Dynamic Connectedness of UK Regional Property Returns

Nikolaos Antonakakis*[†,‡,§] Ioannis Chatziantoniou[†,‡] Christos Floros[¥,¶] David Gabauer[†]

* Corresponding author: E-mail: nikolaos.antonakakis@webster.ac.at Phone: +43 1 269 9293 4354.

[†] Webster Vienna University, Department of Business and Management, Pratesrstrasse 23, 1020, Vienna, Austria.

[‡] University of Portsmouth, Economics and Finance Subject Group, Portsmouth Business School, Portland Street, Portsmouth, PO1 3DE, United Kingdom.

[§] Johannes Kepler University, Department of Economics, Altenberger Strasse 69, 4040 Linz-Auhof, Austria.

[¥] Technological Educational Institute of Crete, Department of Accounting and Finance, 71004 Crete, Greece.

[¶] Hellenic Open University, School of Social Sciences, Greece.

Abstract

In this study, we examine the network topology of UK regional property returns over the period 1973Q4-2014Q4 using a dynamic measure of connectedness developed by Diebold and Yilmaz (2014). Overall, our findings indicate that the transmission of inter-regional property returns shocks is an important source of regional property return fluctuations. What is more, this is a dynamic, event-dependent process which implies that, over time, any UK region can be both a net-transmitter and a net-receiver of shocks. This in turn, is conducive to evidence that the ripple effect is not the only driving force propelling changes in the UK housing market. In fact, we find that the regions of South West, Outer South East, East Midlands and Northern Ireland seem to be dominant transmitters of property returns shocks throughout the sample period. We further suggest that additional evidence regarding weak segmentation in the UK may stem from the fact that there is constant interaction across all regions over time. Most interestingly, we show that London may also act as a net-recipient of shocks. Findings are important for policy makers purporting to alleviate regional imbalances and achieve balanced growth, as well as, investors who formulate portfolio diversification strategies. Our results exhibit robustness to a series of tests.

Keywords: UK Housing Market, Connectedness, Vector Autoregression, Variance Decomposition, Property Returns Shocks

JEL codes: C32; G10; G20

1. Introduction

The importance of housing market developments for the aggregate economy has been clearly emphasized in recent decades, as it has become rather apparent that the financialisation of said market has rendered housing prices a key component of the investigation of the well-being of an economy. In this respect, there has been a substantial academic endeavour to investigate the links between housing prices and other macroeconomic and financial variables, as well as, to effectively identify the transmission mechanisms through which these links may actually be realised (see, inter alia, Mishkin, 2007; Reinhart and Rogoff, 2008; Iacoviello and Neri, 2010; Allen and Carletti, 2011; Attanasio et al., 2011; Bouchouicha and Ftiti, 2012; Ferrero, 2015; Miles, 2015). Furthermore, price discrepancies across markets but also regional contrasts within one single country have also been recorded over the years and have undoubtedly drawn the attention both of researchers and policy makers (see, among others, Vansteenkiste and Hiebert, 2011; Gupta and Miller, 2012; Apergis and Payne, 2012; Cook and Watson, 2015; Gupta et al., 2015; Liao et al., 2015). It follows that, employing an appropriate method in order to provide further evidence with regard to the interaction among housing prices of different geographical regions given a specific shock in the economy, becomes a matter of relative importance.

In relation to the above, a popular approach for the investigation of the interaction of a set of variables to specific economic shocks is the Vector Autoregression method developed initially by Sims (1980). In turn, one of the most useful features of this approach (i.e. the forecast error variance decomposition feature) formed the basis for analysing the connectedness of a system of variables (see, inter alia Diebold and Yilmaz, 2014; Antonakakis et al., 2017). One of the key advantages of the connectedness approach is that it allows researchers to distinguish between net transmitters and net receivers of shocks and thus classify the variables under investigation. In this respect, investigating the connectedness of the various segmented geographical regions within a country in the light of some economic shock, appears to be a very relevant scientific exercise.

What is more, the housing markets of countries such as the UK or the US - which have been through periods of large peaks and troughs in recent years have become the focal point of many studies that purport to investigate either transmission mechanisms or ripple effects.

By concentrating on the UK housing market and by employing the Diebold and Yilmaz (2014) connectedness approach this study further contributes to the investigation of price discrepancies across UK regions. We investigate the degree of their regional interdependence (i.e., the extent to which developments in one region might have an impact on developments in other regions) and then, employing both a static and a dynamic (i.e. rolling windows) framework of analysis we are able to proceed with a classification

of UK regions by virtue of the particular role they assume over time (i.e. we distinguish between net-transmitting and net-receiving UK regions). It is worth noting although, this will also be mentioned in greater detail in the sections that follow that any region can potentially assume both roles interchangeably, depending on the specific period of investigation. In addition, despite the fact that this does not constitute an overriding objective of the current study, we also contribute to the discussion about the ripple effect by presenting our specific findings about London and the South of England.

The contribution of this study is closely related to the aims described above. To the best of our knowledge, this is the first study to employ the connectedness approach introduced by Diebold and Yilmaz (2014) for the examination of the dynamics of UK property returns. Moreover, in contrast with most papers that analyse either short-run or long-run UK housing market relationships and dynamics, this study emphasizes the transmission of inter-regional property returns shocks as an important source of regional property return fluctuations. What is more, we are able to identify both net transmitters and net-recipients of shocks and to focus on key regions within the UK that could be useful for price discovery purposes. As mentioned earlier we also include a short comment in relation to what might the implications of our results be - regarding the ripple effect in the UK. Finally, this study contributes to the recent literature pertaining to the dynamic interrelations within a given set of variables by investigating the importance of the connectedness of the respective shocks.

We consider quarterly data of UK housing prices for the period 1973Q4-2014Q4. In accordance with recent and relevant academic papers (see, for example, Schindler, 2014) we consider data provided by the Nationwide Building Society (NBS) (in particular, see, www.nationwide.co.uk). NBS represent one of the largest mortgage providers in the UK and they provide the largest housing prices database using a widely accepted method of a house price index. NBS's indices are mix-adjusted so that they may track a representative housing price over time more effectively compared to just a simple average price. NBS offers detailed information about UK properties including location, types of properties, as well as, types of buyers.

Our results from the static analysis show that idiosyncratic shocks (i.e. intra-regional shocks) appear to be very important in explaining the forecast error variance. The dynamic analysis on the other hand, is indicative of the fact that connectedness appears to be very responsive to extreme economic events and especially to recessions. In fact, directional connectedness usually peaks during extreme economic events. On top of that, we show that most UK regions may assume an alternative role (i.e. they can be both net-recipients and net-transmitters of shocks) through the course of time. Both static and dynamic analysis suggests that the main sources of inter-regional property return shocks are the regions of the South West and Outer South East. Furthermore, the regions of East Midlands and Northern Ireland also emerge as important net-transmitting regions within the dynamic framework. Thought provokingly, London does not emerge as a dominant net-transmitter of property return shocks although it is evident that it is closely related to its neighbouring

regions. In a later section of this study we explain the relevance of this finding with regard to London and we set out potential future avenues that could help provide further insight. The most interesting finding in relation to London though, is the fact that it can act both as a transmitter and as a receiver of shocks. Finally, our study confirms existing evidence that the UK housing market is not fragmented and that interregional dependencies affect all UK regions over time.

The remainder of this paper is organised as follows. Section 2 presents the relevant literature. Section 3 discusses the application of the connectedness approach and describes the data used. Section 4 presents the empirical findings and purports to explore their relevant implications. Finally, Section 5 summarises the main results and concludes the study.

2. Review of the literature

2.1. Basic characteristics of the UK Housing market

Although a thorough investigation of the literature falls beyond the scope of this study, it is worth dwelling upon specific arguments, that have been developed and put forward over the years by authors conducting research in the field, if only, to better understand the UK housing market. According to Tse et al. (2014) the dynamics of the UK housing market are rather complex and thus deserve in-depth examination.

It is true that the UK housing market has a long history of upswings and downswings. Muellbauer and Murphy (1997) report that starting in the late 1950s one could identify at least two periods of high growth (i.e., in the early 1970s and the late 1980s), as well as, an unprecedented housing prices shrinkage in the early 1990s. From 1997 onward there was again a period of considerable growth (Bone and O' Reilly, 2010). According to Muellbauer and Murphy (1997) the housing prices hike of the late 1980s may very well be attributed to financial liberalisation of the period which in effect permitted higher levels of debt. On the other hand, the authors report that the main factors conducive to the market slump of the early 1990s included weak income growth expectations, the high interest rates of the period 1988-1990, high levels of accumulated household debt, as well as, a noticeable tightening of lending criteria, among other things. Muellbauer and Murphy (1997) specifically emphasize the increased volatility of housing prices for the period between 1989 and 1995. In order to attain a better understanding of how certain decisions affect the housing market, we concentrate on the period after 1997, and we begin our analysis by looking at the relationship of the housing market with monetary policy.

In particular, we focus on the work of Mishkin (2007) who provides a detailed analysis regarding the linkages between monetary policy and the housing market which appear to be very important for any economy. In his work, ensuing linkages can be attributed to either direct effects (i.e. interest rate effects, expectations about future housing prices fluctuations, as well as, housing supply) or indirect effects (i.e. wealth and credit effects). As far as the UK economy is concerned, there is clear evidence of both. In particular, during

the period 1997-2007 housing prices in the UK increased by 200% on average and actually, at a pace greater than the pace of inflation of that period (see, among others, Bone and O' Reilly, 2010; ONS, 2013). Cobham (2012) investigating the response of the Monetary Policy Committee (MPC) of the Bank of England (BoE) to those unprecedented high levels, directs our attention to a list of potential factors which according to the MPC contributed to attaining those levels in the first place. These factors include (i) price stability due to successful inflation-targeting monetary policy conduct, (ii) lower interest rates emanating from high competition in the banking sector, (iii) a shift of investment towards the housing market, as well as, (iv) low supply of dwellings.

The lack of supply of housing in the UK has also been reported by authors such as Bean (2010), Barker (2004), Ball (2011), Reinold (2011), Whitehead and Williams (2011), Poon and Garratt (2012), as well as, Hilber and Vermeulen (2014), among many others. In addition, Hay (2009), Bone and O' Reilly (2010), as well as, Whitehead and Williams (2011), emphasize accommodative monetary policy practices, low interest rates and easy access to credit as factors conducive to higher housing prices within the UK. The fact that interest rate setting by BoE has a key role to play when it comes to the UK housing market, has also been recently underscored by Tse et al. (2014). Gregoriou et al. (2013) identify a link between monetary policy conduct and housing affordability. What is more, the argument that successfully controlling expectations about future levels of inflation is rather a key element in this framework of analysis appears to be in line with Brooks and Tsolacos (1999) who present evidence of negative effects of unexpected inflation on the UK housing market. On a different note, it is still a matter open to question whether the high prices of that period constituted a bubble in the market, and despite the fact that authors such as Blanchard et al. (2010) explain that deciding whether or not there is a bubble in any asset market is rather not straightforward; authors such as Morley and Thomas (2011) put forward the argument that we should not rule out the possibility that before the years of the Great Recession the UK housing market potentially attracted speculators as well. Very recently, the contribution of monetary policy to the development of a bubble in the UK housing market has been emphasized by Tsai (2015a).

Be all this as it may, the upward trend in housing prices in the UK was interrupted by the Great Recession. In August 2007, the global financial meltdown has had a profound impact on the global economy and sparked discussions regarding the efficiency of asset markets and whether asset prices bubbles exist and if they have the potential to nurture financial crises (see, inter alia, Obstfeld and Rogoff, 2009; Bernanke, 2010; Reinhart and Rogoff, 2013). Support for the argument that housing markets are rather inefficient and that price hikes cannot always be construed on the basis of fundamentals, can be found in the work of authors such as Case and Shiller (1989, 2003), and Shiller (2007). With reference to the UK housing market, Barkham and Geltner (1996) find that the UK housing market is inefficient as it takes time for housing prices to fully incorporate new information and this lag has negative implications for new developments' planning. In addition,

Schindler (2014) reports that the UK housing market is characterised by asymmetric information, while, Tsai and Chen (2009) and Tsai (2013) emphasize downward rigidity. More specifically, Tsai (2013) argues that the housing prices in the UK exhibit a crashproof phenomenon (i.e. they exhibit a more stable reaction to bad news). In this regard, UK housing prices tend to over-react in upturns and under-react in downturns.

On a somewhat parallel note, Reinold (2011) takes the view that the lower UK housing prices recorded for the years that followed the Great Recession, could be directly attributed to tighter lending conditions which resulted in fewer housing market transactions and less wealth via housing equity withdrawal (HEW). According to ONS (2014), the UK housing market is slowly recovering with current levels of prices though that are still falling short of their pre- Great Recession period levels. What is more, recent studies also concentrate on the effects of quantitative easing (see, Joyce et al., 2011) and migration (see, Sá, 2015).

2.2. Regional interdependence of UK housing prices

The investigation of the interdependence among regional housing prices has gained much prominence in recent years and many authors have provided evidence for a variety of countries (see, among others, Larraz-Iribas and Alfaro-Navarro, 2008; Zohrabyan et al., 2008; Clark and Coggin, 2009; Lee and Chien, 2011; Apergis and Payne, 2012; Barros et al., 2012; Gupta and Miller, 2012; Zhu et al., 2013; Chowdhury and Maclennan, 2014; Schindler, 2014; Chowdhury and Maclennan, 2014; Stevenson and Young, 2014; Cook and Watson, 2015). Understandably, this is a very important field of study with repercussions which extend towards both investors and policy makers. From a purely financial point of view, investigating regional interdependencies and convergence among the various regions within a country might provide very useful insight in relation to efficiently diversifying investments within a portfolio (e.g. when we investigate the possibility of holding mortgage-backed securities pertaining to different regions within the country to be financially prudent). Furthermore, the investigation of regional disparities might prove a great analytical tool and help policy makers achieve a more balanced development across the country.

As far as the UK housing market is concerned, there have been quite a few studies over the years investigating the transmission of shocks across regional housing markets; that is, the so-called ripple effect[1]. According to Cook and Watson (2015), the ripple effect in the UK basically refers to the hypothesis that changes in housing prices initially occur in London and South-Eastern parts of the UK and are then subsequently transmitted to other regions within the country. In their thorough investigation of this phenomenon, Cook and Watson (2015) report that the most dominant viewpoint in the literature relating to the

[1] A thorough investigation of the literature pertaining to the ripple effect in the UK housing market can be found in Cook and Watson (2015).

ripple effect is that contrasting London to other regions implies a short-term divergence of regional housing prices followed by a longer-term convergence.

Recent empirical evidence is rather inconclusive about the actual manifestation of the ripple effect. Drake (1995, p.357) reports "clear regional differences in the patterns of UK house price movements" with prices in Northern parts of the UK exhibiting higher divergence compared to their South-Eastern counterparts. Results regarding the persistence of the North to price changes in London can also be found in the work of Holmes and Grimes (2008, p.1543) who note that the ripple effect is present; however, "the adjustment speed is considerably slower than for all other regions". Authors such as Meen (1996, 1999) and Cook (2003, 2005) show that increases in housing prices in the South-East have a lagged effect on Northern and Western parts of the UK, lending weight to the argument that regional housing prices are rather stationary (i.e. there is a stable ratio of regional over national housing prices over time mainly reflecting a firm long-run relationship between the two). What is more, Bouchouicha and Ftiti (2012) show that there is a common trend that drives the real estate market in the UK, while Schindler (2014) provides evidence of persistent housing prices and that there may be opportunities for investors to hedge risk in the market of derivatives. In addition, Tsai (2014) distinguishes the information transmission mechanisms between regional and national housing markets in the UK and puts forward the argument that only two regions (i.e. East of England and South West) show signs of comovement with the national housing market over the period 1995-2012.

It is also true that some UK regions exhibit certain characteristics which undoubtedly deserve closer attention by researchers. Northern Ireland for example, is the region for which both the largest increases and the largest decreases in housing prices have been recorded before and after the Great Recession respectively (see, inter alia White, 2015). This fact alone suffices to qualify this region as a major source of shocks. Besides, according to authors such as McKee and Moore (2017) Northern Ireland, in contrast with other UK regions, has achieved since the late 1990s an increased level of independence from the UK Government when it comes to social security provisions and the taxation of its housing market. It is also worth noting that an additional element that makes Northern Ireland quite different from other UK regions is the special relationship that it has with the Republic of Ireland. Early on in the work of Stevenson (2004) we find evidence that a very strong link exists between these two spatial units (e.g., via increased cross-border investments) which has led to a diffusion of housing prices from Dublin to Northern Ireland. It follows that, in the years of the Great Recession, given that the Republic of Ireland found itself at the epicentre of the crisis, housing market developments in Dublin obviously affected housing prices in Northern Ireland at least to some extent, a fact which should be taken into consideration when analysing the UK housing market. What is more, Montagnoli and Nagayasu (2015) in their cluster-approach of UK regions report that Northern Ireland belongs to the group of regions which clearly exhibit convergence with the South East of the UK. They also show that a ripple effect stemming from London may

very well propagate all the way to Northern Ireland. In this regard, there are at least two different sources of influence for the housing market of Northern Ireland.

According to ONS (2017), East Midlands, a region with a very strong manufacturing sector, exhibits a record high level of employment, while at the same time, it has the highest share of jobs in manufacturing in the country. In this regard, East Midlands is another UK region which deserves attention as it may not be as important as London when it comes to services and the financial industry; it is however, very important when it comes to the production sector of the economy. On a parallel note, Bailey and Berkeley (2014) have emphasized the relatively poor economic conditions prevailing in West Midlands which provides some indication that we should expect different responses from these two regions.

The South West, is another interesting case. One of the main characteristics of this region is that its investment in research and development is above the national average, a fact which may very well be closely linked to the findings reported by Lee (2014) according to whom UK regions with highly skilled workforce appear to be less affected by recessionary events. The city of Bristol is one of the biggest cities in the UK and constitutes an integral part of the M4 Corridor, an area along the M4 motorway renowned for attracting high-technology firms Tallon (2007). According to ONS (2017) the South West is one of the UK regions with the highest rates of employment and economic activity.

On a final note, given London's importance for the UK housing market, geographical proximity to London appears to be a decisive factor in relation to the ripple effect. Holly et al. (2011) report that it takes more time for a shock in the housing market of London to propagate another UK region when this region is relatively distant from London. Along a similar vein, Cook and Watson (2015) present evidence in support of the ripple effect; however, they stress the fact that geographical proximity to London appears to be crucial and thus housing prices in South East and East Anglia exhibit a relatively higher degree of comovement. At this point, it would be instructive to emphasize that although London may in fact be a global financial centre closely linked to international economic developments, it remains subject to inter-regional developments and receives feedback from other UK regions. For example, Fingleton and Martin (2012) show that a negative shock to employment in the South East will have a negative impact on employment in London. With regard to the housing market, Holly et al. (2011) put forward the argument that any other UK region may have an impact on London housing prices; however, this impact is relatively short termed. Our study, although not concentrated on the duration of one particular shock, purports to identify potential persistent property return shocks across UK regions.

By investigating regional interdependencies in housing prices amongst the various regions within the UK using the connectedness approach introduced by Diebold and Yilmaz (2014) we aim to further elucidate these issues and eventually provide a more thorough picture of the UK housing market.

3. Data and Methodology

3.1. Data

We collect quarterly series of seasonally adjusted property price indices in 13 UK regions, namely, North, North West, West Midlands, Outer South East, London, Wales, Northern Ireland, Yorkshire & Humberside, East Midlands, East Anglia, Outer Metropolitan, South West, and Scotland from Nationwide database over the period 1973Q4 to 2014Q4. Figure 1 plots these series along with the overall UK property index.

[Insert Figure 1 here]

The price series are then converted to year-on-year returns by taking the fourth change of the natural logarithm of the property price index (PPI_t) as: $\log(PPI_t) - \log(PPI_{t-4})$.

We define $y_t = (North_t, ..., N.Ireland_t)^t$ as the vector consisting of data on 13 UK regional property returns.

Figure 2 and Table 1 illustrate and provide descriptive statistics on the UK regional property returns.

[Insert Figure 2 here]

[Insert Table 1 here]

According to this figure, the feature of booms and busts in UK regional property cycles is evident.

Table 1 presents the descriptive statistics of our data. According to this table, we observe large variability in our main variables. The augmented Dickey-Fuller (ADF) test with just a constant, rejects the null hypothesis of a unit root for each series (i.e. all series are stationary), which motivates the use of a VAR model in these series.

3.2. Empirical Methodology

Our analysis is based on the connectedness approach introduced by Diebold and Yilmaz (2014) which builds on the seminal work on Vector Autoregressions (VAR) by Sims (1980) and the notion of generalised forecast error variance decompositions by Pesaran and Shin (1998) and Koop et al. (1996). In particular, the connectedness approach estimates the dynamic relationship between different variables. According to this approach, we shock one variable, i (where i denotes the property returns of one of the 13 UK regions in our sample), and then look how the other variables, $-i$ (where $-i$ denotes all other, e.g. 12, UK regions apart from, i, the region of interest), respond to that shock. The effects of a shock in variable i are then accumulated and subtracted from the shocks in variable $-i$. This results in the net directional connectedness illustrating the influence that variable i has on the whole UK housing market. That is, if variable i is influencing other variables more than is being influenced by them, it is driving the market, while the opposite means that it is driven by the market. However, such an analysis will mask the influence across pairs of regions within the UK housing market. Therefore, we additionally compute the net pairwise directional connectedness that provides additional insights on the intra-

regional patterns in the UK housing market. Last but not least, the dynamic connectedness relationships can be traced over time via rolling window VAR estimation.

The starting point for the analysis is the following K[th] order, N variable VAR

$$y_t = \sum_{k=1}^{K} \Theta_k y_{t-k} + \varepsilon_t y_t \quad (1)$$

where y_t is a vector of endogenous variables defined above; Θ_k, $k = 1, \ldots, K$, are $N \times N$ parameter matrices and $\varepsilon_t \sim (0, \Sigma)$ is vector of disturbances that are assumed to be independently (though not necessarily identically) distributed over time; t is the year index, ranging from 1973Q4 to 2014Q4.

Key to the dynamics of the system is the moving average representation of model (1), which is given by $y_t = \sum_{p=0}^{\infty} A_p \varepsilon_{t-p}$, where the $N \times N$ coefficient matrices $A_{p\ are}$ recursively defined as follows: $A_p = \Theta_1 A_{p-1} + \Theta_2 A_{p-2} + \ldots + \Theta_p A_{p-l}$, where $A_{0\ \text{is}}$ the $N \times N$ identity matrix and $A_p = 0$ for $p < 0$.

The connectedness approach of Diebold and Yilmaz (2014) is based on the generalized VAR framework (Koop et al., 1996; Pesaran and Shin, 1998), and, in which, forecast error variance decompositions are invariant to the ordering of the variables. Of course, this has advantages and drawbacks. Given our goal to assess the magnitude of UK regional property returns connectedness (as determinants of (the share of) UK regional properties' forecast error variances) rather than identifying the causal effects of structural shocks, this appears to be the preferred choice in the present context[2]. In the generalized VAR framework, the H-step-ahead forecast error variance contribution is

$$\varphi_{ij}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)}, \quad (2)$$

where Σ is the (estimated) variance matrix of the error vector ε, σ_{jj} the (estimated) standard deviation of the error term for variable j, and e_i a selection vector with 1 as the i^{th} element and zeros otherwise. This yields a 13×13 matrix $\varphi(H) = [\varphi_{ij}(H)]_{i,j=1,\ldots,6}$, where each entry gives the contribution of variable j to the forecast error variance of variable i. The main diagonal elements contain the (own) contributions of shocks to variable i to its own forecast error variance, the off-diagonal elements represent cross-regional property returns connectedness, defined here as contributions of other regions j to the forecast error variance of region i.

Since the own and cross-variable variance contribution shares do not sum to 1 under the generalized decomposition, i.e., $\sum_{j=1}^{N} \varphi_{ij}(H) \neq 1$, each entry of the variance decomposition matrix is normalized by its row sum, such that

$$\widetilde{\varphi}_{ij}(H) = \frac{\varphi_{ij}(H)}{\sum_{j=1}^{N} \varphi_{ij}(H)} \quad (3)$$

[2] However, we explore the robustness of our results by using Cholesky factorization with alternative orderings of the variables, as discussed below, and our results remain very similar.

with $\sum_{j=1}^{N} \tilde{\varphi}_{ij}(H) = 1$ and $\sum_{j=1}^{N} \tilde{\varphi}_{ij}(H) = N$ by construction.

This ultimately allows to define total connectedness, which is given by the following:

$$TC(H) = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\varphi}_{ij}(H)}{\sum_{j=1}^{N} \tilde{\varphi}_{ij}(H)} x100 = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\varphi}_{ij}(H)}{N} x100 \quad (4)$$

which measures, on average over all sectors, the contribution of connectedness from shocks to all other sectors to the total forecast error variance.

This approach is quite flexible and allows to obtain a more differentiated picture by considering directional connectedness: Specifically, the directional connectedness received by region *i* from all other regions *j* are defined as follows:

$$DC_{i\leftarrow j}(H) = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\varphi}_{ij}(H)}{\sum_{i,j=1}^{N} \tilde{\varphi}_{ij}(H)} x100 = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\varphi}_{ij}(H)}{N} x100 \quad (5)$$

and the directional connectedness transmitted by region *i* to all other regions *j* as follows:

$$DC_{i\rightarrow j}(H) = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\varphi}_{ji}(H)}{\sum_{i,j=1}^{N} \tilde{\varphi}_{ji}(H)} x100 = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\varphi}_{ji}(H)}{N} x100 \quad (6)$$

Note that the set of directional connectedness provides a decomposition of total connectedness into those coming from (or to) a particular region.

By subtracting Equation (5) from Equation (6) the net connectedness from region *i* to all other regions *j* are obtained as follows:

$$NC_i(H) = DC_{i\rightarrow j}(H) - DC_{i\leftarrow j}(H), \quad (7)$$

providing information on whether a region is a receiver or transmitter of UK property returns shocks in net terms. Put differently, Equation (7) provides summary information about how much each region in the UK contributes to the other regions in the UK, in net terms.

4. **Empirical Findings and Discussion**

In this section, we present the results from our empirical analysis. We start with the estimates of the static connectedness measure (i.e. an average estimate for the full sample period), and then consider the dynamic nature of connectedness using rolling window estimation. It should be noted that, for the sake of brevity, discussion will be mainly centred around the results we obtain in relation to *net directional* and *net pairwise* connectedness especially for the period right before (i.e. increasing housing prices) and after (i.e. deteriorating housing prices) the years of the *Great Recession*. By doing so, we concentrate our analysis on what is perhaps a key consideration of recent literature; that is, to shed additional light to recent dynamic inter- regional features of the UK housing market and provide further evidence associated with the ripple effect and the UK housing market segmentation.

4.1. Connectedness Measures

Table 2 presents the estimation results for the connectedness indices defined in Equations (4)-(7), based on 4-quarter-ahead forecast error variance decompositions. Before discussing the results, let us first describe the structure and elements of Table 2. The ij^{th} entry is the estimated contribution *to* the forecast error variance of property region i coming *from* shocks (innovations) to property region j (see Equation (2)). The diagonal elements ($i = j$) measure intra-regional connectedness of shocks (over time), while the off–diagonal elements ($i \neq j$) capture inter-regional (i.e., cross–variable) connectedness of shocks.

In addition, the row sums excluding the main diagonal elements (labelled 'Connectedness from others', see Equation (5)) report the total connectedness *to* (received by) the particular region in the respective row, whereas the column sums (labelled 'Connectedness to others', see Equation (6)) report the total connectedness *from* (transmitted by) the particular region in the respective column. The difference between each region's (off-diagonal) column sum and the same region's row sum gives the net connectedness of the respective region to all other regions (see Equation (7)). Finally, the total connectedness index defined in Equation (4), which is given in the lower right corner of Table 2, is approximately equal to the grand off-diagonal column sum (or row sum) relative to the grand column sum including diagonals (or row sum including diagonals), expressed in percentage points[3].

[Insert Table 2 here]

Table 2, which summarises the average connectedness for the full sample period reveals

[3] The approximate nature of the result is due to the fact that the contributions of the variables do not sum to 1 under the generalized decomposition framework and have to be normalized (see Equation (3)).

several interesting findings. First, intra-regional connectedness explains the highest share of forecast error variance, as the diagonal elements receive higher values compared with the off- diagonal column-wise elements. For instance, innovations to housing market returns in Northern Ireland explain 37.9% of the 4-quarter-ahead forecast error variance of housing market returns in the Northern Ireland, and only 6.4% and 6.2% of the 4-quarter-ahead forecast error variance of housing market returns in Scotland and London, respectively.

Second, the most important transmitters of inter-regional shocks are the housing market returns in South West, Outer South East and East Anglia regions, while the housing market returns in North, Yorkshire, Scotland and East Midlands are the most important receivers of inter-regional housing market return shocks. These results are supported by the estimated net directional spillovers reported in the last row of Table 2. Put differently, these results indicate that real house market returns shocks in the South West, Outer South East and East Anglia regions have historically been the dominant sources of inter-regional spillovers.

Third, and most importantly, according to the total inter-regional connectedness reported at the lower right corner of Table 2, which effectively distils the various directional connectedness measures into one single index, on average, 83.9% of the forecast error variance in regional hous- ing market returns comes from spillovers across regions, while the remainder can be explained by own-regional shocks.

In retrospect, findings are indicative of a high degree of inter-regional interdependence and this is ultimately reflected on the high average values of both total and directional spillovers across regions reported for the period of investigation[4].

4.2. Connectedness Plots

While the average results for the full sample period in Table 2 are indicative they might mask interesting changes in the pattern of inter-regional connectedness, given the long time span of four decades considered. Hence, we estimate the model in Equation (1) using 60-quarter rolling windows and calculate the variance decompositions and connectedness measures[5]. As a result, we obtain time-varying estimates of connectedness measures, allowing us to assess the evolution of total and directional connectedness over time both within and between the various regions in the UK.

[Insert Figure 3 here]

Total connectedness over time, obtained from a 60-quarter rolling windows approach is illustrated in Figure 3. According to this figure, we observe a large variation in the total connectedness, which turns out very responsive to extreme economic events and UK recessions. For instance, the total connectedness of UK regional housing market returns

[4] We have explored the robustness of our results using alternative forecasting horizons (i.e. 8 and 12 quarters) and the results remain qualitatively similar.

[5] Our results reported below remain robust to alternative choices of window length (i.e. 70 and 80 months).

reaches a peak during the withdrawn of UK from the ERM, the Subprime mortage crisis and due to Eurozone debt worries that pushed up the cost of borrowing for banks, which in turn passed on their higher cost to new mortgage borrowers. This suggests that interdependencies across regions in the UK tend to increase significantly during economic downturns.

In order to attain a better understanding of regional interdependence in the UK housing market it would be instructive to proceed with our analysis and concentrate on "directional connectedness" as this is decomposed into "directional connectedness FROM others" (see, equation (5)) and Table 2 for its average value) and directional connectedness TO others (see, equation (6)) and Table 2 for its average value). A time-varying picture of directional connectedness either FROM or TO others is given by Figures 4 and 5 respectively. It is worth noting that the patterns illustrated in Figure 5 appear to be similar as they merely represent what each UK region receives over time from all other regions together.

[Insert Figure 4 here]

[Insert Figure 5 here]

According to these two figures, directional connectedness from or to each region range be- tween 2% and 18% and are of bidirectional nature. Nevertheless, they behave rather heterogeneously over time and follow a similar pattern as the one found for the total connectedness measure. That is, directional connectedness from or to each region generally peak during the extreme economic events, such as housing bubble bursting and UK recessions.

To the effect that we are able to deduce the extent to which each one of the regions under investigation is either a net transmitter or a net receiver of shocks in housing market returns, we concentrate on the net directional and net pairwise connectedness measures. Starting with net directional connectedness, it is evident in Figure 6 (which plots the time-varying net directional connectedness across the various UK regions) that all regions under investigation appear to frequently switch between assuming a net transmitting and a net receiving role. For instance, the importance of housing market return shocks, and especially those originating in the UK regions of South West, Outer South East, East Midlands and Northern Ireland seem to be the dominant transmitters of property returns shocks during our sample period, with Northern Ireland being at the epicenter of the transmission process in the period of the global financial crisis and the housing market collapse, suggesting that housing markets in the UK regions are highly interconnected and extreme economic event dependent. Conversely, the UK regions of North, Yorkshire and Humbershide, London, Wales and Scotland are mainly at the receiving ends of net inter-regional transmission during the sample period.

[Insert Figure 6 here]

We now turn our attention to net pairwise directional connectedness obtained from the

60- quarter rolling window estimation presented in Figure 7, which bring further insights into the transmission process of property returns shocks across UK regions. For instance, the dominance of the net transmitting role of house returns shocks in the South West region is evident as shocks in that region are being transmitted to all other UK regions, apart from that in Northern Ireland. A similar picture is observed for shocks originating in the regions of Outer South East, East Midlands and Northern Ireland. These results suggest that the information content of house returns shocks in the UK regions of South West, Outer South East, East Midlands and Northern Ireland can help improve forecast accuracy of house returns shocks in the other UK regions. Moreover, while the static analysis discussed above clearly classifies the aforementioned variables into net transmitters and net receivers, the dynamic analysis denotes episodes wherein the net role of transmitters and receivers of house returns shocks can be interrupted or even reversed. Hence, even if certain commonalities prevail in the property market in each UK region, such commonalities are time– and event–dependent.

[Insert Figure 7 here]

A more in-depth look at the results might be quite insightful in relation to the key considerations of our study. In particular, concentrating on the results presented in Figures 6 and 7 we can reach useful conclusions in connection with the dominant character of each region in the transmission of housing returns shocks. As earlier mentioned, our analysis is limited to the period before, during and after the Great Recession, mainly in order to appreciate developments in the UK housing market under the prism of both increasing and decreasing housing prices. In addition, we pay particular attention to the connectedness of London to other regions in the UK because London is a key element of the discussion around the ripple effect. By emphasizing net directional and net pairwise connectedness across UK regions, we aim to provide further evidence regarding the dynamic and mainly event-dependent process of transmission of property return shocks.

To begin with, it is evident from Figure 6 that London throughout the period of study acts not exclusively as a net transmitter of shocks, as someone might initially have thought, but also as a net receiver. In the early and mid-1990s London appears to be a net transmitter of shocks to other regions. The London housing market appears to transmit shocks again during the peak of the UK housing market boom around 2005 and again very recently over the past few years. It is worth noting though, that during the years of the Great Recession and also during the recent European debt crisis which began in 2009, London appears to receive shocks from other regions in the UK as well. Authors such as Holly et al. (2011) emphasize that London is a global financial centre and one of the largest cities in Europe and therefore, Londons residential prices might actually reflect developments both at the international and at the local UK level. Understandably, local UK factors might also include developments in the housing market of other UK regions, while, this might be more evident during turbulent economic periods. Thus, it could make sense

for London to also assume a net recipient role. These findings neither downgrade the importance of London as a net transmitter of property return shocks, nor do they cast doubt on the London South East angle of the UK ripple effect. They merely provide further information regarding potential sources that contribute to price formation within London. In support of this, Holly et al. (2011) report that there may be short-run impact from other UK regions on the housing market of London.

In effect, our findings suggest that housing price developments within the UK (irrespective of how long it takes for these to be realised) cannot be solely attributed to innovations in the housing market of London. According to Tsai (2015b), London is a segmented housing market and innovations within this market can be attributed to factors that do not really propagate other UK regions. By contrast, we find that London is not segmented and it may very well be a net transmitter of shocks; however, considering a dynamic framework of analysis we provide evidence that the ripple effect is a rather more complex notion as its implications appear to be time dependent. In other words, depending on the time period of analysis and the corresponding economic or political events, most regions seem to be conducive to developments in the UK housing market. A stellar example of this argument can be seen in Figure 6 and more specifically, when we look at the strong net transmitting character of Northern Ireland from the outset of the *Great Recession* onwards.

To conclude our discussion about the net transmitting/receiving character of London we concentrate on Figure 7; that is, on net pairwise connectedness. Prominent among the results presented in this Figure is the fact that for almost throughout the period of investigation London has been a net recipient of shocks from the South West. What is more, in the years just before the beginning of the Great Recession, London appears to transmit shocks mainly to West Midlands, Outer South East, as well as, Outer Metropolitan. During the Great Recession, London is a net transmitter of shocks to mainly to the Outer South East. Finally, in the years that followed the Great Recession, London acts as a net transmitter of shocks mainly in relation to North, North West, East Anglia, as well as, Scotland. It should be noted that adopting a spatial VAR approach which allows the weighting of regions according to their importance within the system would help better emphasize London's contribution as a source of property returns shocks. This could be part of future study.

Despite the fact that comovements between housing prices in London and housing prices in the South East have also been emphasized by authors such as Cook and Watson (2015) who further argue that proximity to London constitutes a crucial factor when it comes to analysing the ripple effect and Henretty (2015) who stresses that the impact of the London housing market on its neighbouring regions can be confirmed by investigating housing prices in the cities of Guildford and Reading; our findings again verify that the transmission of housing market shocks in the UK seems to be a dynamic and event dependent process. It is also worth noting, that Tsai (2015b) reports that in terms of price discovery the South-East region is very important and provides evidence that changes in housing prices in the South East affect UK housing prices with some delay.

With reference to results pertaining to other regions within the UK which act as net transmitters of shocks at different periods, identifying factors that drive housing prices within these regions might help explain the dynamics that link housing prices across the UK. The investigation of factors such as the size and the diversity of the job market, the supply of newly built dwellings, migration levels, as well as, existing and planned infrastructure and transport net- works, among others, could potentially provide the basis for a more thorough analysis of ripple effects across the UK regions. Piggott (200) and Holly et al. (2011) report that there exists a considerable number of commuters between London and the South West - a fact that might potentially act as a starting point in explaining the significant role of the South West as a net transmitting region. On a parallel note, Sá (2015) emphasizes the mobility of native population across the UK as a response to migration and its negative effect on UK housing prices. In the same line of reasoning, the continued plummeting of housing prices in Northern Ireland in recent years, could potentially affect other regions (including London), thus justifying Northern Ireland's current strong net transmitting role. What is more, the link between economic activity in Northern Ireland and that in the Republic of Ireland a link which is rather strong should also be investigated.

Finally, in line with Gupta and Miller (2012) we find that geographic regions within the UK all contribute to developments in their respective housing markets. In particular, we provide evidence that the UK housing market is not segmented and that different periods of time in the light of different economic and political events, lend either a net transmitting or a net receiving role to each one of the regions under investigations.

4.3. Robustness analysis

In an attempt to check the robustness of the results obtained based on the generalised version of the connectedness measure by Diebold and Yilmaz (2014), we repeat the VAR-based analysis based on Cholesky decomposition, in which the forecast error variance decomposition is sensitive to the ordering of the variables in the VAR. In particular, we analyse 200 random permutations (different orderings of the 13 UK regional property return in the VAR) and construct the corresponding connectedness indices for each ordering. Figure 8 presents the minimum and maximum values that the total connectedness index receives based on Cholesky factorization. According to this figure, the results are in line with those of our main approach reported in Figure 3. In particular, the connectedness index varies between 72% and 89%. In addition, total connectedness is large in the beginning of the 1990s and thereafter follows a declining trend till the end of the 1990s. Then it follows and increasing trend till the end of our sample period. The similarity of the pattern obtained using these two alternative approaches is reassuring and underlines the robustness of our results.

[Insert Figure 8 here]

5. Conclusion

This study examines the magnitude, importance and evolution of intra- and inter-regional interconnectedness of property returns in the UK, using quarterly data over the period 1973Q4 to 2014Q4. We employ the VAR-based connectedness approach by Diebold and Yilmaz (2014), which is well suited for the investigation of interdependencies but has rarely been used in this strand of the literature so far.

We find that the transmission of inter-regional property return shocks is an important source of regional property return fluctuations in the United Kingdom. On average over the whole sample period, 83.9% of forecast error variance of property returns across the 13 regions in the United Kingdom is due to inter-sectoral spillovers. Moreover, inter-sectoral connectedness shows a large variation over time. The importance of spillovers, and especially those originating in the UK regions of South West, Outer South East, East Midlands and Northern Ireland seem to be the dominant transmitters of property returns shocks during our sample period, with Northern Ireland being at the epicenter of the transmission process in the period of the global financial crisis and the housing market collapse, suggesting that housing markets in the UK regions are highly interconnected and extreme economic event dependent.

With reference to the ripple effect, in line with existing literature we find that London is closely linked to various UK regions and acts as a net transmitter of shocks; however, the regions which receive shocks from London vary depending on the period of focus. In other words, within the dynamic framework of our study, we provide evidence that London is not always important for the same regions over time, as well as, that London itself may also receive shocks from other UK regions. This finding is very important as it implies that further research is necessary in order to identify the specific features within each UK region and better understand the ensuing inter-regional dependencies over time. Finally, we confirm that the UK housing market is not fragmented and that interregional dependencies affect all UK regions throughout the period of investigation.

Overall, our findings have an important policy implication. As the recent subprime mortgage financial and economic crisis has shown, shocks rapidly spread over the various regions of the UK economy and have a magnified impact. The large magnitude of spillover effects obtained in the present study underlines the importance of establishing appropriate regulations and stabilization policies in the housing sector of the economy.

Identifying the determinants of housing returns within the various UK regions, as well as, the specific transmission mechanisms that drive developments in the housing market, would be an interesting area for future research as it would further increase our understanding regarding regional inter-dependence within the UK. In order to effectively account for the different phases of the economy, the development of an asymmetric connectedness index might be another interesting related area. This area of research could further benefit from the development of a spatial VAR model to account for the gravity of each region within the system. Another promising avenue for future research would be to

extend the analysis at an international level, so as to examine whether international housing markets which underwent similar peaks and troughs to the UK housing market are also interconnected.

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Table 1: Descriptive statistics of UK regional property returns

Variable	obs	min	mean	max	std.dev	ADF
North	161	-0.1565	0.0685	0.3595	0.0937	-5.054**
Yorks & Humberside	161	-0.2253	0.0666	0.4221	0.1028	-4.246**
North West	161	-0.1656	0.0715	0.3887	0.0929	-4.557**
East Midlands	161	-0.1893	0.0710	0.4357	0.0981	-4.402**
West Midlands	161	-0.1642	0.0699	0.3983	0.0926	-4.021**
East Anglia	161	-0.2214	0.0729	0.385	0.1081	-4.540**
Outer South East	161	-0.2017	0.0756	0.3117	0.1043	-3.711**
Outer Metropolitan	161	-0.1896	0.0774	0.3133	0.0991	-3.362*
London	161	-0.1995	0.0845	0.3416	0.1017	-3.807**
South West	161	-0.1608	0.0752	0.3706	0.0978	-3.930**
Wales	161	-0.1986	0.0679	0.4192	0.0986	-5.041**
Scotland	161	-0.1341	0.0679	0.2426	0.0711	-4.978**
Northern Ireland	161	-0.4176	0.0657	0.4553	0.1213	-5.731**
UK	161	-0.1797	0.0727	0.2787	0.0854	-3.577**

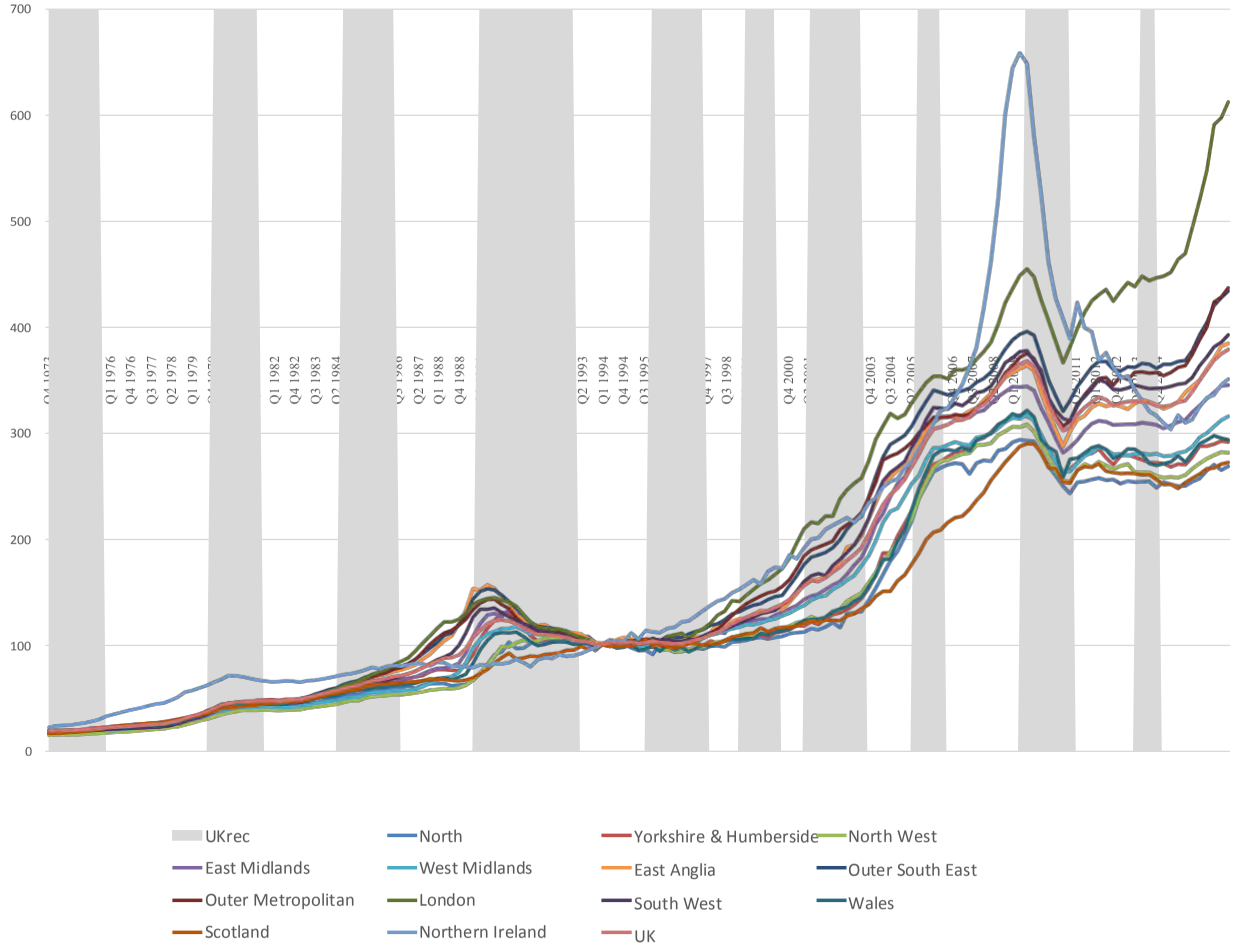
Note: ADF stands for Augmented Dickey-Fuller unit root test statistic. The 5% and 1% ADF critical values are-2.88 and -3.47, respectively. * and ** indicate significance at 5% and 1% level, respectively.

Table 2: Estimation Results for Spillover Indices

	(j)													
(i)	NORTH	YORKSHSIDE	NORTHWEST	EASTMIDS	WESTMIDS	EASTANGLIA	OUTERSEAST	OUTERMET	LONDON	SOUTHWEST	WALES	SCOTLAND	NIRELAND	Connectedness From Others
NORTH	12.0	5.0	6.5	9.7	9.4	6.9	9.7	6.8	3.6	13.5	7.3	7.2	2.4	88.0
YORKSHSIDE	5.4	9.7	6.2	8.1	7.7	10.7	10.9	7.1	4.8	12.5	8.1	5.9	3.1	90.3
NORTHWEST	4.7	5.5	11.3	8.1	10.4	7.8	10.6	7.2	5.0	12.1	7.8	5.4	4.2	88.7
EASTMIDS	4.0	4.9	7.5	9.8	8.9	11.4	13.6	6.3	4.8	15.6	5.9	3.8	3.3	90.2
WESTMIDS	3.1	4.0	7.9	6.7	14.5	10.8	13.4	6.7	4.4	15.5	6.2	3.1	3.5	85.5
EASTANGLIA	3.0	3.2	6.2	4.6	5.0	17.6	16.7	8.9	6.8	15.5	4.7	2.9	4.8	82.4
OUTERSEAST	2.8	4.2	6.7	5.2	5.0	11.2	16.9	9.7	9.0	15.2	5.5	3.7	5.0	83.1
OUTERMET	3.0	5.3	7.0	5.4	3.8	9.3	13.6	14.3	10.2	12.9	5.2	4.6	5.5	85.7
LONDON	2.3	6.3	6.6	5.9	3.2	6.7	13.1	11.7	16.7	11.1	7.0	3.2	6.2	83.3
SOUTHWEST	2.6	3.4	7.0	5.9	6.7	12.2	16.3	7.8	6.3	18.2	5.8	3.3	4.3	81.8
WALES	4.1	5.2	6.9	7.9	8.5	9.0	11.5	6.4	4.9	13.8	12.7	5.8	3.3	87.3
SCOTLAND	4.3	6.6	7.4	5.8	3.7	7.4	8.5	8.1	4.9	9.5	9.7	17.8	6.4	82.2
NIRELAND	1.6	3.7	4.2	1.3	3.0	4.2	7.7	6.5	8.3	7.0	6.7	7.8	37.9	62.1
Conn. to others	40.9	57.3	80.2	74.5	75.3	107.7	145.5	93.3	73.0	154.1	80.0	56.7	52.2	Total Connectedness
Conn. incl. own	52.9	67.0	91.5	84.3	89.8	125.3	162.4	107.6	89.7	172.2	92.7	74.6	90.1	83.9%
Net direct. conn.	-47	-33	-9	-15	-10	26	63	7	-10	72	-7	-25	-10	

Notes: The underlying variance decomposition is based upon a quarterly VAR of order 2. The number of lags (2) have been selected based on the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Connectedness indices, given by Equations (2)-(7), calculated from variance decompositions based on 4-quarter ahead forecasts.

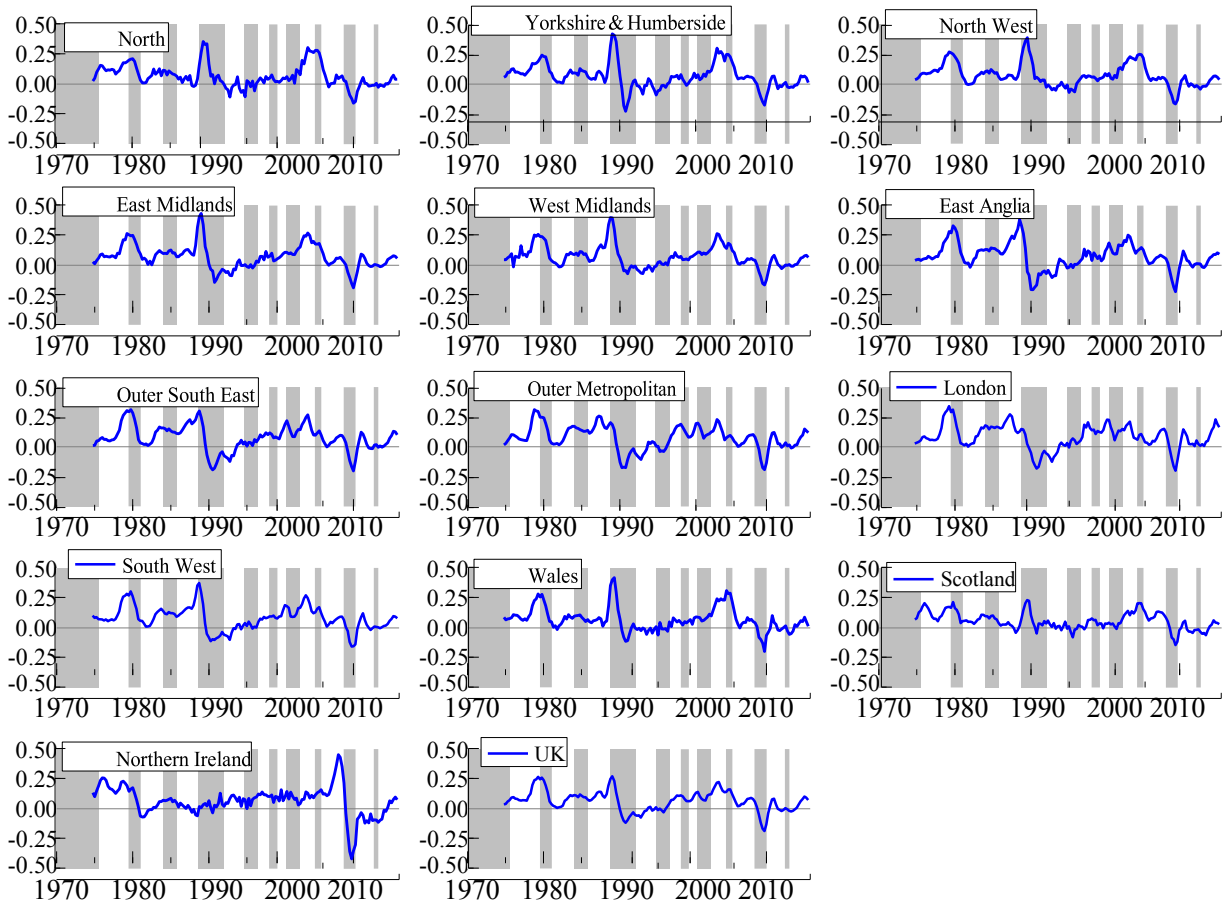
Figure 1: UK regional property price indices



Notes: Grey shading denotes UK recessions as defined by OECD.

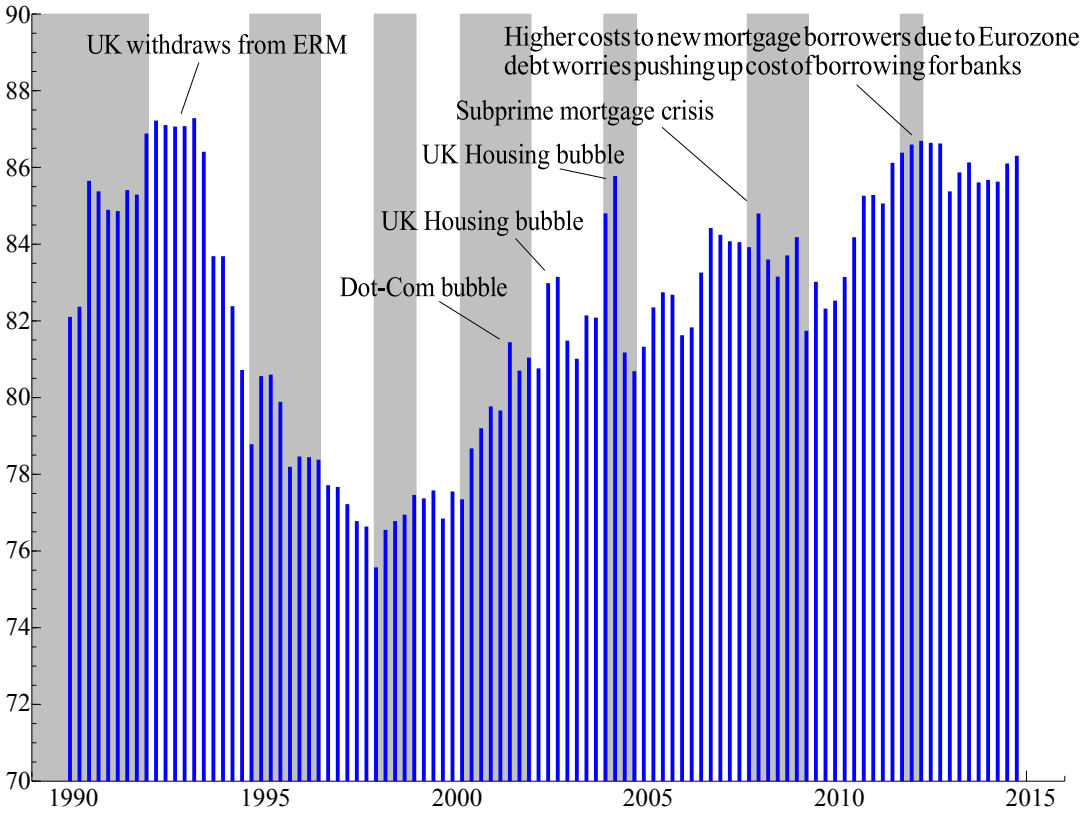
Source: Nationwide database.

Figure 2: UK regional property returns



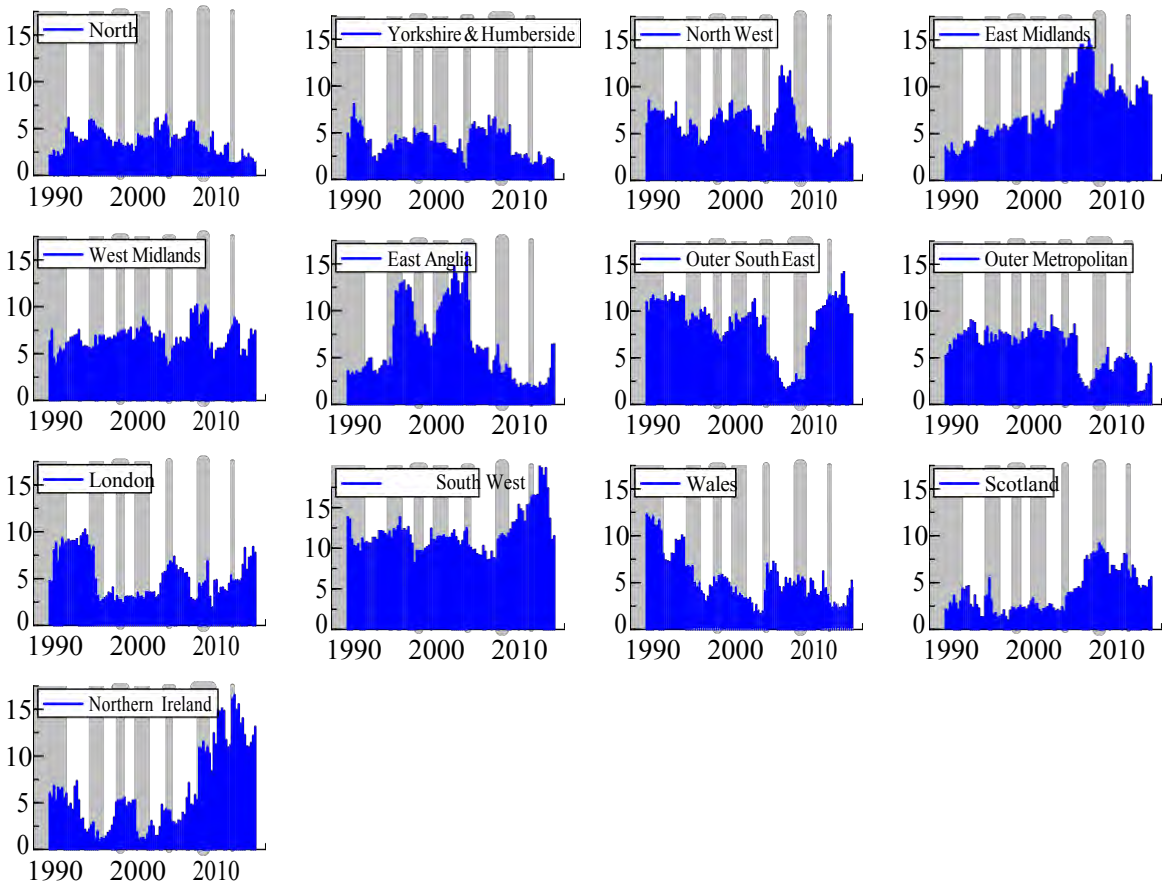
Notes: Author's calculations based on Nationwide statistics. Grey shading denotes UK recessions as defined by OECD.

Figure 3: Total connectedness of UK regional property returns



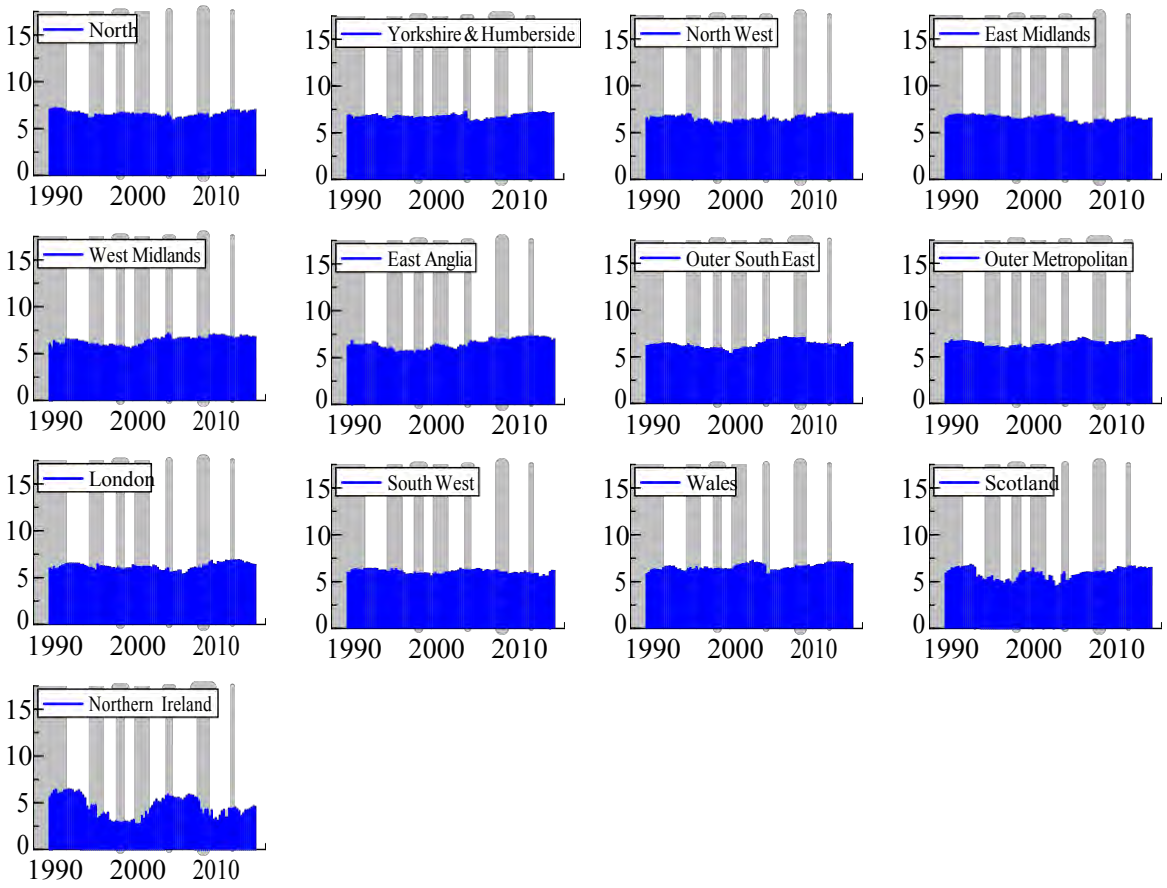
Notes: Plot of moving total connectedness estimated using 60-quarter rolling windows (and hence starting in 1990Q1). Grey shading denotes UK recessions as defined by OECD.

Figure 4: Directional connectedness *from* UK regional property returns



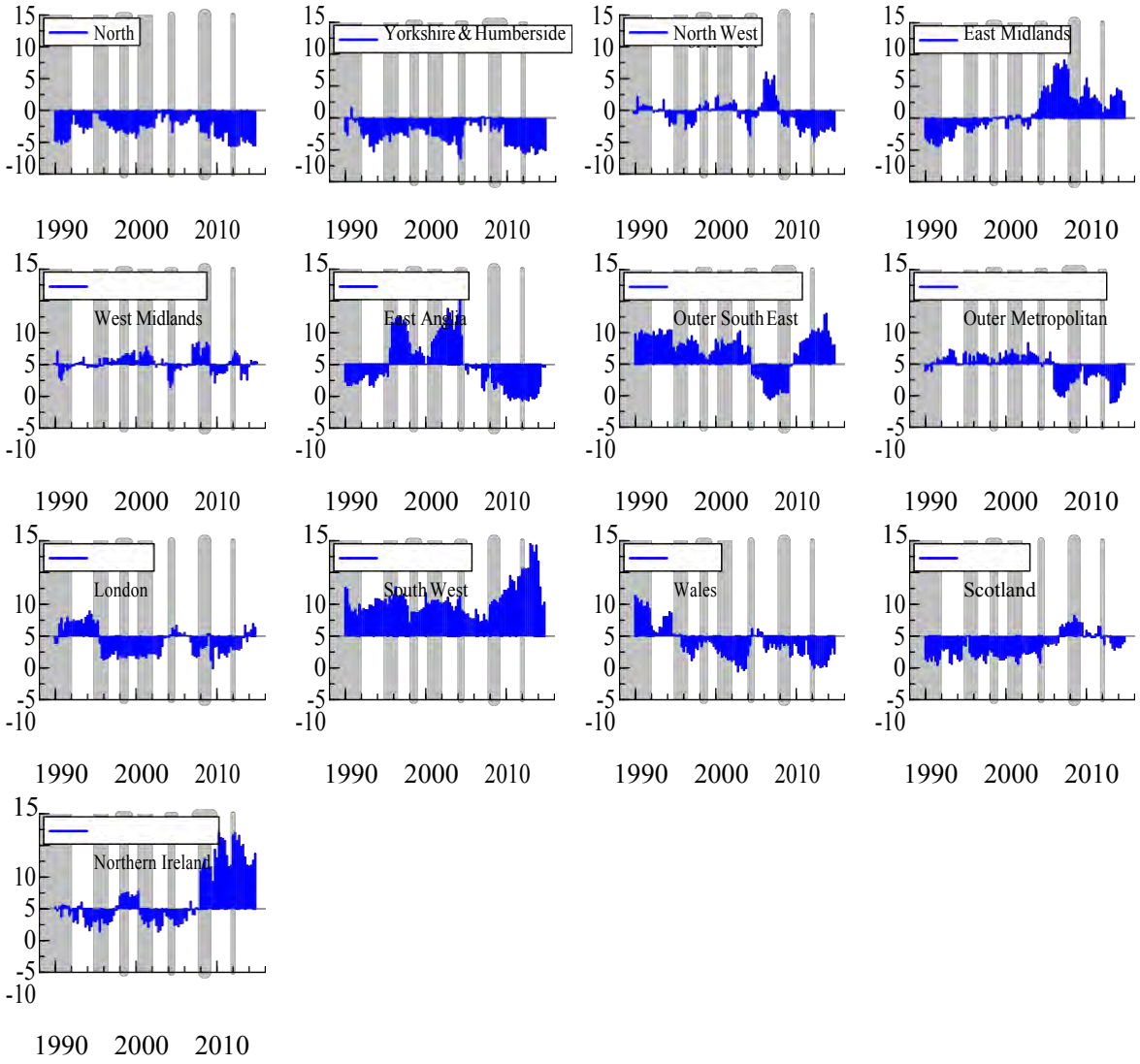
Notes: Plot of moving directional connectedness estimated using 60-quarter rolling windows. Grey shading denotes UK recessions as defined by OECD.

Figure 5: Directional connectedness *to* UK regional property returns



Notes: Plots of moving directional connectedness estimated using 60-quarter rolling windows. Grey shading denotes UK recessions as defined by OECD.

Figure 6: Net directional connectedness of UK regional property returns



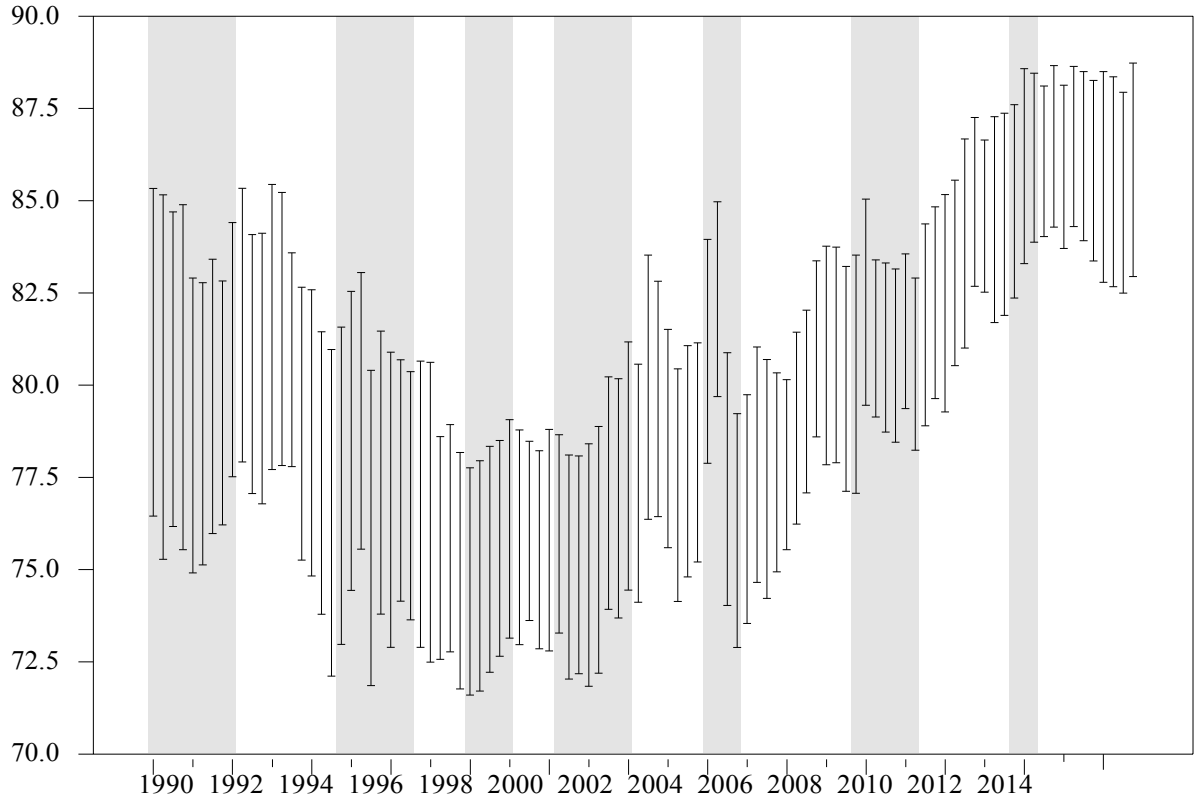
Notes: Plot of moving net directional connectedness estimated using 60-quarter rolling windows. Grey shading denotes UK recessions as defined by OECD.

Figure 7: Net pairwise directional connectedness of UK regional property returns

[Insert url https://goo.gl/miQ3uQ to Fig. 7 here]

Notes: Interactive plot of moving net pairwise directional connectedness estimated using 60-quarter rolling windows. Grey shading denotes UK recessions as defined by OECD. NOR=North, Y&H=York & Humberside, NW=NorthWest, EM=East Midlands, WM=West Midlands, EA=East Anglia, OSE=Outer South East, OM=Outer Metropolitan, LON=London, SW=South West, WAL=Wales, SCO=Scotland, NI=Northern Ireland. Thicker lines between nodes correspond to higher degree of connectedness.

Figure 8: Maximum and minimum total connectedness based on Cholesky factorization with random permutations



Notes: Plot of maximum and minimum moving total spillover index estimated based on Cholesky factorization with 200 randomly chosen orderings using 60-quarter rolling windows. Grey shading denotes UK recessions as defined byOECD.