Measuring the Cointegration of housing types in Northern Ireland.

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Abstract

The primary purpose of this paper is to examine the dynamic and Granger causal (inter) relationships between house prices and to empirically assess the co-movement in house prices across different property types within Northern Ireland (NI). The Johansen cointegration, Granger causality tests and vector error correction model are applied to quarterly house price data for the NI housing market between Q1 1995 and Q2 2018 to determine whether price transmissions are propagated contemporaneously into both short-term and long-term price adjustments. The findings show the stylised facts of lead-lag relationships across property types in NI using long-term Granger causality tests that the performance of the *Apartment* sector systematically and consistently lagged behind all other residential property segments over the period. Indeed, the results indicate that there are obvious market filtration transmission pricing signals in operation in a Granger-causal fashion. Property price signals are observed to be transmitted from the more liquid owner-occupier-led *Detached* and *Semi-detached* segments to the *Apartment* segment, but not vice versa.

Key Words: Price diffusion; Housing markets, Causality, Cointegration, Error correction model

I Introduction

The Northern Ireland (NI) residential property market has experienced severe turbulence over the last 15 years. Initially fuelled by the wholesale availability of comparatively cheap debt finance, and galvanised by the 'feel good' factor radiating from the 'Celtic tiger' effect within the Republic of Ireland, the NI housing market witnessed a dramatic speculative boom-bust cycle far beyond that of any other UK jurisdiction outside of London. During the boom phase, the average house price increased by 178 percent in a three year period (2004-2007), with the bust environment (2007-2013) observing an reduction of circa 50% from market peak. The housing market, although showing signs of stabilisation, arguably continues to exhibit uncertainty compounded by ongoing political instability in to the wake of Brexit and the weaker than expected economic regional recovery. This has raised questions pertaining to market efficiency and the role of irrational house price expectations in driving local housing price cycles. With this in mind, there has been distinctive house price cycles across different property types across Northern Ireland.

Recent literature and studies pertaining to housing price modelling have tended to investigate the importance of spatial interdependence of residential prices or ripple [spill-over] transmission shocks of prices between housing market areas. Indeed, an extensive range of literature (Chen *et al*., 2011; Gray, 2013) at the international level exists which illustrates varying price shocks distribution and impacts between cities and regions. These studies apply various econometric approaches to investigate the transmission mechanism amongst prices revealing high (and low) pattern of causality and the propagation of shocks across cities and regional areas. Acknowledging this wealth of insights into the spatial decomposition of house price analysis, limited empirical insights have sought to capture an understanding of the stylised facts of the lead-lag relationships between the distinctive house prices across the various housing sub-types with the exception of notable investigations into housing sub-market price differences seen in studies by Jones *et al*. (2004), and Hui, (2011). Indeed, whilst the natural assumption may be that the pricing of housing types all move at the same time and are affected in more or less the same way, this may not always be the case. Each housing sector can be, in their own right, conditioned by exogenous market, economic and financial fundamentals with the price mechanism adjusting accordingly, but this may not at the same speed.

This forms the rationale and basis of the empirical analysis and scope for this paper which analyses the cyclical co-variations, interactions and transmission of house prices by sector type in the context of Granger causality in an attempt to understand the characteristics and nature of the price interactions. This enhanced disaggregated analysis of house price dynamics is of fundamental importance for explaining the relative transmittal and endogenous shocks between and within different housing types, which would aid policy makers, valuation and potential investment in future housing provision. Indeed, as Bourassa *et al.* (2003) argue, real estate price movements can be more accurately detected based on the housing market segmentation adopted by valuers. Therefore, this paper examines the following questions. Firstly, is there segmentation between different housing types in Northern Ireland? Namely, are house prices reflective of market integration and covariance. If there is evidence of short- and long-run deviations, or lead-lag relationships evident between the different housing sectors, is this harmonious with expectations adopted or wider non-fundamental based mechanisms. Secondly, do the price movements in one housing type filter through the market and have an auxiliary impact upon another housing type? These are important questions for housing market efficacy, housing market analysis and future housing policy development. In this regard, there is increasing appetite and market demand to accurately forecast fluctuations in future prices of housing.

A better conceptualisation of the price segmentation within property markets of great importance for property valuation, investment and urban planning. Goodman and Thibodeau (1998) concluded that more thorough understanding of housing market segmentation and associated pricing inter-relationships between property typologies will enhance the predicted accuracy of mathematical models employed to determine house prices and will enable academics and practitioners to model spatial and temporal relationships within these prices. With this in mind, assuming expectations of sub-type price patterns, this paper attempts to investigate endogenous time series components by focusing on the trends and relationships by further concentrating on temporal lag patterns and autoregressive structures. Accordingly, this paper, empirically examines the segmented nature of various sub-markets by property type inter-linked by causation of their respective price movements – consistent with the sub-market hypothesis generally confirmed in the housing literature (Allen *et al*., 1995; Rothenberg *et al*., 1991).

The paper is structured as follows. Section II presents a review of the literature, followed by an explanation of the time series data and methodological approach being utilised in Section III and IV. A discussion of the key findings is presented in Section V. Conclusions and policy implications are offered in Section VI suggesting that the causal lead-lag integration of house price cycles within particular sub-market sectors drive price dynamics in other sectors.

II Literature Review

Residential housing markets have been the subject of a plethora of empirical studies examining the dynamic linkages amongst regional house prices and the associated interconnections with the financial landscape, macroeconomy and within the confines of portfolio analysis. Indeed, a wealth of extant research have applied structural time-series models to examine house price series (Chen, 2003), with the vast array using cointegration based analysis for determination of the long and short-run relationships. The first strand in the literature pertains to the economic and financial context where numerous studies (Ho and Calero Cuervo, 1999; Hofmann, 2003; Liang and Cao, 2007; Adams and Füss,2010; Hepşen and Vatansever, 2012; Hinch, McCord and McGreal, 2019) have examined the cointegration of house prices with macroeconomic and lending variables amongst others, with studies (Tse, 2001; Chung, 2012) also investigating the relationships between financial determinants and capital markets.

Secondly, the strand which remains the most extensively researched relates to house price diffusion across space, focusing on the examination of spatial dependence or ripple effect within regional disparities in house price levels and rates of house price growth (Huang, 1999). Seminal studies (MacDonald and Taylor, 1993; Alexander and Barrow, 1994; Ashworth and Parker, 1997; Pollakowski and Ray, 1997; Meen, 1999 and Cook, 2003) signposted that changes in fundamental variables such as regional incomes or differences in the structure of regional markets adjust dynamically and act as a regional adjustment mechanism (Jones and Leishman, 2006). Indeed, a cornerstone of the debate surrounding pricing levels, in a spatial sense, revolve around Pollakowski and Ray's (1997) "positive-feedback" hypothesis and what Wood's (2003) terms the 'perfect ripple'– the propensity for average house prices to rise first in a region and then filter out to the surrounding areas characterised by initial divergence from long-run established norms beyond the normal bounds of its differentials with the rest of the local system which is 'corrected' by the rest of the country catching-up returning the differentials to their long run levels (Gray, 2012). Indeed, a considerable amount of international empirical work on regional house price convergence and the role of spill-over effects has been undertaken since (Oikarinen, 2006; Vansteenkiste and Hiebert, 2011; Shi, Young and Hargreaves, 2009; Luo, Liu and Picken, 2007; Chien, 2010; Chen et al., 2011; Lee and Chien, 2011) presenting mixed results.

Within the UK and Irish context, a wealth of studies have also examined the long - and short-run relationships between house prices advancing the debate using various methodological approaches. Cook and Thomas (2003) find evidence demonstrating that a ripple effect is evident, nonetheless in a follow up study, Cook (2005) uses analysis of cointegration in the presence of asymmetric adjustments and illustrates that whilst the results support the existence of a ripple effect, the extent of cointegration casts doubt upon any notion of weak segmentation in the UK housing market. Despite these claims, Holmes (2007) results indicate that the majority of UK regions exhibit regional house price convergence, nonetheless presented evidence for an east-west split on Mainland UK, in terms of whether regional house prices have a tendency towards long-run equilibrium relationship with UK prices as whole. Further, Holmes and Grimes (2008) conducted analysis to establish whether there is long-run convergence of regional house prices. They find evidence that regional house prices are driven by a single common stochastic trend. Moreover, their results suggest that those regions that are more distant from London exhibit the highest degrees of persistence with respect to deviations in house price differentials.

In a more localised approach, Gray (2012), building upon the work of Jones and Leishman (2006), highlight that house price spill-overs north of the East Midlands appear much more rapid than would be consistent with a 'ripple', suggesting that there is some support for undertaking British housing market analysis on a spatially segmented basis, even at a regional level. This is in keeping with the work of Abbott and De Vita (2013) who tested for stochastic convergence in UK regional house prices, finding was that there is no evidence of long-run convergence among regional house prices or of an equilibrium relationship. Montagnoli and Nagayasu (2015) also analyse the convergence and spill-over effects of house prices across UK regions. Their research rejects the single steady state of a consistent ripple finding that house prices across UK regions can be grouped into four clusters, confirming the heterogeneity and complexity of the UK housing market.

Similarly, for Ireland, the seminal work of Stevenson (2004) revealed evidence of a large degree of diffusion takes place, particularly from Dublin to the other regions, in a manner that is similar and consistent with the UK ripple effect. Interestingly, the results seemingly also appear to support the view that the Northern Irish market is more linked with the housing market in the Republic of Ireland than with the rest of the UK. Similar to the work of Stevenson(2004), Gray (2013) employed spectral analysis showing evidence of a dominant 6-year cycle common to all of Ireland's city markets implying that house prices neither conform to 'a city system' or a ripple thesis – more akin to an olicentric structure.

Whilst the literature investigating spatial ripple effects and the diffusion of price changes has been capacious – arguably revealing mixed results, there has been relatively limited examination of sub-sectoral market analysis and the transmission of non-fundamental components of house prices. Traditionally house price diffusion across geographic market segments and quality tiers (Sweeney, 1974) have lead these discussions. Clapp *et al.* (1995) present seminal arguments for the role of information diffusion processes in and between specific geographic market segments in US cities. More recently, Balcilar *et al.* (2013) analyses house price diffusion across a number of property types in five major metropolitan areas of South Africa over the period 1966 Q1 to 2010 Q1. Using Bayesian and non-linear unit root tests, they find that ripple effects originate in Cape Town for the large housing segment and in Durban for the medium- and small-sized houses. In terms of quality transmission effects, Ho *et al.* (2007) examined the Hong Kong market, dividing housing markets into quality tiers premised upon income level and willingness to pay. The findings revealed that 'wealth shocks' in lower quality homes, spill-over into higher quality homes through this wealth substitution effect which the authors argue manifests in a "domino effect" that spreads across the various quality tiers. Other research has studied the aspect of quality tiers applying cointegration and Granger causality. Indeed, Coulson and McMillen (2007) find that the prices of lower-quality housing in an urban area are kept in line with higher-quality dwellings, with prices of higher-quality houses rising disproportionately with the other property types in the short run, but over the long-run the lower-quality stock catches up.

Apergis and Payne (2011) and Kim and Rous (2012) also study the house price convergence in panels of US states and the possibility of a convergence club where the cross-sectional dispersion of house prices of the club members decreases over time. Applying a clustering algorithm, their results support the view that there is strong evidence of multiple convergence clubs and house prices do not converge to a common trend. This lack of overall or ultimate convergence indicates that individual house prices can be grouped into multiple subgroups such that common house prices are very distinctive across clubs and there is a marked reduction in dispersion of cross sectional variances within a convergence club. Meng, Xie and Zhou (2015) also examine this 'club convergence' of house prices across ten key cities in China based on both linear and non-linear econophysical and econometric methods. The authors identify a common collective driving force which accounts for 96.5% of the house price growth, indicating very high systemic risk in the Chinese housing market. Pertinently, they categorise the cities into clubs and the house prices of the cities in the same club exhibit an evident convergence which are consistent with the conventional classification of city tiers. Their findings indicate that house prices of the first-tier cities grow the fastest, and those of the third- and fourth-tier cities rise the slowest, which illustrates the possible presence of a ripple effect in the diffusion of house prices in different cities.

There has been a paucity of research undertaken which has examined the stylised facts of housing price diffusion across different housing typologies for understanding the cyclic interactions within sub-sectoral market analysis. Renauld *et al.* (1998) originally highlighted that there are distinct differences in cycles across different types of housing, which has been subject to notable investigations into housing submarket price differences such as Jones *et al.* (2004). A more recent study conducted by Hui (2011) examined the cyclical dynamics of landed and non-landed housing sub-markets in Malaysia. Using Band-pass filters to extract the cyclical components from the four house price series, interactions between house price cycles are documented using cross-correlation analysis, Granger causality tests and impulse response functions. The findings demonstrated that condominium price cycles appear to be exogenous and lead the price cycles in other market sub-sectors by one to two quarters and predict the price diffusion across particular sub-sector markets.

Overall, the preceding studies have revealed both complimentary and contrasting findings in terms of house price diffusion and convergence patterns. Whilst a majority of this research shows linkages with the macroeconomy, capital and financial markets to house prices and the spatial dynamics across regions, there is less research regarding the movements between market segments and how house price co-movements interact to generate an urban house price trend. These are equally important considerations given that understanding these cyclic and stylised facts of the price patterns and signals can provide a basis for informing valuation practice, investment decisions for potential and existing home buyers and provides policy makers and particularly lending institutions with understanding of the unique features of the apartment segment and future price movements. In light of this, and in line with the research of Hui (2011), we analyse the price movements between housing market sectors.

III Time Series Data

Over the course of the past two decades the Northern Irish property market has witnessed periods of boom and bust as well as times of temporary stability through the various changes in the political, demographic and socioeconomic landscape (Figure 1). Historically speaking, the *Detached* market has always been the most buoyant and robust housing category in terms of pricing, followed by *Semi-detached*, *Apartment* and *Terraced* market segments. Average house prices witnessed relatively stable and gradual growth starting from 1996, against the backdrop of improved political certainty over issues surrounding the peace process. The normalisation culminated in the signing and implementation of the Belfast Agreement (or more commonly known as the Good Friday Agreement) in April 1998, which maintained the *status quo* and position of Northern Ireland within the United Kingdom. The housing market remained reasonably calm, with price growth measured during the early 2000s. The surge in house price inflation, across all property types became more pronounced and explosive from 2006 with the average price increasing 46% on a year-on-year[1] basis, outstripping growth in any other regions of the U.K. Indeed, price inflation surged to a new peak in Q2 2007 in the form of a bubble for most key property types in response to a confluence of social and

[1] See: http://news.bbc.co.uk/1/hi/northern_ireland/6712089.stm

macroeconomic factors such as easier access to capital on the mortgage market (McCord *et al*., 2011), over-optimism about the property sector, persistent inflow of foreign direct investment, rising employment and strong speculation-driven domestic demand.

The steep escalation of prices was followed by an equally steep decline from 2007 onwards with the process of rapid bubble deflation characterised by growing commercial and residential property loan defaults and repossessions, shrinking of the mortgage market and sharp contraction in construction activity. In contrast to the wider UK regional markets, the average house price plummeted by over 30% during the period of 2007 to 2008 with property prices correcting by as much as 55% in late 2010 in comparison with their peak in 2007 with gradual declines noticeable until the end of 2011 when the market 'bottomed-out'. Since this market correction period, the housing market has observed a gradual recovery, albeit uneven across housing segments, showing signs of price stabilisation and more latterly gradual increases. Nonetheless, the political risk arising from Brexit and the possibility of a hard-border being imposed on the Island of Ireland still pose significant degree of uncertainty to property investors and homebuyers ensuring that market sentiment in the wake of the Brexit vote has remained cautious.

<<<Insert Figure 1: Historical Trends of the Northern Irish Property Markets by property type (1995-2018)>>>

In terms of inter-relationships between housing segments, it is interesting to observe (Figure 1) that whilst the four key property types seem to be trending in a roughly similar direction over time, there indeed seemingly exists lead-lag relationships amongst them. In particular, the *Apartment* market appears to consistently lag other property types. Furthermore, there appears to be evidence of micro-cycles continuing to occur after the market correction period (2012-2018), indicating that market recovery has been relatively volatile – particularly for the *Detached* and *Apartment* sectors of the market. Table 1 presents the descriptive statistics for the property types over the data series, which is also dissected into the boom-bust periods respectively.

<<<Insert Table 1 Descriptive statistics for the property types between 1995 and 2018>>>

IV Methodology

ADF Unit Root Tests

Given these noticeable variations we proceed to empirically examine the causal relationships between the performance of the four main property sub-markets. Accordingly, Cointegration and Granger causality tests are conducted for the period of 1995 Q1 to 2018 Q2. The performance of the sub-markets is proxied by their respective average quarterly prices which are derived from an established property index (UU HPI) which are calculated based on large and representative sample size of open market transactions in Northern Ireland[2]. Initially, the time series is examined for any potential structural breaks given the potential volatility

[2] The UU HPI was established in 1984 and records circa 40% of residential property transactions across the region of NI. The HPI measures the current price and quantities in relation to the base period. The index is based on quarterly returns obtained from 103 contributory estate agency practices from across Northern Ireland and supplemented with recorded and verified sale transactions from Propertynews.com. The sales information is also cross-correlated with the domestic capital valuation register for inspection and verification of attribute information.

evidenced in 2002 for the detached data. Six Chow Tests on the *I*(I) series of Detached across 2001 Q4 – 2003 Q1 were performed to test for structural breaks. The *F*-statistics for each test proved statistically insignificant thereby confirming that no structural breaks were present[3]. The data was further examined for the presence of non-stationarity and a unit root which renders spurious regressions that could result in unreliable inference (Granger and Newbold, 1974; Banerjee et al., 1993). In this regard, we employ the Augmented Dickey-Fuller (ADF) unit root test which is given as follows:

$$\Delta Y_t = \alpha + \beta T + \emptyset Y_{t-1} + \sum_{i=1}^{k} \partial \Delta Y_{t-i} + \varepsilon_t \qquad (1)$$

where Y_t is the level of the time series in question; α is a constant term and T is a time trend; $\emptyset$ is to be tested for the existence of unit root with the null hypothesis (H_0) being $\emptyset = 0$ against the alternative hypothesis (H_1) of $\emptyset \neq 0$, k is the number of time lags for obtaining white noise, which is in our analysis determined by Schwarz information criterion; and ε_t is an error term with mean equal to zero and constant variances.

Cointegration Tests

To analyse whether long term equilibrium cointegration relationships exist between the time series of the sample property types, we utilize the Cointegration tests developed by Johansen (1991; 1995) which takes the form of:

$$\Delta Y_t = ɳ Y_{t-1} + \sum_{i=1}^{k} ɽ_i \Delta Y_{t-i} + BX_t + \varepsilon_t \qquad (3)$$

where $ɳ = \sum_{i=1}^{k} A_i - I$ and $ɽ_i = -\sum_{j=1+1}^{k} A_i$. Y_t is a k-vector of $I(1)$ that is no-stationary. X_t is a *d*-vector of variables that are deterministic and ε_t is an vector of error terms with zero mean and finite variance. ɳ is called the rank of the coefficient matrix, which indicates the number of cointegrating vectors in the equation[4]. As determined by Engle and Granger (1987), it is to be highlighted that the main variables under investigation should have the same order(s), and are integrated of order one.

Granger Causality Test in Error Correction Models

According to Engle and Granger (1987) and Granger (1988), if two variables are statistically significantly cointegrated at the first or higher level, their long-run relationship would be mis-specified if the traditional Granger method is employed. An ECM-based Granger causality equation is given by:

$$\Delta Y_t = \lambda + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + \sum_{j=1}^{q} \beta_j \Delta X_{t-j} + \phi z_{t-1} + \varepsilon_t \qquad (4)$$

[3] The Chow test results can be evidenced in Appendix 1.

[4] According to Johansen (1991), the cointegration test should be carried out by first estimating ɳ in an unrestricted form, and then establish whether or not the restrictions implied by the reduced rank of ɳ can be falsified. Trace test statistic can then be obtained by conducting the likelihood ratio test for the hypothesis that there are at most *r* cointegrating vectors, against the alternative of m cointegrating relations.

where λ is the intercept. p and q are the length of lags that are sufficiently large enough to produce an error term ε_t that is white noise. z_{t-1} is the error correction term and ϕ is the coefficient to be estimated. In the equation, all terms are $I(1)$.

An ECM Granger causality test is statistically appealing in that it can capture both short- and long-run equilibriums or dynamics, if any, of a given cointegration relationship. In Equation 4, $\beta_j's$, representing the coefficients of lagged independent variables ΔX_{t-j}, indicates the short term response of Y to change in X. In other words, β_j reflects the short term elasticity of Y with respect to X. z_{t-1} represents the long run dynamic between the two variables. Mathematically this is expressed as follows:

$$z_{t-1}=Y_{t-1}-w_0-w_1X_{t-1}+w_2t \qquad (5)$$

The coefficient of X_{t-1}, w_1 measures the long run elasticity of Y with respect to X (Thomas, 1997). t is a time trend and w_2 its coefficient. Furthermore, ϕ, commonly known as adjustment coefficient, signals the speed with which the variables adjust their short run disequilibria towards an equilibrium in the long run, or the degree of correction the short run disequilibria achieved relative to their long run equilibrium during the next time period t. Mathematically, the error correction term is positive if changes in the dependent variable are above its average value. In other words, ΔY_t has to move downwards to converge to the path of equilibrium in the long run, making ϕ negative. On the other hand, if ΔY_t is below its average value, the EC term is negative and the coefficient ϕ should be expected to be negative to drive the dependent variable upward (Ghosh, 1995). To summarise, the error correction term is designed to "push" *Y* back toward the long term equilibrium position[i].

V Empirical Results

Results of ADF Unit Root Tests

According to Hamilton (1994), if the time series appears to exhibit a trend, whether it is stochastic or deterministic, the approach should incorporate both a constant term and a trend in the regression equation. Preliminary analysis indicates that the time series in this study appears to display trends and exhibit non-zero means over the investigation period, and hence both a constant term and trend are included. The results of the ADF Unit Root tests on both level and first difference series of the variables are reported in Table 2. The tests show that the time series is non-stationary at levels and stationary when first differenced at the 5% confidence level. Accordingly, we use an $I(1)$ series in our analysis.

<<<Insert Table 2: Results for ADF Unit Root Tests>>>

Cointegration Tests

The results of the Johansen cointegration tests on all pairs of sub-market performance time series are presented in Table 3, with the results revealing that all market sectors are cointegrated at the 5% confidence level. Accordingly, there exists empirical evidence suggesting a long-term equilibrium relationship linking each of the sub-markets[5].

<<<Insert Table 3: Results of Cointegration Tests>>>

In light of the above, the cointegrating vector (z_{t-1}) of the equilibrium relationship for each pair of performance time series is investigated as per Equation 6 (a-f), with the findings observed in Table 4. The cointegrating vector indicates the long-term elasticity of variable Y with respect to variable X. In our analysis, for instance, the estimates for cointegrating vector ($z_{t-1,a}$) suggests that the long-run elasticity of the price of *Apartment* with respect to that of *Detached* is -1.0455, which is nearly negative unitary. In all other cases, the absolute magnitude of the vector is below 1, which seemingly suggests that prices of each pair of those house types tend to diverge over time. Most noteworthy of all is the cointegrating relationship between *Semi-detached* and *Terraced* houses, whose cointegrating vector ($z_{t-1,e}$) reveals the smallest absolute magnitude of elasticity of 0.6780, implying that the price dynamics between this pair of housing sub-types is the least responsive and the most inelastic compared to the others' in the long-run. The other time series combinations reveal values of w_1 in the range of 0.77 to 0.97. Overall, the results on z_{t-1} infer that the Northern Ireland's property markets do not seem to display any significant 'ripple effect' in the short term. With regards to estimates on ***t*,** all of the pairs of time series exhibit a downward-sloping trend with the exception of that of $z_{t-1,c}$. The graphical presentations of cointegrating vector for each pair of property sub-markets against time are displayed in Figures 4a– 4f.

<<<Insert Table 4: Coefficient Estimates for Cointegration Equations>>>

<<<Insert Figure 2: Cointegrating relationship between housing segments over time>>>

Granger Causality Tests in the ECM

Given that all sub-type performance time series are $I(1)$ processes but cointegrated over the investigation period, we perform the Granger causality test in the framework of ECM in first differences to examine the long-run lead-lag effects with Wald X^2 tests being utilised to determine the lead-lag relationship[6]. As observed in Table 5, the estimates of the ECMs (Models 1 to 12) as well as the results of the Granger causality tests for each of the sample sub-market time series have passed the conventional diagnostic tests[7]. With regards to the short-run Granger causality tests on the lagged regressors, the Wald test statistics (X^2) for the null hypothesis of no Granger causality is rejected for Models 1, 3, 6, 8 and 12 at the 5% confidence level, as revealed by the corresponding p-values. Hence, it can be inferred that both *Detached* and *Semi-detached* Granger-cause *Apartments*, whilst *Apartments* and *Semi-detached* both Granger-cause *Terraced* in the short-run. All other remaining models do not

[5] We observe at least one unidirectional Granger causality link between each pair of time series. Note each pair of time series may have one or more linear combinations that are stationary.

[6] The Chow test was performed to test for structural breaks within the causality equations over the sample period. We observe various structural breaks at differing points in the cycle between the property types. The findings however show no inconsistencies between the full period and sub- periods. The results presented in Table 6 account for the inclusion of the Chow test findings.

[7] To check the stability and robustness of each model, we perform a number of conventional diagnostic tests. The Breusch-Pagan-Godfrey test is conducted to test for heteroscedasticity and Jarque-Bera test for normality. At the 5% confidence level, all models reveal no heteroskedasticy and their residuals are normally distributed.

show statistically significant results with respect to X^2, implying that there is no empirical evidence indicating any short-term lead-lag relationships between the respective property types.

We detect the long-term casual relationships, if any, between the time series by examining the signs as well as the statistical significance of the error correction terms (EC) of the ECM models. In total, six models display such lead-lag relationships (namely Models 1, 3, 5, 7, 9 and 11), suggesting that (i) the performance of *Detached*, *Semi-detached* and *Terraced* all Granger-cause that of *Apartment*; (ii) the performance of *Semi-detached* and *Terraced* Granger-cause that of *Detached* and (iii) the performance of *Semi-detached* Granger-causes that of *Terraced*.

<<<Insert Table 5: Results of Granger causality tests in ECMs>>>

It is further noteworthy that the direction of causality between any pair of housing sub-markets is uni-directional. Table 6 summaries the results of the short-term and long-term Granger causality tests.

<<<Insert Table 6: Summary of Granger Causality Tests>>>

Pairwise Granger Causality tests

As a robustness check, we further perform *Pairwise* Granger causality tests on the performance variables over quarterly time lags of one to four. Mathematically, the pairwise Granger causality Equation for two time series, Y_t and X_t, can be expressed as follows:

$$Y_t = a_o + \sum_{i=1}^{p} a_i Y_{t-i} + \sum_{j=1}^{p} b_i X_{t-j} + u_t \quad (7a)$$

$$X_t = c_o + \sum_{i=1}^{p} c_i X_{t-i} + \sum_{j=1}^{p} d_i Y_{t-j} + v_t \quad (7b)$$

For Equation 7a, the null hypothesis subject to empirical falsification is that X_t does not Granger-cause Y_t, which holds when $b_1 = b_2 ... = b_p = 0$. Similarly for Equation 7b, Y_t does not Granger-cause X_t when $d_1 = d_2 ... = d_p = 0$. u_t and $v_t$are error terms of the equations. If either hypothesis is statistically rejected, it implies Granger causation exists between the two variables. The results are presented in Table 7 with the F-statistic of each Granger equation reported. It is observed that the results are, at the 5% significance level, overwhelmingly consistent with those in Table 5. For example, it is revealed that *Detached* Granger-causes *Apartment* over time lag periods of one to four. *Semi-detached* and *Terraced* both tend to lead *Apartment* over all selected time lag periods. *Semi-detached* and *Terraced* both are (Granger) causally moving ahead of *Detached*. Lastly, *Semi-detached* is found to Granger-cause *Terraced*.

<<<Insert Table 7: Pairwise Granger Causality (over various time lag periods)>>>

Discussion of results

The empirical results stemming from the findings highlight a number of noteworthy characteristics about the underlying pricing structure of the residential housing market in Northern Ireland. First and foremost, *Apartment* appears to exhibit a very robust but asymmetric pricing dynamics with other property sub-market types in the long-run, with the performance of *Apartments* Granger-caused by *Detached* and *Semi-detached* in the short-run, and by all other sub-markets in the long-run. The pairwise Granger causality tests further indicate that the persistence of the Granger causal relationship could last up to four quarters. Interestingly, *Apartment* does not Granger-cause any other sub-market in the long-run and only Granger-causes *Terraced* in the short-run, which generally tends to be on the same pricing level in terms of market substitution. In other words, *Apartment* seems to lag behind other sub-markets in terms of price movement. We surmise that the findings could be attributed primarily to the unique nature of the Northern Irish Apartment sector, of which the market players are predominately speculative investors, the most typical rental product for young professionals and international visitors and predominantly the preferred choice (option) for first-time-buyers entering into the market.

A further explanation for the long-term lagged price performance of *Apartment* is concerned with the relatively thin liquidity of the sub-market. The Northern Irish property market is composed mainly of detached, semi-detached and terraced dwellings which are inhibited predominately by owner-occupiers, with apartments being the minority type of housing. Traders of apartment housing are prone to rely on transaction information of other property types to determine the prices of the properties, especially when the overall market trading volume is low (e.g. during the economic downturn post-*GFC*). Hence, price signals tend to diffuse to *Apartment* from other property sub-markets with a time lag. Moreover, this sector is reliant upon both rental price movements and mainstream market pricing to determine the market yield.

Secondly, random noise[8] associated with short-run supply and demand dynamics seem to be at play within the Northern Irish housing market system over the investigation period. Whilst it can be observed that *Apartments* appear to be Granger-caused by other property types in the long-run, it indeed Granger-causes *Terraced* in the short-run unidirectionally. We further note that *Semi-detached* Granger-causes *Terraced* and *Apartment* are led by *Detached* and *Semi-detached*. It is however evident that no statistically robust Granger causal relationship is found amongst the remaining eight pairs of property sub-markets for the short-run, implying indiscernible Granger lead-lag co-movement of the property types. Thirdly, there is empirically significant evidence suggesting that *Semi-detached* Granger-causes *Terraced*, which in turn Granger-causes *Detached*. Being the largest sub-markets in Northern Ireland in terms of amount of stock and trading volume, *Detached* seems to be leading the other sub-markets in terms of pricing. We further surmise that such Granger causal association between the sub-markets should become particularly robust and prevalent when the overall market liquidity is low, since property traders would rely more on price information emanating from relatively more abundantly traded sub-markets (e.g. *Semi-detached*) to infer prices of more thinly transacted sub-markets (e.g. *Detached*). Fourthly, we observe a short term bi-directional Granger causality link between *Semi-detached* and *Terraced*, suggesting possible bilateral information flow between the two sub-markets. However, such Granger causality effects tend to be short-lived and are largely dissipated after two lag periods (six months).

Overall, the findings provide evidence of segmentation of the pricing structure with the patterns of price changes not consistent placing an important emphasis on understanding house price activity. The results, in a Granger sense, suggest that both *Apartment* and to a lesser extent the *Detached* sector are exogenous to the rest of the remaining market sectors and act

[8] "Random noise" is defined as anticipated but not materialised information about market fundamentals (Giovanni, 2016)

independently. Indeed, these movements are congruent with Beltratti and Morana (2009) who propose that price surges or contagion may be a consequence of non-fundamental based mechanisms, such as ‘‘exuberant” expectations of future price increases, as the findings here arguably show that particular housing segments, as evidenced by their prices, may not be entirely reflective of underlying fundamental determinants.

There are obvious market filtration transmission pricing signals in operation from both the higher and lower end of the market pricing mechanism in a Granger-causal fashion. Both the *Detached* and *Semi-detached* sector appear to drive the lower end of the market with prices percolating into the *Apartment* segment, however, the same does not hold true filtering up the market pricing. This suggests that there are perhaps quality tiers in operation – reflecting a tiered market (pricing) system. This is also noticeable when considering the short and long-term relationships. At the higher end of the pricing levels, *Detached* and *Semi-detached* appear to show distinctive trends. The *Detached* sector does not show any short or long-term cointegration with the *Semi-detached* sector, however over the long-term, the *Semi-detached* sector appears to Granger-cause price movements in the *Detached* sector indicating that price movements are causally linked. Similar observations are also found in the sectors of *Terraced* and *Semi-detached* with the former leading the latter in terms of pricing.

VI Conclusion

Understanding the importance of pricing relationships between property types remains under-researched. The knowledge of how property prices are structured within a system of sub-markets is an area of profound research potential and bears significant practical implications for investors, academics, practitioners and policymakers. Indeed, new insights can be garnered through examination of how temporal price trends and patterns of different segments of a given property market vary with respect to consumption-investment behaviours of real estate traders, substitutability amongst property attributes, government policies and other idiosyncratic factors inherent in real estate such as heterogeneity and durability. This paper has examined the nature of the linkages between property types showing that a common price trend is present between a number of the sectors inferring that over the long-run prices do show co-movements and adjustments, or that the speed of adjustment, or adjustment mechanism, thereby shows that the price movements across most property types stay in line with one another in the long-term. In the short-run, the findings show the cyclic component and time delay between house prices, namely that the higher priced sectors move out of line with the apartment segment but over time the middle and lower pricing adjust accordingly, or in other words, price movements in the lower strata of the market over the long-term ‘catch-up’ and the market pricing structure is maintained. More specifically, we reveal the stylised facts of lead-lag relationships across property types in Northern Ireland using long-term Granger causality tests that the performance of the *Apartment* sector systematically and consistently lagged behind all other residential property segments over the period 1995 to 2018. These findings are important for understanding housing market segmentation and can feed into the topographical nature of understanding the housing market structure for future housing policy. Moreover, for valuation and pricing practices, this research is in line with Bourassa *et al*. (2003) who argued that real estate price movements can be more accurately detected based on the housing market segmentation adopted by valuers.

We posit, within the context of Northern Ireland, that the results emanating from this research could be due to the distinctiveness and uniquely exogenous nature and the underlying investor composition of the *Apartment* segment within which trading activities tend to be more speculative and investor driven, typically non-landed and more of an investment based product (buy-to-let) than the other housing types, being seemingly driven by the financial, lending and investment cycles as opposed to the housing market cycle.

With regards to the apartment sector demonstrating distinct market features, it is interesting to consider the requirements of many municipal authorities to repopulate their urban cores. Belfast is certainly amongst these, with ambitious plans to increase the central urban population. It seems difficult to envisage how the level of housing provision required can be delivered without extensive apartment development – the densities required are not possible without considerable use of this housing type. However, this research implies that there are distinct market factors separating apartments from other types – even the somewhat similarly sized terraced properties. It may imply that there are characteristics of apartment ownership and occupation which entice some and deter others, whilst also enacting a pricing discontinuity. There is likely to be a complex interaction of factors including more limited accommodation options (predominantly two-bed configuration), lack of outdoor space, including limitations on car parking, the implications of a very central location with associated noise, traffic and light pollution and also a generally rather high average access price. This has repercussions for any attempt to repopulate urban areas, with further consideration needed in relation to the ways in which the apartment provision can be tailored to broaden its appeal. Indeed, price signals occurring within other housing types will provide more certainty for implementing wider development objectives and planning to perhaps deliver higher density conforming to planning policy statements and development viability assessments for mixed tenure schemes. The findings, from a policy perspective may provide some insights for assisting government policy in terms of removing some of the speculation for strategic urban regeneration development and housing schemes.

Similarly, the findings can help inform the role of economic stimulus into the nature of government schemes such as help to buy initiatives which the results infer would not transmit into price inflation in the wider market. Considerable changes are occurring in many urban areas in Northern Ireland with alternative forms of residential property developments such as student accommodation and Private Rental Sector developments becoming increasingly effective and efficient. These unconventional development strategies both cannibalise and support existing and future provision of apartments, offering a different 'take' on city living, with a wide range of support services and more professional property management for prospective homebuyers and/or tenants. The scale of these changes is sufficient to suggest that added insight into the operation of market segments such as the apartment sector, which is warranted and valuable. In terms of bank financing, the apartment sector in NI currently requires higher Loan-to-Value ratios and depository requirements for mortgages. The findings pave the way to shed some empirical light on the pricing levels and inter-relationships between housing submarkets, which can perhaps assist private sector in undertaking financial stress tests in provisioning models for debt and for monitoring performance to reduce risk. Moreover, from a municipal finance perspective, it is important to note that differing pricing structures within the market place need to be understood to facilitate accurate valuation in any property taxation context and also in terms of forecasting such revenues for the purposes of financing urban renewal schemes.

Against the above contextual backdrop, the Northern Irish housing market could serve as a "social laboratory" for real estate researchers in the sense that its performance is governed by both local and global economic forces, which are in turn driven by a wide spectrum of investors, speculators and homebuyers of varying levels of consumption/investment elasticities and capital constraints. Moreover, the market is immensely compartmentalised along income, geographical, social, cultural and religious lines composing old and modern developments which should be the subject of further research in this area. We are therefore of the view that as an extension of this paper, future research efforts could be directed at exploring how the property price determination process (demand and supply determinants) in Northern Ireland varies amongst different cross sections of the market by utilising different methods of sub-market delineation.

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Appendix 1 Chow Test for structural breaks

	F-statistic	p
2001Q4	0.2702	0.604
2002Q1	0.5441	0.462
2002Q2	0.5441	0.462
2002Q3	0.1898	0.664
2002Q4	0.5735	0.451
2003Q1	0.6178	0.432

Varying regressors: All equation variables
Null Hypothesis: No breaks at specified breakpoints
Equation Sample: 1995Q2 2018Q2

[i] ECM methods must be employed to conduct the Granger causality test if the variables are cointegrated. Under the ECM framework, short-run and long-run causality tests are separately performed. More specifically, the Wald test can be used to test for the coefficient restriction on the first differenced terms since the coefficients β_j's measures the short term dynamics between the variables (Toda and Phillips, 1993). Long term causality between the variables can be examined by testing for the coefficient restriction on the error correction term. The null hypothesis of non-Granger causality should not be rejected if ϕ does not statistically deviate from zero. Conversely, ϕ should be negative and statistically significant if and only if a long run Granger causal relationship exists (Enders, 1995; Masih and Masih, 1997).

Tables and Figures

Table 1: Descriptive statistics for property types between 1995 and 2018

1995Q1-2007Q3	Avg.	Max	Min	S.D.
Apartment	£100,770	£205,178	£39,140	£39,076
Detached	£162,464	£369,609	£72,292	£71,983
Semi-detached	£99,169	£243,223	£39,554	£49,143
Terraced	£79,897	£199,392	£23,904	£42,653
All	£112,189	£262,150	£45,294	£51,383
2007Q4-2018Q2				
Apartment	£128,020	£238,449	£90,835	£34,923
Detached	£246,350	£354,527	£198,607	£32,870
Semi-detached	£143,942	£225,544	£117,607	£22,469
Terraced	£104,359	£187,350	£78,236	£26,029
All	£154,296	£253,073	£122,121	£29,270
1995Q1-2018Q2				
Apartment	£107,985	£238,449	£39,140	£41,398
Detached	£193,805	£369,609	£72,292	£75,011
Semi-detached	£115,248	£243,223	£39,554	£47,202
Terraced	£87,196	£199,392	£23,904	£39,180
All	£126,254	£262,150	£45,294	£49,764

Table 2: Results for ADF Unit Root Tests>>>

Time Series	*I(0)*	*I(1)*
Ln Detached	-1.42	-13.37
	(-3.46)	(-3.46)
	Lag Length =1	Lag Length =0
	R^2=0.14	R^2=0.67
	Adj. R^2=0.12	Adj. R^2=0.66
	DW= 2.08	DW= 2.11
	AIC= -1.84	AIC= -1.84
	F=4.96	F=89.43
Ln Semi-detached	-1.54	-4.46
	(-3.46)	(-3.46)
	Lag Length =2	Lag Length =1
	R^2=0.17	R^2=0.45
	Adj. R^2=0.14	Adj. R^2=0.43
	DW= 2.11	DW= 2.08
	AIC= -3.20	AIC= -31.9
	F=4.53	F=24.09
Ln Terraced	-1.70	-9.00
	(-3.46)	(-3.46)
	Lag Length =0	Lag Length =0
	R^2=0.09	R^2=0.48

	Adj. R^2=0.07 DW= 1.78 AIC= -2.53 F=4.34	Adj. R^2=0.47 DW= 1.99 AIC= -2.56 F=40.61
Ln Apartment	-2.04 (-3.46) Lag Length =0 R^2=0.05 Adj. R^2=0.03 DW= 2.22 AIC= -1.78 F=2.56	-10.86 (-3.46) Lag Length =0 R^2=0.57 Adj. R^2=0.56 DW= 2.00 AIC= -1.75 F=59.01

Note: The figures in parentheses are MacKinnon critical values at the 5% significance level.

Table 3: Results of Cointegration Tests

Apartment vs Detached	Hypothesis of cointegration equation(s)	
	None	At most 1
Eigenvalues	0.4296	0.2062
Trace test statistics	71.3126	20.7872
5% critical values	15.4947	3.8415
Probability	0.0000	0.0000
Apartment vs Semi-detached	Hypothesis of cointegration equation(s)	
Eigenvalues	0.3986	0.1072
Trace test statistics	55.9747	10.205
5% critical values	15.4947	3.8415
Probability	0.0000	0.0014
Apartment vs Terraced	Hypothesis of cointegration equation(s)	
Eigenvalues	0.4377	0.1243
Trace test statistics	63.7592	11.942
5% critical values	15.4947	3.8415
Probability	0.0000	0.0005
Detached vs Semi-detached	Hypothesis of cointegration equation(s)	
Eigenvalues	0.4782	0.0945
Trace test statistics	67.4746	8.9345
5% critical values	15.4947	3.8415
Probability	0.0000	0.0038
Detached vs Terraced	Hypothesis of cointegration equation(s)	
Eigenvalues	0.4643	0.1254
Trace test statistics	68.2424	12.0582
5% critical values	15.4947	3.8415
Probability	0.0000	0.0005
Semi-detached vs Terraced	Hypothesis of cointegration equation(s)	
Eigenvalues	0.4476	0.0931
Trace test statistics	62.1998	8.7939
5% critical values	15.4947	3.8415
Probability	0.0000	0.0030

Table 4: Coefficient Estimates for Cointegration Equations

Equation 6: $z_{t-1}=Y_{t-1}-w_0-w_1X_{t-1}+w_2t$					
Dependent variable	Independent Variable		Coefficient		
z_{t-1}	Y_{t-1}	X_{t-1}	w_0	w_1	w_2
$z_{t-1,\ a}$	ln(Apartment)	Ln(Detached)	-0.9125	1.0455	-0.0044

$z_{t-1,b}$	ln(Apartment)	Ln(Semi-detached)	0.5424	0.9637	-0.0035
$z_{t-1,c}$	ln(Apartment)	Ln(Terraced)	2.5772	0.7937	0.0002
$z_{t-1,d}$	Ln(Detached)	Ln(Semi-detached)	1.8702	0.8781	-0.0014
$z_{t-1,e}$	Ln(Detached)	Ln(Terraced)	4.2098	0.6780	-0.0050
$z_{t-1,f}$	Ln(Semi-detached)	Ln(Terraced)	2.5844	0.7796	-0.0040

Table 5: Results of Granger causality tests in ECMs>>>

Model 1

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
Apt	Constant	λ	0.0278	0.0215	1.2896	0.2007	
	Trend	T	-0.0003	0.0004	-0.8346	0.4063	
	EC	z_{t-1}	-0.1924	0.0808	-2.3825	0.0195	
	Lagged regressors	Apt(-1)	-0.0897	0.1069	-0.8389	0.4039	
		Apt(-2)	-0.0908	0.1059	-0.8569	0.3939	
		Det(-1)	0.0255	0.1259	0.2026	0.8399	X^2=6.53 Prob =0.04
		Det(-2)	0.2623	0.1120	2.3428	0.0215	

R^2=0.21 , Adj R^2=0.15 , DW=2.02 , AIC=-1.85 , F=3.66

Model 2

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
Det	Constant	λ	0.0442	0.0216	2.0479	0.0437	
	Trend	T	-0.0006	0.0004	-1.4844	0.1414	
	EC	z_{t-1}	0.0631	0.0810	0.7789	0.4382	
	Lagged regressors	Apt(-1)	0.1883	0.1073	1.7552	0.0829	X^2=4.63 Prob=0.10
		Apt(-2)	-0.0848	0.1063	-0.7977	0.4273	
		Det(-1)	-0.3272	0.1263	-2.5907	0.0113	
		Det(-2)	-0.1322	0.1123	-1.1774	0.2424	

R^2=0.21 , Adj R^2=0.15 , DW=1.98 , AIC=-1.85 , F=3.65

Model 3

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
Apt	Constant	λ	0.0196	0.0214	0.9191	0.3607	
	Trend	T	-0.0002	0.0004	-0.6192	0.5375	
	EC	z_{t-1}	-0.2998	0.1067	-2.8113	0.0061	
	Lagged regressors	Apt(-1)	-0.1370	0.1253	-1.0927	0.2777	
		Apt(-2)	-0.2154	0.1173	-1.8362	0.0699	
		SDet(-1)	0.0726	0.2357	0.3079	0.7589	X^2=7.11 Prob=0.03
		SDet(-2)	0.6056	0.2273	2.6638	0.0093	

R^2=0.27 , Adj R^2=0.22 , DW=2.03 , AIC=-1.93 , F=5.14

Model 4

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
SDet	Constant	λ	0.0204	0.0115	1.7653	0.0812	
	Trend	T	-0.0003	0.0002	-1.2818	0.2034	
	EC	z_{t-1}	-0.0300	0.0576	-0.5206	0.6040	
	Lagged regressors	Apt(-1)	0.0106	0.0677	0.1568	0.8758	X^2=2.83 Prob=0.24
		Apt(-2)	-0.0945	0.0633	-1.4915	0.1396	
		SDet(-1)	0.1175	0.1272	0.9234	0.3584	
		SDet(-2)	0.3502	0.1227	2.8532	0.0054	

R^2=0.19 , Adj R^2=0.13 , DW=2.07 , AIC=-3.17 , F=3.18

Model 5

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
Apt	Constant	λ	0.0305	0.0209	1.4560	0.1491	
	Trend	T	-0.0004	0.0004	-0.9536	0.3430	
	EC	z_{t-1}	-0.5281	0.1269	-4.1633	**0.0001**	
	Lagged regressors	Apt(-1)	0.0138	0.1257	0.1101	0.9126	
		Apt(-2)	-0.0384	0.1091	-0.3520	0.7257	
		Terr(-1)	0.1019	0.1769	0.5762	0.5660	X^2=0.60 Prob=0.74
		Terr(-2)	-0.0542	0.1580	-0.3430	0.7325	

R^2=0.30 , Adj R^2=0.25 , DW=1.95 , AIC=-1.98 , F=5.99

Model 6

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
Terr	Constant	λ	0.0390	0.0157	2.4874	0.0148	
	Trend	T	-0.0005	0.0003	-1.9193	0.0583	
	EC	z_{t-1}	-0.1833	0.0952	-1.9264	0.0574	
	Lagged regressors	Apt(-1)	0.2675	0.0943	2.8374	**0.0057**	X^2=8.18 Prob=0.02
		Apt(-2)	0.1265	0.0818	1.5468	0.1257	
		Terr(-1)	-0.1319	0.1327	-0.9938	0.3232	
		Terr(-2)	-0.2126	0.1185	-1.7939	0.0764	

R^2=0.13 , Adj R^2=0.07 , DW=1.97 , AIC=-2.55 , F=2.13

Model 7

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
Det	Constant	λ	0.0227	0.0192	1.1790	0.2417	
	Trend	T	-0.0003	0.0003	-0.8877	0.3772	
	EC	z_{t-1}	-0.5751	0.1562	-3.6808	0.0004	
	Lagged regressors	Det(-1)	-0.1697	0.1371	-1.2380	0.2192	
		Det(-2)	-0.1059	0.1062	-0.9976	0.3213	
		SDet(-1)	0.1929	0.2034	0.9485	0.3456	X^2=3.67 Prob=0.16
		SDet(-2)	0.3326	0.1910	1.7417	0.0852	

R^2=0.41 , Adj R^2=0.37 , DW=2.02 , AIC=-2.15 , F=9.86

Model 8

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
SDet	Constant	λ	0.0163	0.0116	1.4072	0.1631	
	Trend	T	-0.0002	0.0002	-0.9915	0.3243	
	EC	z_{t-1}	0.0773	0.0939	0.8233	0.4126	
	Lagged regressors	Det(-1)	0.0248	0.0824	0.3011	0.7641	X^2=0.86 Prob=0.65
		Det(-2)	0.0567	0.0638	0.8888	0.3767	
		SDet(-1)	0.1497	0.1222	1.2244	0.2242	
		SDet(-2)	0.2659	0.1148	2.3168	0.0230	

R^2=0.18 , Adj R^2=0.13 , DW=2.08 , AIC=-3.17 , F=3.18

Model 9

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
Det	Constant	λ	0.0322	0.0204	1.5785	0.1182	
	Trend	T	-0.0004	0.0004	-1.1178	0.2668	
	EC	z_{t-1}	-0.4752	0.1377	-3.4505	0.0009	
	Lagged regressors	Det(-1)	-0.2100	0.1335	-1.5725	0.1196	
		Det (-2)	-0.1019	0.1103	-0.9245	0.3579	
		Terr(-1)	0.1083	0.1605	0.6749	0.5016	X^2=1.05 Prob=0.59
		Terr(-2)	0.1272	0.1474	0.8626	0.3908	

R^2=0.33 , Adj R^2=0.28 , DW=2.01 , AIC=-2.02 , F=6.93

Model 10

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
Terr	Constant	λ	0.0347	0.0160	2.1697	0.0329	
	Trend	T	-0.0005	0.0003	-1.6874	0.0952	
	EC	z_{t-1}	-0.1147	0.1079	-1.0629	0.2909	
	Lagged regressors	Det(-1)	0.1403	0.1046	1.3415	0.1834	X^2=3.98 Prob=0.14
		Det(-2)	0.1701	0.0864	1.9689	0.0523	
		Terr(-1)	-0.0114	0.1258	-0.09	0.9279	
		Terr(-2)	-0.1429	0.1155	-1.2372	0.2195	

R^2=0.09 , Adj R^2=0.03 , DW=2.04 , AIC=-2.50 , F=1.39

Model 11

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
SDet	Constant	λ	0.0186	0.0111	1.6774	0.0972	
	Trend	T	-0.0002	0.0003	-1.2392	0.2187	
	EC	z_{t-1}	-0.4014	0.1276	-3.1467	0.0023	
	Lagged regressors	SDet(-1)	0.3090	0.1417	2.1803	0.0320	
		SDet(-2)	0.3551	0.1336	2.6577	0.0094	
		Terr(-1)	-0.1152	0.1180	-0.9762	0.3318	X^2=1.17 Prob=0.56
		Terr(-2)	-0.0792	0.0942	-0.8411	0.4027	

R^2=0.25 , Adj R^2=0.20 , DW=2.13 , AIC=-3.25 , F=4.64

Model 12

Dep. Var	Regressor	Indep. Var	Coeff.	Std. error	t-value	Prob	G.C. test
Terr	Constant	λ	0.0234	0.0140	1.6688	0.0989	
	Trend	T	-0.0004	0.0002	-1.5037	0.1364	
	EC	z_{t-1}	-0.0620	0.1608	-0.3858	0.7006	
	Lagged regressors	SDet(-1)	0.8467	0.1787	4.7386	0.0000	X^2=24.29 Prob=0.00
		SDet (-2)	0.4766	0.1684	2.8297	0.0058	
		Terr(-1)	-0.3880	0.1487	-2.6085	0.0108	
		Terr(-2)	-0.3505	0.1187	-2.9527	0.0041	

R^2=0.31 , Adj R^2=0.26 , DW=2.07 , AIC=-2.78 , F=6.36

Notes: The number of lags for the above models is initially set at 2. It is observed that four of the six pairs of sample times series have number of lags equal to 2 as determined by AIC. Robustness checks are subsequently carried out using specifications determined by AIC for the two pairs of time series and the results are consistent with our initial findings in terms of signs, magnitude and statistical significance of the key variables.

Table 6: Summary of Granger Causality Tests

Direction of Causality	Short-term	Long-Term
Detached Granger-causes Apartment	Yes	Yes
Apartment Granger-causes Detached	No	No
Semi-detached Granger-cause Apartment	Yes	Yes
Apartment Granger-causes Semi-detached	No	No
Terraced Granger-causes Apartment	No	Yes
Apartment Granger-causes Terraced	Yes	No
Semi-detached Granger-causes Detached	No	Yes
Detached Granger-causes Semi-detached	No	No
Terraced Granger-causes Detached	No	Yes
Detached Granger-causes Terraced	No	No
Terraced Granger-causes Semi-detached	No	Yes
Semi-detached Granger-causes Terraced	Yes	No

Table 7: Pairwise Granger Causality (over various time lag periods)

Direction of Causality	No. of lags (quarter(s))			
	1	*2*	*3*	*4*
Detached → Apartment	5.92**	2.35	4.51***	3.89***
Apartment → Detached	2.1	2.92	2.12	1.47
Semi-detached → Apartment	9.37***	4.32**	6.77***	5.67***
Apartment → Semi-detached	1.02	0.6	1.15	0.98
Terraced → Apartment	29.40***	13.47***	8.67***	7.40***
Apartment → Terraced	0.02	1.96	2.37	1.54
Semi-detached → Detached	47.32***	16.46***	11.47***	8.24***
Detached → Semi-detached	0.27	1.09	1.21	0.92
Terraced → Detached	16.24***	6.52***	5.00***	4.04***
Detached → Terraced	0.13	0.12	1.37	0.98
Terraced → Semi-detached	3.49*	3.54*	0.71	0.69
Semi-detached → Terraced	1.15	10.30***	11.47***	7.19

*Notes: "***", "**" and "*" represent statistical significance at the 1%, 5% and 10% respectively.*

Figure 1: Historical Trends of the Northern Irish Property Markets by property type (1995-2018)

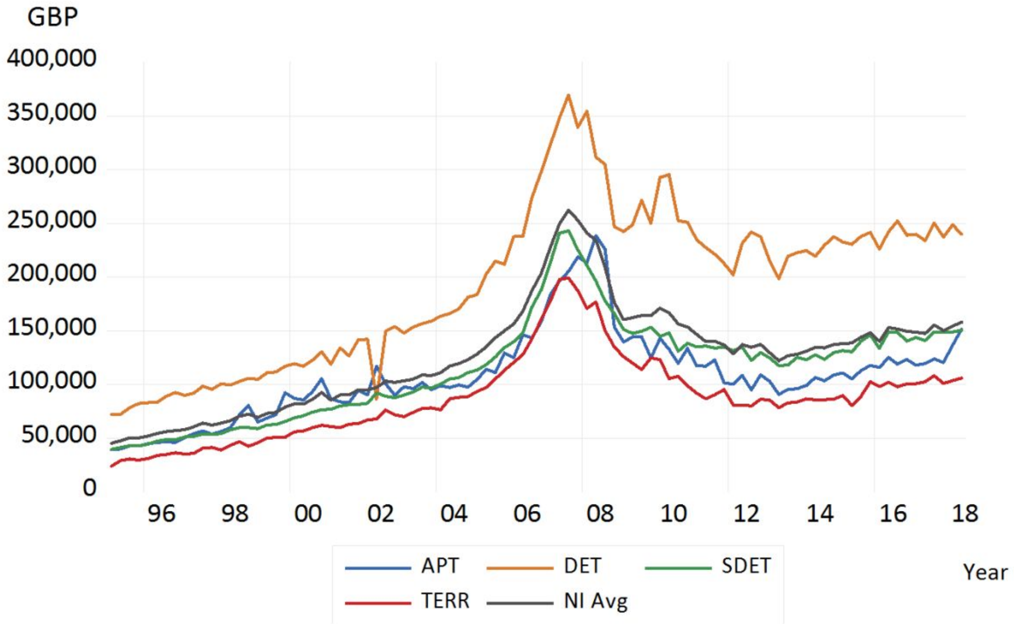
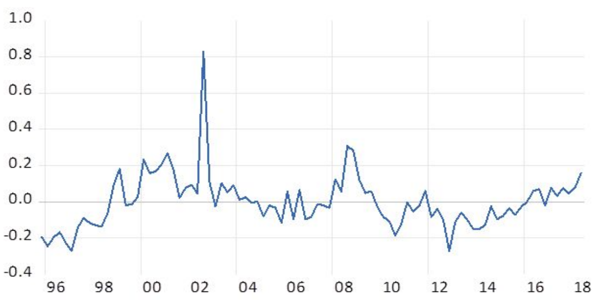
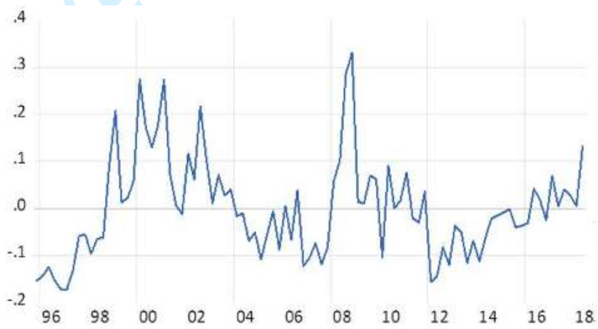


Figure 2: Cointegrating relationship between housing segments over time

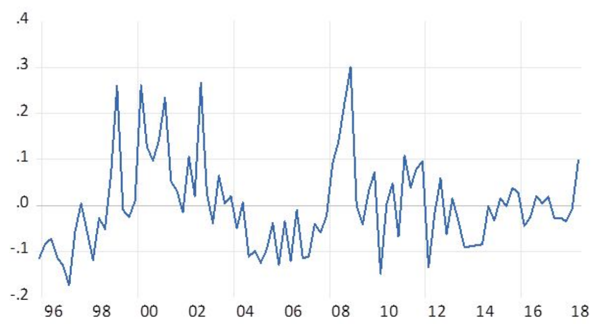
(a) Apartment and Detached



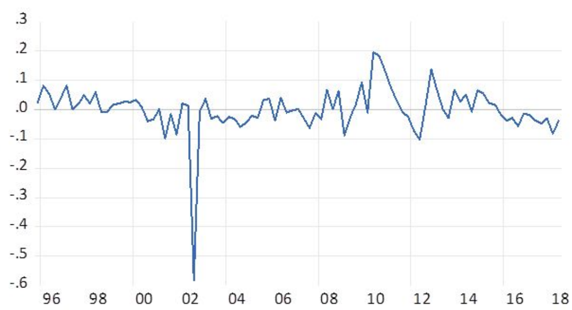
(b) Apartment and Semi-detached



(c) Apartment and Terraced

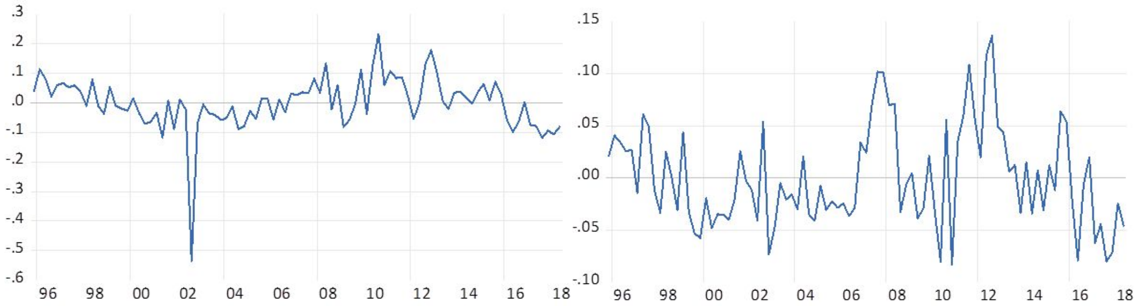


(d) Detached and Semi-detached



(e) Detached and Terraced

(f) Semi-detached and Terraced


.3
.2
.1
.0
-.1
-.2
-.3
-.4
-.5
-.6
96 98 00 02 04 06 08 10 12 14 16 18
.15
.10
.05
.00
-.05
-.10
96 98 00 02 04 06 08 10 12 14 16 18

Comments to the Author

The paper "Only New Kids on the Block: Measuring the Cointegration of house prices in Northern Ireland" is a case-study applying cointegration techniques to a long term dataset of 25 years of property returns in Northern Ireland. It highlights the co-movements between the various property types and studies the mechanism of price transmission both in the short and the long term.

The paper is well written, the academic literature well reviewed and the applied econometric models well explained.

The data section should mention the source of the data. Figure 2 is not adding much information, except showing there might be an issue with the data for "Detached" around 2002. Instead, it would be nice to see a graph with the cumulated returns on the series or simply a table with the statistics of the returns on each series (average, volatility, max/min etc.).

We have removed the figure in line with the reviewers comments and inserted a table of descriptive statistics (Table 1).

The extreme negative return for "Detached" around 2002 followed by an extreme positive return is probably also affecting all estimations presented in the paper, and may change some of the conclusions presented by the author(s) in the "Discussion of the results" section. Maybe the author(s) can give a good explanation for these extreme negative and positive returns.

The data point 2002 is an anomaly we believe. We had already considered this and tested the data around this period for structural breaks using the Chow Test. The findings showed no structural breaks to be observed. We have included this as a Table in the Appendix and as text and associated footnote within the body of the paper.

Also, the authors mention "Exhibit 2 depicts the quarterly change of the four sub-markets as well as that of the NI average over the 13-year time series.". Is 13-year a typo or do I miss something?

Apologies, this was a typing error, 23 as opposed to 13. This has been amended

Reviewer: 2

Comments to the Author
This paper is an empirical study using Johansen cointegration techniques examining the relationship between the prices of different types of properties in Northern Ireland and the extent of market segmentation. It could be made clearer in the title that the study is dealing with different property types, rather than the more common spatial differences.

We have amended the title to reflect the reviewers comment.

The study deals with a relatively short period since 1995 and therefore only captures a limited number of cycles. Since the data appear to be available from 1984 (footnote two), it is not clear why a longer sample could not be used. This is potentially important since behaviour is not necessarily the same across different cycles.

Whilst we would have liked to have used the data series back to the year 1984, we could not get this and have used the longest series made available to us. Also, the NI market has been relatively sheltered from property boom-busts given its more troubled past with the GFC the first real notable bubble in NI. There was a stable and linear price movements evident in the NI market from the period 1984 to 1995 as per the UU House price Index.

The paper contains a comprehensive international literature review but one might question the extent to which some of it is fully relevant to the current study. For example, much of the existing literature is concerned with spatial differences and the so-called ripple effect; by contrast, the literature concerned with differences in the prices of property types – detached, semis, terraced and apartments - is more limited (as the review suggests). I would therefore have liked to have seen a more focused review rather than trying to include everything. One of the points of a literature review is to identify gaps in past research and how previous research can inform the current methodology. Despite the length of the literature review the overall conclusions of the review (page 7) are rather weak.

We have reduced the literature and focused it as suggested by the reviewer and added in a discussion of where this paper is positioned.

The empirical results include both estimates of the long-run relationships between the prices (the cointegrating vectors) and estimates of causality. It is probably fair to say that more attention is paid to the latter and particularly the responses of the apartment market. However, I would suggest that the long-run results are just as interesting, given in Table 6. The key coefficients are (w1): in most cases these coefficients are well below one – noticeably in the relationship between detached and terraced houses (0.67). This implies that the gap between the price of the two property types will increase over time and it is hard to believe that this can continue forever. This might be the result of a fairly short sample period or possibly because of the inclusion of a time trend, which might be contentious. But it is not consistent with the ripple effect where prices diverge in the short run but not the long run. Perhaps more comment on these important coefficients is in order, in addition to that given on page 12, in terms of the implied economics.

We thank the reviewer for these insightful comments which we have inserted into the findings. We have attempted to present these findings in text.

By contrast, I felt that Section IV on the methodology could be reduced in length since these approaches are now well known and no new approaches are used in the paper.

We have tried to parch this down further as suggested by the reviewer.

The paper stresses the differences in behaviour of the apartment sector (e.g. page 14), which is probably not surprising, but at the moment I feel that the paper overstates its importance, notably in the concluding paragraph (page 16). To substantiate these claims fully, I think the paper would benefit from a more detailed policy analysis – how do these results improve policy for example? Should governments encourage more building of particular property types and so on?

We have attempted to temper this discussion point and have attempted to insert further policy implications/discussion

Reviewer: 3

Comments to the Author
Journal of Property Research

Manuscript no. RJPR-2019-0043

New Kids on the Block:
Measuring the Cointegration of House Prices in Northern Ireland

This paper studies whether the different types of dwellings (detached, semi-detached, apartment, terraced) in the housing market of North Ireland are segmented and whether prices spill over from one segment to another. The paper is not well written and needs a substantial rewriting and polishing. In particular, I miss a theoretical discussion why prices among these segments should co-move or spill over. Moreover, there are also some severe flaws in the methodological part. In general, I believe that the paper does qualify for publication in the Journal of Property Research at its current status. Let me elaborate on the above issues in more detail in the following. I hope that my comments might be helpful for the author in order to improve the paper.

We have undertaken an edit and structural changes to the flow of the document. We have included a more theoretical basis for justifying why the different segments may or may not co-move. We have addressed the methodological flaws.

Major Comments:

1. I believe that the paper needs a better motivation for the research question. So far it only asks whether these market segments are corelated or not. We can naturally assume that all four segments are affected in a more or less similar way. Why should we assume different price developments among these segments? Perhaps, it is driven by the location, because detached homes might cluster in certain regions similar as apartments or multifamily homes do. Prices can also comove because of quality reasons. For instance, detached and semi-detached are dominated by existing homes, whereas terraced homes and apartments are newly constructed, and thus, of higher quality. However, we can also argue in the opposite direction, i.e. because apartments are mainly rental units, they tend to be of lower quality. In both cases the error terms would be correlated and spatial econometrics might be more appropriate in this case. In a nutshell, I think that the paper needs some hypotheses to be tested rather than a lengthy and unstructured literature review.

Our original basis is the question whether these property types move together and the results show that whilst the natural assumption is that they all move at the same time and are affected in more or less the same way they do not. Each sector is in their own right conditioned by exogenous market, economic and financial dynamics and the price mechanism established will adjust accordingly, but not at the same rate or speed, thus the rationale for our research. The location aspect is to examine any spill-over effect which is subject to another piece of research. We do examine more the quality tier dimension in this paper. We are examining whether the sectors are interrelated and if so (or not) what does this mean. We have culled the literature review to make it more focused.

2. I would be really cautious in using the term "causal relationship". None of the time series methodologies the author uses do allow for a causal interpretation. Granger causality does not mean causality in terms of causal inferences. Again, the author should explain why one segment might cause prices to increase in the other sector. Is it because one segment shows a higher price elasticity of demand or less supply elasticity than others? Hence, a further question could be: Which demand and supply factors lead to co-movements and spillovers among different dwellings?

We have revised the term causal relationship and have employed the term "Granger-cause" to make it statistically more precise to highlight the context of Granger causality of the paper. Our paper does not intend to empirically study the underlying reasons why one segment of the RE market leads/lags behind the others. That's beyond the scope of our paper and the subject of further research – but we acknowledge the reviewers point. Undoubtedly, the granger causality of the submarkets could be caused by demand/supply, which could in turn be caused by some other social factors like local demographic conditions, which could be due to some specific government policies, and those policies could be caused by wider politics. We do acknowledge other underlying causal factors are at play and we will be looking to undertake this further research in subsequent research. Upon proving that there is indeed granger causal existence – further research can investigate the underpinning market mechanics and dynamics which causes this to occur.

3. There are severe structural breaks around 2002 and the GFC, which are not taken into account in the specifications. What happened around 2002 in the market for detached dwellings? Is this an outlier?

We believe that this is an anomaly in the data that have received. We have inserted commentary to account for this. We had tested for structural breaks in the data for the detached. The results are included within the body/footnote of the paper. We have tested for structural breaks using the Chow test within the causality equations.

4. On page 14, the author argues that “random noise” could be at work. The author should include these demand and supply factors in his/her estimation strategy (see comment above). In general, in the section “Discussion of results” a lot of speculation is going on such as “… Terraced seem to serve as “price setters” whereas detached tend to be “price takers”. This is not really tested in the empirical part.

We have revised the phraseology and wording within the body of the text to explain the findings. Inclusion of demand/supply factors we feel is the basis of other research to understand from this paper as to the underpinning dynamics which culminate in the differences in price movements etc.

Furthermore, why is there a segmentation when the time series are cointegrated. Moreover, cointegration cannot be put on a level with integration, i.e. cointegrated segments are not necessarily integrated markets. These are different concepts. (which part of the paper do we mention that the submarkets are integrated? Maybe we should simply remove “price-taker” and “price-setter” to avoid confusion.)

We have revised the text and removed this as per the reviewers comments to avoid this confusion

Minor comments:

- The abstract is much too long and includes a lot of details, in particular at the beginning, which are absolutely in the wrong place and can be skipped. In contrast, it should include a brief summary of the main empirical results.

We have revised the abstract and included the main findings.

- Similarly, the literature review is extremely long. The author should only discuss those studies that directly refer to the research question. In addition, studies with the same focus and similar results can be summarized.

We have culled the literature review to be more focused as per the reviewers suggestion

- The correlation and cross-correlation structure on level data (prices) in Tables 1-3 do not provide any substantial information. I would suggest skipping them. (Just remove them) I also do not understand the sentence (“NB. Based on the assumption ….”) in the captions below Tables 2 and 3. In general, the captions should include more information about the content shown in the corresponding tables and figures.

We have removed in accordance with the reviewers suggestion

- In Equation (1), the most important parameter Φ is not explained at all. (Explained on Page 9)

This has been revised and explained

- Note that in the first step of the Engle-Granger approach the variables must be I(1) (or of higher order of integration) at a 1% significance level.

We have inserted further explanation as per the reviewers comments (0 under the section of *Granger Causality Test in Error Correction Models*)

- There is a typo in Equation (4) "… + + …" It is also not true that all variables are I(0); only zt-1 is I(0), whereas the other variables are I(1) (see first differences).

We have corrected this, apologies

- There is a coefficient missing for the trend component in Equation (5).

This has been included, apologies

- Page 11, second paragraph: It is wrong to assume that the coefficient of the lagged error term has to be positive. The error correction term must be negative, because if the prices deviate from the long-term equilibrium, they must adjust accordingly in the next period.

It is our understanding that the coefficient of the EC term must be negative – in the range of [-1, 0]. We used conditional sentences to describe different possible scenarios of ΔY_t and argued the coefficient of the EC term must be negative.

- There is a lot of redundancy between the sections on "Discussion of results" and "Conclusion".

We have tried to ensure that this redundancy has been reduced.

- Finally, I did not get it, why the title of the paper starts with "New Kids on the Block". Why not choosing a title such as "Prophets of Rage"?

We were trying to use a pun for apartments (they are newer type stock (private) generally in NI from the early 1990s and the word block is suggestive of apartment blocks. We do acknowledge that this has dramatically failed. We have revised the title accordingly. Though, not into American pop/rock supergroups "Profits of Rage" may work….