the demographic and economic fundamentals and characteristics of the given cities or countries.

Existing empirical literature seems to suggest that spatial arbitrage and economic shocks resulting from the economic imbalances between regions are the most common sources of property price spatial diffusion. In addition, this spatial linkage usually commences from regions of higher economic standing and/or dominance. For instance, Pollakowski and Ray find empirical evidence confirming growth-induced spatial spillover of house prices from New York to neighbouring towns and cities within the Primary Metropolitan Statistical Area of Greater New York. In the context of Western United States, Kuethe and Pede (2011) reveal statistically significant house price response in Arizona, Nevada and Oregon to economic shock arising from higher unemployment levels in California. Similar evidence is also observed in Meen (1999) and Sean, Peasaran, and Takashi (2011) which illustrate how London and the Southeast of England lead the house price cycle of the U.K. through spatial arbitrage and macroeconomic spillovers.

Studies investigating housing market affordability have traditionally all attempted to analyse and define housing affordability applying 'ratio'

CONTACT Daniel Lo d.lo@ulster.ac.uk Faculty of Computing, Engineering and the Built Environment, Ulster University, Belfast BT15 1ED, UK

and 'residual' approaches as identified by the influential work by Stone (2006a, 2006b). This discussion has been expanded within the literature in attempts to more quantitatively measure the affordability paradigm. For example, Mulliner, Smallbone, and Maliene (2013) proffered a more holistic sustainability measure of housing affordability by applying multi-criteria decision-making (MCDM) to simultaneously incorporate location amenity considerations that are economic, social and environmental in nature. In a similar vein, McCord et al. (2016) applied co-integration, Granger causality and impulse response analysis to test the movement and shocks of the key affordability indicators and the two common ratio-based affordability metrics to define the cyclic nature of affordability.

Despite the significant research into and understanding of spatial diffusion and the attempts to measure and define affordability, there remains limited empirical insights into the understanding of housing (un)affordability at the regional level, particularly for first-time buyers (FTBs). Some research has demonstrated that the spatial nature of affordability for FTBs occurs at more peripheral locations than within the urban core (Hong 2013); however, there are limited insights into whether spatial diffusion exists between different regional submarkets in relation to housing affordability indicators. To start to unpack these relationships and diffusion, this research identifies two broad research questions: (1) is there any lead–lag relationships between the housing affordability of different national regions of the U.K. and subset of London and (2) to explore whether spatial diffusion exists between different regional submarkets within the FTB segment of the market. We focus upon the FTB segment of the housing market given the critical importance of FTB oriented policy, arguments that subsidies to FTBs can smooth or stabilize the volatility of the housing market (Lee and Reed 2014) and that FTBs are dependent on the financial viability of land (Kupke and Rossini 2011; Hong 2013). In terms of the affordability debate, FTB support is particularly important given that credit for younger buyers at the lower end of the market can tend to experience constraints relative to mortgage lending and depository requirements (Carozzi 2020).

The article is structured as follows. We first explore the related literature with respect to spatial diffusion of residential real estate. Second, we present an overview of the data used, along with the various tests and models adopted to observe related phenomenon in the case of the national regions of the U.K. and subset of London. Third, we report our empirical findings focusing on some exogenous shocks such as the GFC (2007–08) and Brexit, whilst withholding COVID-19 pandemic (2020) interpretations given the relatively new and irregular observations at the time of publication (Malpezzi 2022). Fourthly, discussion draws on the diffusion debate by considering geography for the first-time buyer variables. In particular, the discussion considers interpreting the cointegration and causality of the first-time buyer variables in space, whilst also inferring any exogenous shocks in time. Finally, the article concludes with a summary and possible recommendations for further research and policy discussion.

II. Literature review

The underlying mechanism through which spatial diffusion of property prices or returns takes place has been subject to both theoretical and empirical scrutiny by a number of studies. Most prominently, Meen (1999) put forward a number of explanations for the occurrence of ripple effects between regional housing markets under the assumption of efficient market hypothesis. Indeed, Meen (1999) suggested that the inter-regional migration of people is driven by differential living conditions between places. When residents from a region (e.g. London) migrate to another region (e.g. the North of England) in search of better and more affordable housing, the housing prices of the latter region would inevitably rise following the migration trend of the residents. In other words, prices would 'spillover' from the first region to the second region over time. The second explanation is related to ownership transfers of real estate. Repeated house purchases by home buyers could result in increases in property prices in neighbouring regions. The spillover of house prices could also take place when property traders look for price differences between regions through spatial arbitrage. When the market is inefficient due to the presence of search costs, informed traders could sell overpriced properties in one region and invest in places where housing assets are underpriced, causing a ripple effect of prices. Fourth, the property prices of two regions of similar levels of economic development and prosperity should move in tandem and converge in the long-run, to the extent that their prices initially diverge in the short-run, meaning that the lagging region will catch up with the leading region in the long-run resulting in the formation of a price 'ripple'. Thirdly, spatial diffusion (or spatial autocorrelation) of property prices, in a microeconomic sense, can take place as a result of the information discovery process of real estate. Lo et al. (2022, 2022) and McCord et al. (2022) have all demonstrated that homebuyers and real estate traders are subject to imperfect market information and have to rely on historical transaction data to infer prices. Such a price determination process would invariably establish linkages between property prices over time and across space with the degree of diffusion or autocorrelation dependent on the levels of liquidity and volatility of the market.

The importance of both fundamental and non-fundamental factors in determining spillovers and synchronicities among real estate markets has been a key area of research in later studies. Clayton et al. (2009) and Ling, Naranjo, and Scheick (2014) both demonstrate that homebuyers' commonly shared sentiments have a crucial role to play in dictating the co-movements of regional house prices. More recently, Agyemang, Chowdhury, and Balli (2021) examined a sample of 18 national property markets over four decades, revealing that the U.K. and the U.S. are the largest transmitters of real estate price signals to other national housing markets, with Italy, Finland and Ireland the heaviest recipients of return shocks. They further illuminated that bilateral trade linkages have a significant positive effect on the level of pairwise return spillovers, whereas positive sentiments about the general economy proxied by consumer confidence mitigate them. This was a similar finding by the study undertaken by de Bandt, Barhoumi, and Bruncau (2010) who also reported evidence of spillovers of return shocks from the U.S. housing market to other OECD countries.

Following the work of Meen (1999) which laid the theoretical foundation of the literature on property price diffusion, numerous investigators have undertaken empirical studies to search for evidence for spatial and temporal convergence/divergence of housing prices and/or rents in the U.K. and elsewhere. For example, Cook (2003) employed a threshold autoregressive model to examine the pricing interactions between different regions in the U.K. based on the assumption of rolling and asymmetric unit roots of the time series. The author observed that the Southeast region experiences more rapid convergence after a downward adjustment of prices, whereas other regions show faster convergence following upswings in prices. In a follow-up study, Cook (2012) applied a generalized least square Dickey–Fuller test in addition to a stationarity test developed by Kwiatkowski et al. (1992) to determine the existence of stationarity for a number of regions in the U.K. The results confirmed the previous research findings determining that spatial diffusion takes place across the regional U.K. housing markets. Following Cook (2012), Holmes (2007) developed a new ratio that takes into consideration housing quality and proposed a novel stationarity test to detect unit roots in the ratio of regional to national property prices. The results suggested that property prices fluctuated over the short-run in most regional markets, but they seemed to converge over a longer time horizon. Further, Sean, Peasaran, and Takashi (2011) revealed using non-stationary dynamic system analysis that spatial and temporal diffusion of house prices is evident in the U.K. with price signals tending to propagate from an economically dominant city such as London to other regions contemporaneously and spatially. Their models allowing for lagged price effects to diffuse back to the dominant region illustrated that the ripple effect was induced by housing demand within a given region and the fashion in which it interacted with prices in neighbouring regions. In addition, it was observed that house prices in the London market, in turn, are influenced heavily by house prices in other international financial centres such as New York.

The interrelationships between different regional markets can indeed be time-varying or dependent on external factors. Miao, Ramchander, and

Simpson (2011) investigated the Case-Shiller Home Indices to explore the intercorrelations between 16 residential markets in the U.S. for a 25-year period. They concluded that the housing markets were more correlated and inter-dependent during the boom period, suggesting that analysis could produce spurious results if the analysis ignores the time dimension or economic cycle of the housing market. Similarly, Pijnenburg (2017) based on a study of 319 cities in the U.S., that spatial spillovers were more pronounced during price increases and less so when property prices of proximal cities were declining. The authors attributed this phenomenon to the effect of disposition, meaning that homeowners and traders are not willing to realize losses which depress the downward adjustment of property prices, hence a subdued level of spatial spillover.

Several other studies have presented empirical evidence that the way in which spatial spillover of house prices occurs is associated with market trading volume. By employing a search model to study the monthly property data of Sweden, Hort (2000) demonstrates that trading volume leads prices by reflecting price information. Similar evidence was also reported by Leung and Feng (2002) who examined the Hong Kong housing market and Clayton, Miller, and Peng (2010) who studied the regional property data of over 100 cities in the U.S. In addition, the literature seems to suggest that the spatial linkage of regional property prices/returns tends to start from regions of higher economic standing and/or dominance. In the context of Australia, Costello, Fraser, and Groenewold (2011) observed significant spatial return spillovers from major capitals to other smaller cities.

The general empirical consensus based on the aforementioned literature is that housing unaffordability has been a matter of great social concern in various regions across the U.K. over the past two decades. Past research has shown that regional spatial diffusion of house prices would affect housing market affordability (Brady 2014); however, this line of research is solely focused on the spatial diffusion of pricing and returns. In light of this, the current study aims to expand on the existing literature by examining the diffusion effect of property pricing in three important ways that diverge from traditional research approaches. First, rather than exploring the spatial diffusion of house prices, rents and returns as typically considered by real estate researchers, we pay exclusive attention to the spatial diffusion of housing (un)affordability. To the best of our knowledge, the present study is the first attempt that investigates whether, and to what extent, housing unaffordability is diffused from one region to another at a national regional level. Secondly, we focus on the first-time buyers' housing market which we contend is one of the most relevant market segments to investigate when addressing the housing shortage problems and affordability issues in practice, particularly in the context of the U.K. Over the past decade housing unaffordability for first-time buyers has been an entrenched social problem of grave concern in the U.K. that has attracted considerable attention of the media, politicians and academics. As policy responses, the U.K. government has introduced and implemented various measures to help FTBs get on the property ladder, including a reduction of stamp duty and a financial scheme known as Help to Buy Individual Saving Account (commonly known as the ISA), through which first-time buyers could obtain a subsidy of up to £3,000 from the government for their first home purchase. Third, echoing other studies (e.g. Cook 2012) which indicate the time-varying nature of spatial diffusion of property pricing, we undertake our study through a split-sample analysis. Cook and Watson (2016) illuminate that since regional housing markets within the U.K. behave differently during different phases of the business cycle, it would be inappropriate to use a single sample combing differing economic phases to examine the ripple effect of regional house prices. In light of this, we examine the interrelationships between the four regional markets by considering three economically and politically distinctive time-periods which we will elucidate further in the next sections.

Recent property research studies have further documented policy effects on the spatial spillover of housing (un)affordability, particularly in the context of Asia. For instance, by using panel dataset of over 270 prefecture cities in China, Li, Qin, and Wu (2020) demonstrated severe housing affordability issues in large metropolitan cities such as Beijing, Shenzhen, Xiamen and Shanghai, which were primarily caused by a shortage of housing supply within the space market and mispricing in the asset market as a result of home purchase restrictions (HPR) imposed by the government. Consequently, housing space consumption in these cities decreases whilst housing prices in surrounding towns and cities escalated, giving rise to a spillover effect of housing affordability. In a similar vein, Zheng, Chen, and Yuan (2021) by adopting the difference-in-differences approach further revealed a strong dynamic spatio-temporal relationship amongst 195 Chinese cities with respect to their housing affordability. More specifically, the HPR policy implemented in several large metropolitan areas was found to result in a 10.3% increase in land prices in neighbouring cities with such causal effects being robust across different statistical model specifications. The authors attributed this phenomenon to the fact that the HPR policy tended to result in a spillover of regulation-induced housing demand to surrounding cities without such restrictions in place, thereby causing an increase in housing prices and land demand through inter-city home purchases.

III. Data and methodology

In this study, Johansen Cointegration and Granger Causality methods are utilized within a bivariate analytical framework to determine, if any, the existence of long-term cointegration and lead–lag linkages between the time series of affordability of the four countries within the U.K. Given its political and economic importance in dictating general market performance and policy direction of the U.K. We further include an additional geographical layer of the London market in our analysis. Yet, it must be caveated that the London market data is a subset of that of the English market.

There are several advantages to our methodological approach. First, Granger Causality can be utilized to infer the direction of information flow between two time series, which is also referred to as directed functional connectivity. Thus, if past values of x can improve the prediction of future values of y, we can conclude that x Granger-causes y (Granger 1969). Secondly, when examined in the context of the error correction model, Granger Causality can be used to detect and quantify the short- and long-term causal correlation between two given time series separately. Within the study, three indicators, namely the Price-to-Income (P-t-I), (ii) Advance-to-Income (A-t-I), and (iii) Price-to-Advance (P-t-A), are investigated using data obtained from official government data derived from the Office for National Statistics, U.K., to measure the degree of housing unaffordability for each constituent country within the U.K., as well as for the aggregate housing market for FTBs over the period of 2000 Q1 to 2021 Q1[1] Indeed, the investigation period chosen in our study is the longest possible that allows us to evaluate the relationships between the time series on the three ratios for all the four regions in the U.K. on a consistent basis, ensuring the highest degree of freedom for our statistical models. In addition, the data is measured on a quarterly basis with a higher (*lower*) value indicating a lower (*higher*) degree of housing (un)affordability.

The time series are subjected to bivariate cointegration tests to determine whether housing affordability in one region is cointegrated with another during the sample period. Granger Causality tests in the framework of Error Correction Model (ECM) are conducted to reveal, if any, both short- and long-term lead–lag relationships between the variables. Spill-over of housing unaffordability is said to be evident if, for instance, one region leads another with respect to any of the three aforementioned indicators in a Granger fashion. Spline analyses are further undertaken for three economically and/or politically distinct subperiods: (a) 2000 Q1 to 2007 Q4, (b) 2008 Q1 to 2016 Q1 and (c) 2016 Q3 to 2021 Q1, which are identified and confirmed with

[1]We accept in the analysis that each of ratios have a very separate and non-mathematical meaning when applied to the reality of the housing market. For instance, the amount of advance households need to save depends on house price changes (e.g. due to the size of deposit required), just as the amount of advance households have also separately depend on the level of income (e.g. to be able to save for the deposit). We therefore accept pure mathematical benefits and drawbacks, in that some ratios involve the same values in the denominators and/or numerators. For instance, the 'Price-to-Income ratio' and 'Advance-to-Income' ratio can obviously indicate affordability in that the lower the denominator relative to the nominator, the more unaffordable the housing market is. However, it seems that the same cannot be applied to the 'Price-to- Advance ratio' in a straightforward way – because the latter is often expressed as a percentage of the former. It is taken in this study that the valuable real and applied nature of each individual ratio is important, and thus we take a less positivist and more grounded theoretical philosophical approach. In short, each ratio is considered for both its numerical sign and what this signifies in the 'real world'..

structural break tests [2] to investigate the effects arising from the Global Financial Crisis (GFC) in 2007/2008 and the U.K.'s decision to depart from the European Union in 2016, both of which are characterized by periods of extreme market volatility and uncertainty.

ADF unit root tests

Since spurious statistical results arising from the presence of unit root of the data might occur if it is not accounted for, we examine the stationarity of the time series by conducting ADF Unit Root tests prior to undertaking further empirical tests (Granger and Newbold 1974). To achieve this, we employ the Augmented Dickey Fuller (ADF) Unit Root Test to test for stationarity of the time series at level, first difference and, where necessary, second difference. The ADF equation is given by:

$$\Delta Y_t = c + \beta T + \emptyset Y_{t-1} + \sum\nolimits_{i=1}^{k} \partial \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

where Y_t is the level of the dependent variable; c is a constant term and T is a linear trend; k represents the number of time periods for achieving white noise based on Schwarz Information Criterion (SIC); and ε_t is a regression residual term.

Cointegration tests

In our study, cointegration techniques developed by Johansen (1991, 1995) are employed to explore whether there is a long-term cointegration relation between a given pair of time series. In line with the analytical framework of Leung, Leong, and Wong (2006), McCord et al. (2019) and Lo et al. (2021, Lo et al. 2022b, 2022a, 2023) for time series of relatively small sample size, as in our case, we apply a bivariate ECM-based regression.

Statistically, the components of a vector V_t are said to be cointegrated of order i, j if V_t is I(1) and a non-zero vector α such that $\alpha' V_t$~I(i – j) where i≥ j > 0 can be observed with α being the cointegration vector. According to Engle and Granger (1987), we can establish whether two $I(1)$ time series, say, X_t and Y_t, are cointegrated in the long run by regressing Y_t on X_t. The regression residual series u_t can then be examined by conducting the ADF test to determine whether it is stationary or not. Accordingly, we can formulate Equation 2 below:

$$Y_t = \alpha + \beta X_t + u_t \quad (2)$$

However, previous studies point out that the regression outcomes of Equation 2 are in some cases sensitive to the choice of the regression specifications, potentially giving rise to statistical inconsistency (Engle and Granger, 1987). In light of this, Johansen (1991) developed a new method to test for cointegration, which considers the following equation:

$$\Delta Y_t = \eta Y_{t-1} + \sum_{i=1}^{k} \tau_i \Delta Y_{t-i} + BX_t + \varepsilon_t \quad (3)$$

where NIL $=\sum_{i=1}^{k} A_i - I$ and $_i$=-$\sum_{j=1+1}^{k} A_j$. Y_t is a k-vector of non-stationary variables that is I(1), whereas X_t represents d-vector deterministic variables. The rank of the coefficient matrix is given by NIL, which shows the number of cointegrating relations within the equation. By estimating NIL in an unrestricted manner, we can establish whether or not the restrictions indicated by the reduced rank of NIL should be rejected (Johansen 1991). Trace statistical tests can then be carried out, which are indeed likelihood ratio tests used to verify the hypothesis that there are at least r cointegrating vectors.

Granger causality test in error correction models (ECMs)

Engle and Granger 1987 suggest that if two time series, say X and Y, are cointegrated over time, their long-term equilibrium should be analysed and interpreted within an ECM framework, which can be represented by Equations 4 and 5 below:

[2] We performed Chow's breakpoint tests on the three unaffordability time series for the four countries in the U.K. as well as the capital city of London, and observed one break for each of these time series. The exact quarter of the break varied slightly for each time series based on F-statistic but took place between 2007Q4-2008Q3. For instance, a structural break occurred at 2008Q1 for P_t_I of London and at 2008Q2 for p_t_A of Scotland. For analytical consistency, we delineated the time series on the same basis according to the defined subperiods in the Methodology Section. It should also be emphasized that statistically speaking, the absence of structural breaks between the second and third subperiods should not affect the empirical robustness of our models.

$$\Delta Y_t = c + + \sum_{i=1}^{r} \alpha_i \Delta Y_{t-i} + \sum_{j=1}^{s} \beta_j \Delta X_{t-j} + \phi z_{t-1} + \varepsilon_t \quad (4)$$

$$\Delta X_t = c + \sum_{i=1}^{r} \alpha_i \Delta X_{t-i} + \sum_{j=1}^{s} \beta_j \Delta Y_{t-j} + \phi z_{t-1} + \varepsilon_t \quad (5)$$

where c is an intercept term. r and s represent the length of time lags that are sufficiently large to make the residual term to be I(0). z_{t-1} is known as the cointegration vector or the error correction (EC) term ($z_{t-1}=Y_{t-1} - w_0 - w_1 X_{t-1} + w_2 t$) representing the long-term equilibrium among the variables. w_1 is the coefficient of X_{t-1}, which indicates the magnitude of long-run elasticity of Y with respect to X (Thomas 1997). t is a linear trend of the sample period with a coefficient of w_2.

An ECM-based Granger causality test can be used to explore both short- and long-run equilibriums and/or temporal dynamics of a given pair of cointegrated time series variables. In Equation (4), the coefficient $\beta_j^{\prime} s$ signals the short-run response of X upon change in Y. On the other hand, z_{t-1} denotes the long run dynamics between the two variables with the coefficient ϕ modelling the pace with which the variables adjust their short-term disequilibrium values towards a longer term equilibrium. Terminologically, ϕ is called the coefficient of adjustment. According to Ghosh (1995), if changes in Y are greater than its long-term average value, the sign of the EC term should be negative. Conversely, the EC term should be positively signed if ΔY_t is below its average value, and ϕ should therefore be negative in order to 'push' Y upward over time.

Lastly, we can explore short-term causal relationship between a given pair of time series variables by using the Wald test. It examines the coefficient restriction on the first difference terms given that the coefficients β_j's implies short-term temporal dynamics between the time series (Toda and Phillips 1993). On the other hand, we can perform a test on the coefficient restriction on the EC term to detect whether lead–lag relationships exist in the long run. Statistically, the null hypothesis of non-Granger causality should not be rejected if ϕ does not significantly deviate from zero (Enders 1995).

IV. Findings

Descriptive statistics

When looking at the descriptive statistics and visualization of the data, we see important trends in the devolved national regions of the U.K., alongside the influence of England's capital city, London (Figure 1). The P-t-I ratio exhibits London to have the highest ratio at almost 5.5 times by 2020. It is particularly interesting to see both England and the U.K. ratios tracking at the same rate throughout the 2000–2021 time series. Similarly, Scotland and Wales display similar trends over the time series. Northern Ireland trends are the most cross-cutting, with a rise in the P-t-I ratio rising to almost 5 times, and the highest of all devolved nation-regions plus London by 2007. This exponential increase was followed by a continual fall in Northern Ireland to the lowest affordability ratio (3.5) by 2021. Post 2007–08 GFC, there is a notable divergence of groupings around (1) London, (2) England/U.K., (3) Scotland/Wales/Northern Ireland. Further, the 2016 post-Brexit (British Exit of the European Union Referendum Result on 23rd June 2016), there appears more uniform upward trends in the P-t-I ratios.

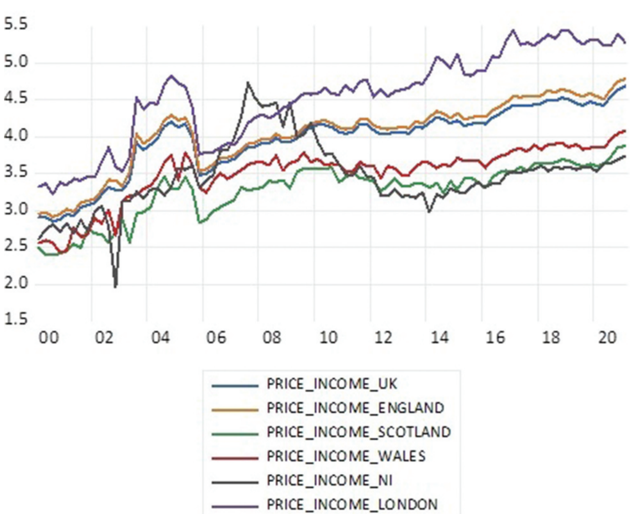

Figure 1. Price to Income Ratios (2000Q1-2021Q1).

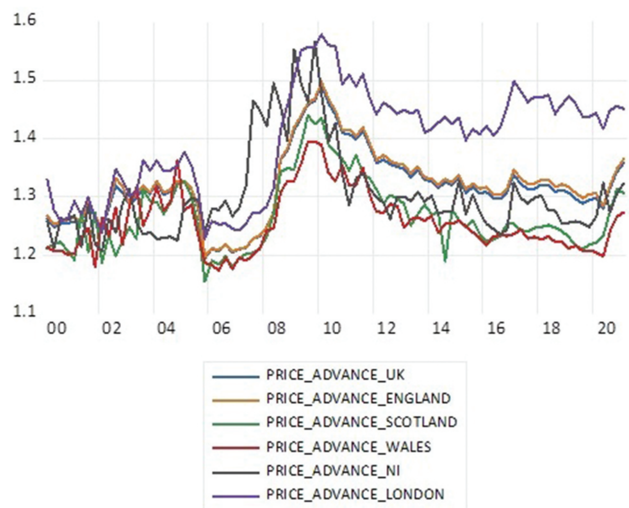

Figure 2. Price to Advance Ratios (2000Q1-2021Q1).

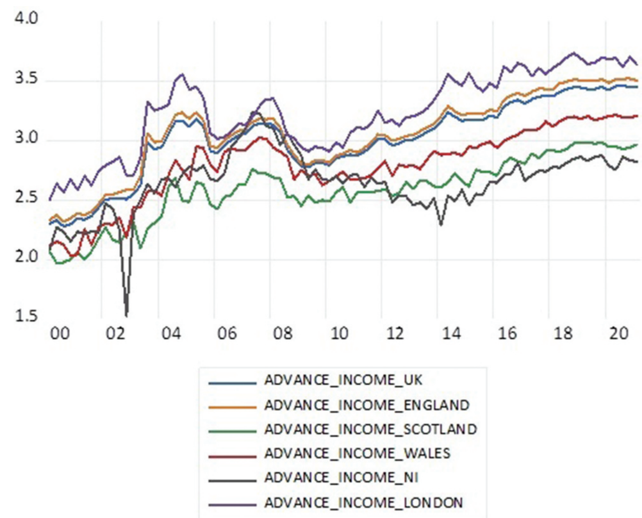

Figure 3. Advance to Income Ratios (2000Q1-2021Q1).

Observation of the P-t-A (Equity including Deposits) exhibits similar clustering around (i) London, (ii) England/U.K., (iii) Scotland/Wales/ Northern Ireland (Figure 2). However, it is noteworthy that the P-t-A ratios reached their highest point during the 2007-08 Global Financial Crisis (GFC), followed by a gradual decline until the 2016 Brexit period. Interestingly, there was an upward spike in ratios during this period, and another significant increase occurred with the onset of the COVID-19 pandemic in early 2020. For Wales, there has been a more consistent, albeit lower P-t-A ratio that has generally been sitting at 1.2 to 1.3 times house prices, indicating that equity advance including equity-deposit have averaged at 20% to 30% of house prices. In contrast, Northern Ireland P-t-A trends displayed an upward trajectory from 2004 to 2010 and pertinently moving from the lowest (1.22) to highest ratio (1.56) respectfully. Of further significance, is that in the environment post-GFC from 2010, and particularly 2016 onwards, there is a discernible divergence, or separation, between London with the other U. K. regions which have exhibited increased convergence or clustering. The London region has displayed a consistent P-t-A ratio above 1.40, whereas the remaining U.K. and devolved nation-regions have shown more elongated declines and variability in their ratios which have more generally ranged between 1.20 and 1.35.

The Advance-to-Income ratios are less volatile in the post-GFC setting, with trends in all devolved nation-regions following a similar trajectory, with the slight exception of Northern Ireland which continued to show a decline until 2014, whereas the remaining regions noting small gradual increases in their respective ratios (Figure 3). Invariably, London retains highest A-t-I ratio following the rationale that the proportion of incomes taken up in equity-deposit contributions for buyers is in the location with the highest house prices. The second highest A-t-I ratio is seen in England followed by Wales, Scotland and Northern Ireland, respectively. An interesting observation shows London and Northern Ireland over this period to have more volatility in their A-t-I ratios relative to the other regions. This dynamism in both these regions is particularly interesting and points towards the impacts of the GFC (2007–08) and its aftermath and the Brexit (2016) referendum, in essence financial and political shocks to the housing markets do have a more variable effect in these particular regions.

ADF unit root and cointegration

The main results of the ADF analysis are presented in Table 1. It is observed that all of the time series are non-stationary at level and stationary at first difference for all time periods. Hence, we treat them as $I(1)$ in the subsequent parts of the empirical examination in line with Granger and Newbold (1974).

Table 1. Summary of the results of ADF Tests 2000Q1-2021Q1.

	Price to Income	Price to Advance	Advance to Income
U.K.	Stationary at first difference	Stationary at first difference	Stationary at first difference
England	Stationary at first difference	Stationary at first difference	Stationary at first difference
Wales	Stationary at first difference	Stationary at first difference	Stationary at first difference
Scotland	Stationary at first difference	Stationary at first difference	Stationary at first difference
Northern Ireland	Stationary at first difference	Stationary at first difference	Stationary at first difference
London	Stationary at first difference	Stationary at first difference	Stationary at first difference

All model specifications include a constant term and a time trend with results determined by the 95% confidence interval. Full results (including results for the subperiods) are available upon request.

The results of the cointegration tests on each pair of time series for each time period/subperiod are determined based on the trace statistics as well as the eigenvalues[3] The findings exhibit all pairs of affordability series for the four constituent regions (countries) of the U.K. and London sub-set are cointegrated at the 5% level of statistical significance, and the results remain the same across all time subperiods examined. In other words, there exists strong empirical evidence confirming that time series are moving in tandem in the long term. Hence, it should be statistically likely that the variables are temporally inter-related by one or more unidirectional Granger causal links.

Granger causality tests in the ECM

Given that all pairs of the time series display cointegration over the sample period, Granger Causality tests are conducted using ECM to detect whether any long-term lead–lag relationships exist. Wald exogeneity tests are also employed to examine causality over the short term. In total, 240 Granger causality models are developed with each exploring the lead–lag associations between two given affordability time series over a specific time period or subperiod. More specifically, Models 1 to 60 (Table 2), Models 61–120 (Table 3), Models 121 to 180 (Table 4) and Models 181 to 240 (Table 5) study the time periods of 2000 Q1 to 2021 Q1; 2000 Q1 to 2007 Q4; 2008 Q1 to 2016 Q1; and 2016 Q1 to 2021 Q1, respectively. For example, Model 1 and Model 2 investigate the Granger causal relationship between the P-t-I ratios of England and Scotland for the period of 2000 to 2021, whereas Model 239 and Model 240 examine the A-t-I ratios of Northern Ireland and London for the subperiod of 2016 Q2 to 2021 Q1. For brevity, we only report the findings on the Chi-square statistics of the Wald tests and *t*-statistics of the Granger causality equations.

The Granger Causality analysis shows a number of noteworthy and interesting results, which are determined by the 5% level of statistical significance. First, over the entirety of the sample period, the four national regions of the U.K. and the London subset seem to be causally correlated with respect to their P-t-I ratios in either short or long term. For instance, England leads Scotland and Wales in the short term but lags behind Northern Ireland (Models 1, 3 and 5), whereas Scotland and Northern Ireland display a bi-directional causal relationship over the short-term time horizon (Model 9). London is a leading indicator for Scotland but a lagging indicator for Northern Ireland in terms of the P-t-I ratio in the short-run (Models 15 and 19). Second, the long-term lead–lag relationships between the four national regions seem to suggest that housing unaffordability appears to spatially diffuse from national regions of lower economic standing to national regions of higher economic development. For example, it is evident that the long-term causal pathways for the P-t-I ratio emanate from Scotland to England (Model 2); Wales to England (Model 4); Wales to Scotland (Model 8); Northern Ireland to England, Scotland, Wales and London (Models 6, 10, 12 and 20). This seemingly suggests that housing unaffordability for FTBs takes place in less developed regions initially with spill-over effects evident to more developed markets over time.

Third, the results for the other two affordability indicators, namely the P-t-A and the A-t-I ratios, appear to be more empirically ambiguous with fewer models displaying statistically significant findings. Nonetheless, it is

[3]The results are available upon request..

Table 2. Results of Granger Causality (2000Q1-2021Q1).

	Price to Income		Price to Advance		Advance to Income	
	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)
	Models 1 & 2		Models 21 & 22		Models 41 & 42	
England → Scotland	15.03948	−0.830510	3.237575	2.478870	5.042479	4.711878
	(0.00)***	(0.41)	(0.19)	(0.02)**	(0.08)*	(0.00)***
Scotland → England	2.233999	−2.947095	4.893601	−0.617026	4.578976	1.970503
	(0.33)	(0.00)***	(0.09)*	(0.54)	(0.10)	(0.05)*
	Models 3 & 4		Models 23 & 24		Models 43 & 44	
England →Wales	8.575745	−0.223452	2.039356	1.813524	12.91848	3.889637
	(0.01)**	(0.82)	(0.36)	(0.07)*	(0.00)***	(0.00)***
Wales→ England	1.729104	−2.824353	1.765082	−1.234506	1.070612	−0.024708
	(0.42)	(0.00)***	(0.41)	(0.22)	(0.58)	(0.98)
	Models 5 & 6		Models 25 & 26		Models 45 & 46	
England → N.I.	0.454506	−0.886329	19.06376	−4.402278	1.703093	−1.573254
	(0.80)	(0.38)	(0.00)***	(0.00)***	(0.4268)	(0.12)
N.I. → England	10.95779	−3.031600	1.142854	−2.678160	29.53378	−4.309772
	(0.00)**	(0.00)***	(0.56)	(0.00)***	(0.00)***	(0.00)***
	Models 7 & 8		Models 27 & 28		Models 47 & 48	
Scotland → Wales	27.91991	−1.112672	5.182765	1.403081	4.449590	0.653739
	(0.00)***	(0.27)	(0.07)*	(0.16)	(0.11)	(0.52)
Wales → Scotland	3.041871	−3.316577	1.177299	−2.802407	6.773060	−4.180057
	(0.22)	(0.00)***	(0.56)	(0.01)***	(0.03)**	(0.00)**
	Models 9 & 10		Models 29 & 30		Models 49 & 50	
Scotland → N.I.	7.308454	−0.557765	9.338032	−2.354592	0.466619	2.811591
	(0.03)**	(0.5787)	(0.00)***	(0.02)**	(0.79)	(0.00)***
N.I. → Scotland	7.182920	−3.250633	2.666294	−3.987796	7.052512	−1.749979
	(0.03)**	(0.00)***	(0.26)	(0.00)***	(0.03)**	(0.08)*
	Models 11 & 12		Models 31 & 32		Models 51 & 52	
Wales → N.I.	0.480161	0.092646	8.008668	−2.278809	3.218799	4.159310
	(0.79)	(0.93)	(0.02)**	(0.03)**	(0.20)	(0.00)***
N.I. → Wales	0.557050	−2.193219	0.232051	−2.810123	7.865766	2.567119
	(0.76)	(0.03)**	(0.89)	(0.01)***	(0.02)**	(0.01)**
	Models 13 & 14		Models 33 & 34		Models 53 & 54	
England → London.	3.314755	3.089432	0.974238	2.747651	6.159331	2.814452
	(0.19)	(0.00)***	(0.61)	(0.01)***	(0.04)**	(0.01)***
London → England	0.676298	2.945743	3.068179	1.972076	0.060804	1.097560
	(0.71)	(0.00)***	(0.22)	(0.05)*	(0.97)	(0.28)
	Models 15 & 16		Models 35 & 36		Models 55 & 56	
Scotland → London.	2.564218	−3.214754	1.383478	1.349152	1.660409	1.559293
	(0.28)	(0.00)***	(0.50)	(0.18)	(0.44)	(0.12)
London → Scotland	9.507665	−2.707415	3.212613	3.212613	0.373940	−2.581222
	(0.01))***	(0.04)**	(0.20)	(0.04)**	(0.83)	(0.01)**
	Models 17 & 18		Models 37 & 38		Models 57 & 58	
Wales → London.	4.976049	3.263691	1.114504	1.917098	1.799287	2.323821
	(0.08)*	(0.00)***	(0.57)	(0.06)*	(0.41)	(0.02)**
London → Wales	3.707771	0.825323	4.506793	−1.626221	0.832399	−2.077818
	(0.16)	(0.41)	(0.11)	(0.11)	(0.44)	(0.04)**
	Models 19 & 20		Models 39 & 40		Models 59 & 60	
N.I → London.	14.20591	−3.126469	2.580068	3.064365	30.57878	−4.213625
	(0.00)***	(0.00)***	(0.27)	(0.00)***	(0.00)***	(0.00)***
London → N.I.	0.297739	−1.486689	17.35111	4.147035	0.001117	−0.785280
	(0.86)	(0.14)	(0.00)***	(0.00)***	(0.99)	(0.42)

'*', '**' and '***' indicate statistical significance at the 10%, 5% and 1%, respectively. Full results are available upon request.

observed that the P-t-A ratios of England and Northern Ireland are causally correlated in a bi-directional fashion (Model 26) and Wales and Northern Ireland lead Scotland in the long-run (Models 28 and 30). In relation to the A-t-I ratio, it is also worth noting that over the longer time horizon, Northern Ireland is a leading indicator for England and London (Models 46 and 60), with Scotland Granger-caused by both Wales and London (Models 48 and 56), whereas London Granger-causes Wales (Model 58).

Spline analysis

Subperiod: 2000 Q1 to 2007 Q4 (Table 3)

The first subperiod is largely characterized by a steady and robust economic growth, low

Table 3. Results of Granger Causality (2000Q1-2007Q4).

	Price to Income		Price to Advance		Advance to Income	
	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)
	Models 61 & 62		Models 81 & 82		Models 101 & 102	
England → Scotland	1.030085	2.937848	2.788930	3.012588	3.455212	3.634293
	(0.60)	(0.01)***	(0.24)	(0.00)***	(0.17)	(0.00)**
Scotland → England	4.011855	1.414460	4.612555	0.899326	3.90278	1.794741
	(0.13)	(0.17)	(0.09)*	(0.37)	(0.14)	(0.09)*
	Models 63 & 64		Models 83 & 84		Models 103 & 104	
England →Wales	6.452123	4.697363	0.734572	0.889765	8.329047	5.651116
	(0.04)**	(0.00)***	(0.69)	(0.38)	(0.0155)**	(0.00)***
Wales→ England	0.563006	0.281182	2.535629	−2.627729	3.687533	2.077412
	(0.75)	(0.78)	(0.28)	(0.02)**	(0.16)	(0.05)**
	Models 65 & 66		Models 85 & 86		Models 105 & 106	
England → N.I.	1.256425	−2.477477	3.492289	−1.963258	1.583023	−3.477236
	(0.53)	(0.02)**	(0.17)	(0.06)*	(0.45)	(0.00)***
N.I. → England	18.29027	−3.002323	2.445576	−2.1818	21.71025	−2.881804
	(0.00)***	(0.00)***	(0.29)	(0.04)**	(0.00)***	(0.01)***
	Models 67 & 68		Models 87 & 88		Models 107 & 108	
Scotland → Wales	2.622996	0.691437	5.354501	−0.666682	2.467976	2.125491
	(0.27)	(0.50)	(0.07)*	(0.51)	(0.29)	(0.04)**
Wales → Scotland	4.227458	−2.096464	5.496665	−3.876023	2.315077	−1.125173
	(0.07)*	(0.05)**	(0.06)*	(0.00)***	(0.31)	(0.27)
	Models 69 & 70		Models 89 & 90		Models 109 & 110	
Scotland → N.I.	5.828832	−1.563790	3.479246	−1.686635	5.929248	−4.030420
	(0.05)*	(0.13)	(0.18)	(0.11)	(0.05)***	(0.00)***
N.I. → Scotland	4.988704	−2.339561	3.237695	−1.868842	6.208219	−0.312391
	(0.08)*	(0.03)***	(0.20)	(0.08)*	(0.04)**	(0.76)
	Models 71 & 72		Models 91 & 92		Models 111 & 112	
Wales → N.I.	0.979446	−2.609573	2.304803	−1.637988	0.91252)1	−3.336258
	(0.61)	(0.02)**	(0.32)	(0.11)	(0.6336)	(0.00)***
N.I. → Wales	3.343695	−2.037117	3.282557	−1.709042	4.839380	−2.264232
	(0.19)	(0.05)**	(0.19)	(0.10)	(0.09)*	(0.03)**
	Models 73 & 74		Models 93 & 94		Models 113 & 114	
England → London.	5.863515	3.427652	3.170708	1.602440	1.508122	2.957546
	(0.05)***	(0.00)***	(0.2049)	(0.12)	(0.47)	(0.00)***
London → England	4.697498	2.375732	2.183143	0.554894	2.760404	1.903950
	(0.09)*	(0.0.3)**	(0.36)	(0.58)	(0.25)	(0.07)*
	Models 75 & 76		Models 95 & 96		Models 115 & 116	
Scotland → London.	2.469397	−0.298693	0.822726	0.318011	0.196689	0.009453
	(0.29)	(0.77)	(0.66)	(0.75)	(0.91)	(0.99)
London → Scotland	0.593147	−2.505424	2.993830	−2.633747	2.378701	−3.461091
	(0.74)	(0.02)**	(0.22)	(0.02)**	(0.30)	(0.00)***
	Models 77 & 78		Models 97 & 98		Models 117 & 118	
Wales → London.	0.628695	0.783641	7.203713	4.216753	1.180648	−1.121370
	(0.73)	(0.44)	(0.03)**	(0.00)***	(0.55)	(0.27)
London → Wales	3.668156	−3.196359	0.809252	−0.123449	6.587318	−4.758971
	(0.16)	(0.00)***	(0.67)	(0.90)	(0.04)**	(0.00)***
	Models 79 & 80		Models 99 & 100		Models 119 & 120	
N.I → London.	23.22350	−2.985683	1.023335	−2.067976	21.07904	−2.523244
	(0.00)***	(0.00)***	(0.60)	(0.05)**	(0.00)***	(0.02)**
London → N.I.	0.785693	−2.440035	3.668775	−2.181410	1.150693	−3.444530
	(0.68)	(0.02)**	(0.16)	(0.04)**	(0.56)	(0.00)***

'*', '**' and '***' indicate statistical significance at the 10%, 5% and 1%, respectively. Full results are available upon request.

unemployment levels, higher interest rates and a relatively low degree of political uncertainty across the four constituent countries in the U.K. The results for the long-term Granger causation of the P-t-I ratios indicate that Northern Ireland is a leading indicator for the three other regions as well as for London (Models 66, 70, 72 and 80). The findings show Wales and London to Granger-cause Scotland (Models 68 and 76) and it is also revealed that bi-directional causal relationships are found between Northern Ireland and London (Model 80), as well as between Wales and Northern Ireland (Model 72). Similar results are evident for the P-t-A and A-t-I indicators. For instance, Granger causal links are observed to run from Northern Ireland to England, Wales and London

Table 4. Results of Granger Causality (2008Q1-2016Q1).

	Price to Income		Price to Advance		Advance to Income	
	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)
	Models 121 & 122		Models 141 & 142		Models 161 & 162	
England → Scotland	4.212591	0.866781	0.353637	3.270569	0.930107	−3.372931
	(0.12)	(0.40)	(0.84)	(0.00)***	(0.63)	(0.00)***
Scotland → England	1.476671	−2.457828	0.979477	−1.616967	4.213941	4.213941
	(0.48)	(0.02)**	(0.61)	(0.12)	(0.12)	(0.03)**
	Models 123 & 124		Models 143 & 144		Models 163 & 164	
England →Wales	0.371542	−0.988451	2.045535	0.947811	9.892882	5.246679
	(0.83)	(0.33)	(0.36)	(0.35)	(0.00)***	(0.00)***
Wales→ England	1.045369	−2.412740	3.421258	−2.480267	7.269265	2.703215
	(0.59)	(0.02)**	(0.18)	(0.02)**	(0.03)***	(0.01)**
	Models 125 & 126		Models 145 & 146		Models 165 & 166	
England → N.I.	5.858087	−1.246261	25.09495	2.034954	3.420729	0.808804
	(0.05)*	(0.23)	(0.00)***	(0.05)*	(0.1808)	(0.43)
N.I. → England	0.444283	−2.530977	0.367604	−2.180226	0.708200	−3.394555
	(0.80)	(0.02)**	(0.83)	(0.04)**	(0.70)	(0.00)***
	Models 127 & 128		Models 147 & 148		Models 167 & 168	
Scotland → Wales	2.056188	1.475583	1.663951	−0.509137	9.690758	−3.660330
	(0.36)	(0.15)	(0.44)	(0.62)	(0.00)***	(0.00)***
Wales → Scotland	1.204949	−1.580007	4.695900	−3.971485	10.21841	−3.624583
	(0.55)	(0.13)	(0.09)*	(0.00)***	(0.01)**	(0.00)***
	Models 129 & 130		Models 149 & 150		Models 169 & 170	
Scotland → N.I.	4.926506	−0.703043	6.824584	−0.936827	1.297272	0.580500
	(0.09)*	(0.49)	(0.03)**	(0.36)	(0.52)	(0.57)
N.I. → Scotland	0.862815	−2.632529	0.307221	−3.751663	1.527132	−4.161297
	(0.65)	(0.02)**	(0.86)	(0.00)***	(0.47)	(0.00)***
	Models 131 & 132		Models 151 & 152		Models 171 & 172	
Wales → N.I.	1.244696	−0.385105	13.12339	−0.732478	0.157160	−0.147689
	(0.54)	(0.70)	(0.00)***	(0.47)	(0.92)	(0.88)
N.I. → Wales	4.385282	−3.425)701	0.926090	−3.577789	3.791230	5.007808
	(0.11)	(0.00)***	(0.63)	(0.00)***	(0.15)	(0.00)***
	Models 133 & 134		Models 153 & 154		Models 173 & 174	
England → London.	1.041918	−0.001096	0.362975	1.055342	4.308726	−0.478732
	(0.59)	(0.99)	(0.83)	(0.30)	(0.12)	(0,64)
London → England	6.363129	2.559169	0.638989	−1.148030	2.775485	−2.964773
	(0.04)**	(0.02)**	(0.73)	(0.26)	(0.25)	(0.00)***
	Models 135 & 136		Models 155 & 156		Models 175 & 176	
Scotland → London.	0.545167	−0.181415	3.426867	2.787024	3.158396	−0.864109
	(0.76)	(0.86)	(0.18)	(0.01)**	(0.21)	(0.40)
London → Scotland	0.242718	−2.651653	0.173162	−3.245367	0.093392	−3.390227
	(0.89)	(0.01)**	(0.92)	(0.00)***	(0.95)	(0.00)***
	Models 137 & 138		Models 157 & 158		Models 177 & 178	
Wales → London.	0.163012	1.076209	7.547009	3.684639	3.315555	−1.421746
	(0.92)	(0.29)	(0.02)**	(0.00)***	(0.19)	(0.17)
London → Wales	0.701213	−2.572418	3.749589	−1.500170	8.010147	−5.565050
	(0.70)	(0.02)**	(0.15)	(0.15)	(0.02)**	(0.00)***
	Models 139 & 140		Models 159 & 160		Models 179 & 180	
N.I → London.	0.214155	0.034751	3.145910	4.241969	3.314819	0.086875
	(0.90)	(0.97)	(0.21)	(0.00)***	(0.19)	(0.41)
London → N.I.	2.274022	−2.037979	16.09206	−0.785795	0.086875	−3.340930
	(0.32)	(0.05)**	(0.00)***	(0.44)	(0.96)	(0.00)***

'*', '**' and '***' indicate statistical significance at the 10%, 5% and 1%, respectively. Full results are available upon request.

(Models 106, 112 and 120), with bi-directional lead–lag associations found between Northern Ireland and London (Model 120), Wales and Northern Ireland (Model 112) and England and Northern Ireland in the long-term (Model 106). However, the statistical patterns for the short-term Granger causal relationships are less clear, particularly for the P-t-A ratio.

Subperiod: 2008 Q1 to 2016 Q1 (Table 4)

This subperiod, which began with the market turbulence stemming from the GFC followed by the gradual economic and housing market recovery, can perhaps be distinguished from the other two subperiods by a higher degree of price volatility, reduced consumer confidence, contracted trading volume in real estate and the increase in money supply as a result of

Table 5. Results of Granger Causality (2016Q2-2021Q1).

	Price to Income		Price to Advance		Advance to Income	
	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)	Short-term Chi. Sq (Prob)	Long-term t-statistic (Prob)
	Models 181 & 182		Models 201 & 202		Models 221 & 222	
England → Scotland	1.112428	0.327927	2.052377	0.467440	13.61717	3.575680
	(0.57)	(0.75)	(0.36)	(0.65)	(0.00)***	(0.00)***
Scotland → England	1.020851	−2.342149	1.640329	−3.735995	0.028391	0.303146
	(0.60)	(0.04)**	(0.44)	(0.00)***	(0.99)	(0.77)
	Models 183 & 184		Models 203 & 204		Models 223 & 224	
England →Wales	9.694747	−2.042805	1.234304	−0.904359	1.518797	0.228939
	(0.00)***	(0.07)*	(0.5395)	(0.39)	(0.4679)	(0.8235)
Wales→ England	42.55952	−4.003764	7.617950	−4.150353	15.68767	−3.558265
	(0.00)***	(0.00)***	(0.02)**	(0.00)***	(0.00)***	(0.01)**
	Models 185 & 186		Models 205 & 206		Models 225 & 226	
England → N.I.	0.087068	1.061225	17.07218	−3.492808	7.140329	5.701927
	(0.96)	(0.31)	(0.00)***	(0.00)***	(0.03)**	(0.00)
N.I. → England	1.134724	−1.895736	2.457984	−2.361971	2.675118	1.314405
	(0.57)	(0.09)*	(0.29)	(0.04)**	(0.26)	(0.22)
	Models 187 & 188		Models 207 & 208		Models 227 & 228	
Scotland → Wales	0.092805	2.207866	1.235041	2.628836	5.721086	0.097538
	(0.95)	(0.05)*	(0.54)	(0.03)**	(0.06)*	(0.92)
Wales → Scotland	1.218913	−1.376786	1.041044	1.154261	5.638733	−4.058108
	(0.54)	(0.20)	(0.59)	(0.28)	(0.06)*	(0.00)***
	Models 189 & 190		Models 209 & 210		Models 229 & 230	
Scotland → N.I.	0.092805	2.207866	22.14405	−3.967390	3.412766	3.225126
	(0.95)	(0.05)*	(0.00)***	(0.00)***	(0.18)	(0.01)***
N.I. → Scotland	1.218913	−1.376786	10.53366	2.010753	4.344316	0.836255
	(0.54)	(0.20)	(0.00)***	(0.07)*	(0.11)	(0.42)
	Models 191 & 192		Models 211 & 212		Models 231 & 232	
Wales → N.I.	0.807486	2.389408	14.95570	−3.473195	5.451162	5.386293
	(0.67)	(0.04)**	(0.00)***	(0.00)***	(0.07)*	(0.00)***
N.I. → Wales	0.734622	−0.981660	2.722669	−0.443811	0.311743	−0.508749
	(0.69)	(0.35)	(0.26)	(0.66)	(0.86)	(0.62)
	Models 193 & 194		Models 213 & 214		Models 233 & 234	
England → London.	0.629600	2.254896	21.43743	6.549032	0.306689	2.677146
	(0.73)	(0.05)**	(0.00)***	(0.00)***	(0.8578)	(0.02)**
London → England	2.640818	2.704369	4.816276	3.454820	0.522997	0.657979
	(0.27)	(0.02)**	(0.09)*	(0.00)***	(0.77)	(0.53)
	Models 195 & 196		Models 215 & 216		Models 235 & 236	
Scotland → London.	0.555989	1.714332	10.07078	5.552541	0.479698	2.869597
	(0.76)	(0.12)	(0.00)***	(0.00)***	(0.79)	(0.02)**
London → Scotland	0.782285	1.346809	0.862020	−0.102522	0.432850	−0.183557
	(0.68)	(0.21)	(0.65)	(0.92)	(0.81)	(0.86)
	Models 197 & 198		Models 217 & 218		Models 237 & 238	
Wales → London.	0.321988	1.899360	18.46209	5.527035	2.130472	2.624933
	(0.85)	(0.09)*	(0.00)***	(0.00)***	(0.3446)	(0.03)**
London → Wales	5.396785	5.396785	1.546775	1.351896	2.987133	−0.241694
	(0.07)*	(0.11)	(0.46)	(0.21)	(0.22)	(0.81)
	Models 199 & 200		Models 219 & 220		Models 239 & 240	
N.I → London.	0.619659	−1.237612	1.740106	5.020309	9.384667	4.386955
	(0.73)	(0.14)	(0.42)	(0.00)***	(0.00)***	(0.00)***
London → N.I.	0.798410	−1.535488	14.86839	2.477796	0.143004	−0.437281
	(0.15)	(0.16)	(0.00)***	(0.03)**	(0.93)	(0.67)

'*', '**' and '***' indicate statistical significance at the 10%, 5% and 1%, respectively. Full results are available upon request.

the introduction of Quantitative Easing. During this period, the London housing market seemed to dictate the movements of other regional markets. More specifically, the P-t-I ratios, as well as the A-t-I ratios of London Granger-caused those of Scotland, Wales and Northern Ireland in the long term (Models 136, 138, 140, 176, 178 and 180), seemingly suggesting that London was a leading indicator in terms of price discovery for FTBs. However, England overall appears to lag behind Scotland, Wales and Northern Ireland with respect to long-term Granger causation of the three affordability indicators (Models 122, 124, 126, 144, 146, 162 and 166).

Subperiod: 2016 Q2 to 2021 Q1 (Table 5)

This subperiod is marked by political uncertainty resulting from Brexit and the outbreak of COVID-19 during the first two-quarters of 2000 that led to a temporary 'shutdown' of the economy in general. Based on the *t*-statistics of the Error Correction terms of the Granger causality equation, the four sample regions of the U.K., as well as London, seem to be less causally correlated than during the first two subperiods under investigation. For example, Northern Ireland does not show any long-term Granger lead–lag associations with the other three regions in the U.K., and London in terms of P-t-I and A-t-I ratios (Models 185, 186, 189, 190, 191, 192, 226, 230 and 232). Similarly, the London housing market does not appear to be moving in tandem, in a Granger sense, with the four regional markets in the long-run given that they are not causally correlated across any affordability indicators (Models 194, 196, 198, 200, 234, 236, 238 and 240). Nonetheless, Granger causal links are evident over the long term for the English, Scottish and Welsh real estate markets (Models 182, 184, 202, 204, 224 and 228), with the causality directions generally running from less developed countries to more prosperous countries, confirming the aforementioned spatial spill-over proposition.

V. Discussion

The empirical findings stemming from the cointegration and Granger Causality tests reveal a number of noteworthy and somewhat novel insights into the spatial-temporal dynamics and interactions between the affordability ratios of the national regional submarkets within the U.K[4] First and foremost, as evident in the results of the cointegration analysis, we observe strong temporal co-movements and co-trending in the four national regions of the U.K. housing market over the sample periods and subperiods. Such findings are indeed in line with our expectations and consistent with previous literature which reported strong inter-regional linkages in terms of real estate pricing within a country such as the U.K. (e.g. Brady 2014; Chen, Hui, and Chiang 2021).

The relatively high magnitude and persistence of cointegration of the four national housing markets can be attributed to the fact that the submarkets share very similar underlying economic, demographic and social features and fundamentals including but not limited to migration, net inflows of capital, monetary policies such as interest rates and money supply, housing policies (e.g. stamp duties and property taxation) and macroeconomic attributes. In relation to labour law and general taxation, which partially determine overall housing affordability, the four national regions of the U. K. tend to adopt largely similar policies and regulations, which to certain extent, explain why the housing markets tend to be inextricably intertwined over the long-run.

Secondly, the results of the long-term Granger Causality tests suggest that the economically less developed regions such as Northern Ireland and Wales tend to be the largest 'spill-over transmitters' in terms of the three housing affordability ratios examined for the most part of the sample period and subperiods. In other words, housing affordability seems to be an issue of social concern observed in areas of slower economic growth first before it is spatially 'diffused' to more affluent and developed cities and regions. On first viewing, the results may appear counter-intuitive, especially considering that a number of previous research findings revealed the process of real estate price discovery or price shock, endogenous or exogenous, usually emanate from regions of higher socio-economic standing and dominance to other contiguous locales of shared market features through equity transfer, spatial arbitrage and the like (e.g. Pollakowski and Ray 1997; Meen 1999; Kuethe and Pede 2011; Sean, Peasaran, and Takashi 2011; Agyemang, Chowdhury, and Balli 2021).

However, in the context of housing affordability, particularly against the background of the U.K., spatial diffusion of market signals could indeed take place in the opposite direction. We posit that this is primarily because during times of economic expansion, income levels relative to property prices tend to grow more slowly in less prosperous regions such as Northern Ireland than in the remainder of the (mainland) U.K., resulting in a time delay in housing unaffordability between the former and the latter, which explains the observed Granger causation. To illustrate, our

[4]As suggested by an anonymous reviewer, we performed a number of robustness tests across the model specifications using time lags of ±1 quarter relative to the optimal ones. The results, which are available upon request, are highly consistent with the presented findings in terms of direction of causations of the variables and statistical significance..

data show that income growth for FTBs during 2000 Q1–2004 Q4 was 18.7% for Northern Ireland and 28.3% for England. However, the former observed a higher growth rate of 41.6% than the latter's 22.4% during 2005 Q1–2007 Q4, implying that it took time for some regions to catch up with the others economically and from a financial market perspective, and hence the observed temporal disparity in housing affordability.

Another significant revelation of our empirical study is that in the aftermath of the GFC in 2008 to 2016, London shows strong cointegration and causal linkages with the other regional markets. Upon closer examination, the capital city of the U. K. tends to Granger-cause Scotland, Wales and Northern Ireland in terms of the P-t-I and A-t-I ratios in the long-run. This can indeed be explained by a corollary to Sean, Peasaran, and Takashi (2011), who posited that exogenous shocks to U.K. house prices often originate in London since the city accounts for the largest percentage of income and wealth within the U.K. In this regard, external macroeconomic and financial shocks are hence more likely to have their first effects in London by virtue of the role that the city has played as one of the most open and important international global financial centres.

Lastly, it can be inferred from the results for the third sample subperiod (2016–2021) that the U.K'.s decision to depart from the E.U. seems to have created more divergence among the four regional housing markets in terms of pricing. Out of the sixty long-term pairwise Granger long-term causality models, only nine exhibits statistical significance at the conventional confidence levels, compared to nineteen and twenty-three for the first and second sample subperiods, respectively. Most noteworthy is perhaps the finding that during the subperiod, Northern Ireland displays no significant lead–lag associations with any of the three regions in mainland U.K. in terms of the P-t-I and A-t-I ratios in the long-run, despite the submarkets being cointegrated.

Indeed, prior to the EU-UK Withdrawal Agreement being concluded in October 2019, there had been wide and growing speculation within the wider market and amongst the general public that Northern Ireland would adopt a socio-political arrangement radically different from that of mainland U.K. in relation to the EU customs rules, business regulations, taxation, issues surrounding the supremacy of the European Court of Justice and the free flow of citizens within the U.K. and the E.U. (particularly between Northern Ireland and the Republic of Ireland), which could have a long-term impact on the N.I. real estate market. Such political uncertainty arising from Brexit, we surmise, is the primary reason why there has been a reduced degree of causal interconnectedness between the housing submarkets in Northern Ireland and mainland U.K.

Similarly, we observe that during the subperiod, the London housing market has become less causally correlated to the other submarkets. One possible explanation to such empirical phenomenon is that unlike other parts of the U.K., the housing market of London has long been more internationalized, significantly driven by the inflows of international capitals and buoyed by the demand from expatriates and migrants from the EU. These factors, in addition to COVID-19 (2020 onwards) pandemic shocks, we contend, have affected the London property market to a greater extent than other regions in England, Wales, Scotland and Northern Ireland, giving rise to the observed less causal interdependence between the submarkets.

VI. Conclusion

Governments across advanced economies are committed to ensuring that housing affordability remains within an acceptable level in order to ensure stability, inclusiveness and sustainable functional housing market and society. Thus, from a policy perspective, housing affordability is central to achieving the socio-economic goals of government and tackling the social disparity and socio-economic segregation within and across housing markets. An important corollary of this is to ensure access to the mainstream housing market.

However, first-time buyers trying to access the housing market remain impacted by movements in market pricing levels and income relative to macro-prudential policy movements and the availability of lending. In this regard, housing market affordability is contextualized by the interaction of a number of disparate indicators reflective of the wider financial and macroeconomic environment. Accordingly, the role of various housing and macroeconomic policies is integral to housing market behaviour, and in particular to the stability of the housing market and accessibility of FTBs.

A volume of existing research has demonstrated that feedback loops exist regionally (spatially) in terms of house price diffusion and co-integration, with other research illustrating evidence of short- and long-term interactions between key indicators and policy tools such as loan-to-value ratios can have both direct and indirect causal impacts on unaffordability. Whilst important, the examination of housing market affordability and the integration of the affordability ratios in a spatial sense remains limited and there are limited insights as to the role of market diffusion of key FTB housing affordability ratio measures.

This article, concentrating on the FTB segment of the market, empirically examined the three prominent housing affordability ratios for accessing the housing market in the U.K. in an attempt to identify whether (1) there are any lead–lag relationships between the housing affordability of different regions of the U.K. and (2) to explore whether spatial diffusion in the form of Granger causation exists between different regional submarkets within the FTB segment of the market.

The findings emanating from this study have exhibited some nuanced insights and intricacies relating to the spatial dynamics and interactions between the affordability ratios of the regional submarkets, and the presence of cointegration between the regional markets, invariably due to overarching macroprudential policy and socioeconomic characteristics. Appositely, three key findings emerged from the study. The first uncovered that during periods of economic expansion, housing unaffordability tended to diffuse from regions of slower economic growth to regions of higher economic status. This tends to infer that there is less disparity between incomes relative to house prices in these regions, which signals differences in the level of unaffordability.

Secondly, the findings also revealed that after extreme periods of housing market imbalance and disturbance, notably the GFC of 2008, in the U.K., the London housing market Granger-caused other regional markets in terms of housing unaffordability. Thirdly, we further found that exogenous political shocks, specifically Brexit and its aftermath, have also resulted in differential effects on pricing levels and behaviours and reduced causal interdependence between the submarkets, culminating in increased divergence between the regional submarkets across the U.K.

Interestingly, the findings revealed that the devolved region of NI displayed no associations with the other U.K. regions over this period in relation to the FTB affordability ratios, which has seemingly detached NI from the other U.K. regional housing markets. In a similar vein, the results also demonstrated the regional London housing market to also become more separated to the other regional submarkets. This is invariably due to the 'uniqueness' of the international nature of the London regional housing market, and indeed the political and economic uncertainty as a consequence of Brexit (and even COVID-19 exogenous shocks for future focus) for the London housing market relative to the other U.K. regions. In this sense, the findings illustrate that in these episodes of political turmoil and ambiguity, the different regional submarkets become less cointegrated due to the underlying macroeconomic and political fundamentals.

The research findings are important for policy and practice on a number of fronts. Housing market affordability does not move in tandem across the regional markets of the U.K. in times of housing market instability, despite similar macroprudential and housing policy. Therefore, uniform policy prescriptions enacted to 'cool' market pricing or breathe new life into the housing market may act to distort the national regional markets in a differential fashion impacting upon housing market unaffordability. Secondly, the evidence of price diffusion also requires not only a more comprehensive set of policy interventions tuned to the market cycle but those which can prohibit the onset of ripples linked to affordability from manifesting. Finally, times of wider political disturbance necessitate more targeted interventions by regional/local governments to ensure market processes, practices and affordability are adequately monitored and thus tailored towards local market demand-supply pressures and localized incomes and the lending environment. This change certainly extended to further research given COVID-19 pandemic impact that was unusual in changing housing affordability in both space and time.

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No potential conflict of interest was reported by the author(s).

ORCID

Michael James McCord http://orcid.org/0000-0002-5629-2765
Graham Squires http://orcid.org/0000-0003-0131-782X

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