Conditional variances in UK regional house prices

Paper submitted for review to Spatial Economic Analysis ISSN: 1742-1772

Geoff Willcocks, Centre for Finance and Risk, Business School, Bournemouth University. willcocks@bournemouth.ac.uk

Introduction

In this paper each UK region is examined to establish if the variance of house price returns is constant or time varying and if it can be modelled using fairly typical time series data generating processes. The approach is very common in finance research, but has not been applied to housing; an omission that is strange given the importance of housing to the UK economy. There is a large body of empirical literature on financial markets but only a limited amount on housing, with little of that focussed on the regions. The current importance of house prices in relation to volatility in the banking, mortgage and housing markets makes the review timely.

The motivation for this paper is three-fold, or rather the convergence of three separate aspects of house prices in a regional context. The first of these is the ripple effect, identified by MacDonald and Taylor (1993) and extensively discussed and researched since. In this there seems to be a tendency for changes, originally upswings, to start in the South East region and then move out across the country over the next two or three periods, moving to adjacent regions over time. The second is that of time-varying volatility in 17% of US metropolitan regions (Miller & Peng, 2006). Finally there is the possibility or suggestion of some UK regions having conditional volatilities identified in a review of national house price time series in Willcocks (2008). Each of these is expanded on below.

Papers by MacDonald and Taylor (op cit) and Alexander and Barrow (1994) considered relationships existing between UK regions' house prices. In particular the former used cointegration to suggest that Greater London price movements were producing a 'ripple down' effect which culminated in "weak segmentation …. …concerning Northern and Southern house prices". Muellbauer and Murphy (1994), using a different approach, stated that regional divergence from the UK average house price was a function of income, the rate of return from owner occupation and unemployment rates. Meen (1999) confirmed the ripple effect results with the use of Augmented Dickey Fuller tests to establish the stationarity of the ratio of regional prices to the national average. As with previous papers, the acceptance of stationarity was very marginal, but a more significant result was obtained by Cook (2003). In this paper he utilised an asymmetric adjustment in the tests for stationarity, so that regions where house prices were diverging from a stable ratio with the national average moved back to equilibrium at different rates for positive or negative changes.

Four possible causes of the ripple effect, as set out in Meen (1999), have been suggested. Migration triggered by households relocating to lower priced regions, although the low level of migration was seen as fairly unlikely to cause significant price changes. Equity transfer, such that purchasers move from the South East to take advantage of their greater buying power, in effect a version of migration. (Both of these reasons are supported by Petersen et al (2002) who stated that "prices in the SE appear to serve as an indicator of house prices in other regions".) Spatial arbitrage:

whereby “if new information becomes available in one area, this information is transmitted first to contiguous areas”. Finally spatial patterns in economic factors that determine house prices themselves following a ripple effect.

The second motivating factor is one of the results of Miller and Peng (2006) who used a panel VAR to examine house price volatility in US regions. In studying house prices in 277 metropolitan areas they set up heteroskedastic ARMA models and tested the unpredictable components for GARCH. Using 5% significance they identified a variety of areas, with no common economic or demographic attributes, that exhibited a (Generalised) Autoregressive Conditional Heteroskedastic structure. Using Granger causality they concluded that volatility causes future volatility and (to a less extent) income growth rate and that Gross Metropolitan Product growth rate causes volatility. There was no discussion on transmission of shocks between regions and no economic justification for the relationships, but the similarities between the US and UK housing markets warrant a British version of this analysis.

The third motivating factor is Willcocks (2008), where the UK house price return time series as a whole was described with a variety of ARMA data generating processes. The validity of each being confirmed or rejected using BDS tests for identical and independent distributions (iid) of the residuals from the mean process. Of the many time series formats tested, the only version giving iid residuals was that of EGARCH in mean. One of the conclusions was that perhaps conditional variance was a regional issue rather than systemic to the whole country.

Data and Method

Quarterly data on UK house price time series is obtained from the “Nationwide quarterly by region indices”, fourth quarter 1973 to fourth quarter 2007, giving a total of 137 observations for each of the 13 regions. For differencing purposes they are converted to natural logarithms (LN) with the return based on equation 1.

$$R_{ti} = LN(I_{ti}) - LN(I_{t-1i}) \quad (1)$$

where R_{ti} is the log return in quarter t for region i and I_{ti} is the index value in quarter t for region i. The returns are not smoothed as this could hide the impact of volatility changes between regions over adjacent time periods. Similarly, the values are not adjusted for inflation or a risk premium.

House price indices are well known for issues surrounding their validity or appropriateness. The non-fungible nature of housing, the various ‘prices’ involved in the transaction process, the protracted period of the transaction and the different governmental and commercial index providers give rise to a range of conceptual issues. For the purpose of this paper, the pragmatic approach was to select an index that gave regional data for as long a period as possible, due to the data requirements of autoregressive conditional heteroskedastic analysis. Government indices are available for the longest periods, but changes in regional boundaries invalidated their use in regional analysis, so Nationwide was selected as it maximised the number of data points.

The first stage of this (positivist) analysis follows the approach of Miller and Peng (op cit), where they assumed that for the American regional markets “investors use an ARMA model…to form their expectations”. Consequently each region is modelled in this format, using information criteria to select the appropriate regional lag structure on the basis that expectations in the various metropolitan areas are heterogeneous. The residuals from these are tested for existence of ARCH and the results form two groups: those regions where the test results indicate a linear structure with constant variance (equivalent to the 83% of the US regions); and the set of regions with an indication of conditional variance. The second stage is to focus on the non-constant variance group and to use the ARMA process to create a set of new time series of the conditional variances. Residuals are then tested for iid via the BDS test to ensure that ‘there is nothing else there’. The derived conditional variances in effect form the basic data for subsequent analysis. The final stage is to identify time series processes that successfully describe the conditional variances.

It should be noted that the analysis can suffer from two particular methodological flaws: sample size and the combination of ARCH and BDS tests. Selection of the Nationwide index gives a sample size of 137 quarterly observations for each of the 13 UK regions: not only is GARCH more applicable to high frequency data (monthly regional series exist but for fewer observations), but also it is best suited to data sets of at least 250 observations. Hwang and Pereira (2006) suggest that with small samples there is a tendency for negative parameter bias, so any conclusions should be tempered with caution as positive but non-significant parameters may suffer from this reduction and could in fact be significant. Similarly, small negative parameters may have been made significant due to the bias. The use of BDS tests when GARCH is used to cope with non-linearity was discussed by Brooks and Heravi (1999) with the concern that existence of GARCH can produce incorrect results in the BDS test. Caporale et al (2005) combined both of these problems by showing that small samples can distort the BDS test. These factors cast doubt on the validity of any strong conclusions, but are offset, albeit to a limited extent, by Fernandes et al (no date) who suggest that in small samples of non-linear structures two of the biases work in opposite directions and can cancel each other out.

Analysis

Descriptive statistics

Basic descriptive statistics are given in Table 1. All quarterly mean returns are in the range 2.05% (Yorkshire & Humberside) to 2.46% (Northern Ireland). The highest regional standard deviation is 3.59% in East Anglia and lowest is 2.67% in Scotland. Based on the Jarque-Bera test (Jarque and Bera, 1980, 1987), at 5% significance there are five regions where their returns are normally distributed whilst the remaining eight plus the UK as a whole reject the null of normality. Tests show with a probability of 0.9997 that the null of equal means cannot be rejected, whilst Bartlett’s test, with a probability of 0.0003, rejects strongly the null of equality between variances.

Table 1: Descriptive statistics of regional log returns

Region	**Mean return**	**Standard**	**Jarque-Bera**

		deviation	test
East Anglia	0.021400	0.035894	12.42008*
East Midlands	0.021237	0.031437	45.19623*
London	0.023257	0.031693	0.680289
North	0.020948	0.034784	1.269981
Northern Ireland	0.024573	0.035033	2.625725
North West	0.021968	0.027936	9.698772*
Outer Metropolitan	0.022082	0.029591	3.872780
Outer South East	0.021907	0.032004	1.878708
Scotland	0.020767	0.026709	8.494153*
South West	0.022435	0.031713	48.28500*
Wales	0.020964	0.032742	22.41807*
West Midlands	0.021071	0.032143	93.55457*
Yorkshire & Humberside	0.020503	0.034684	8.833971*
UK	0.021586	0.025023	7.835281*

*significant at 5%

All of the series were tested for stationarity using Augmented Dicky Fuller tests, with heterogeneous lags based on the significant autocorrelations for each series. None rejected the null of a unit root in levels (statistics not shown here) but all were stationary when first differenced. This result is in line with other house price index research papers. Table 2 shows the results of the first difference tests, indicating that various series required an intercept and/or trend or neither.

Table 2: ADF tests on first differenced series

Region	**Lag**	**Trend & Intercept**	**Intercept**	**Neither**
East Anglia	4	-3.1868	-3.1605*	-2.4036*
East Midlands	4	-3.5105*	-3.4772*	-2.4935*
London	7	-2.9765	-2.9598*	-1.9860*
North	3	-3.8307*	-3.8018*	2.7359
Northern Ireland	4	-2.9766	-2.8949*	-1.8165
North West	4	-3.3323	-3.3059*	-2.2853*
Outer Metropolitan	5	-3.6593*	-3.6008*	-2.5413*
Outer South East	5	-3.8737*	-3.8478*	-2.8055*
Scotland	4	-3.8198*	-3.7861*	-2.2172*
South West	4	-3.7377*	-3.7162*	-2.6504*
Wales	3	-4.1730*	-4.1808*	-3.1260*
West Midlands	4	-3.2154	-3.1920*	-2.2765*
Yorkshire & Humberside	2	-4.6011*	-4.6011*	-3.6436
UK	4	-3.7243*	-3.7004*	-2.4257*

* significant at 5%

Each of the 13 stationary return series is now modelled by an autoregressive moving average data generating process with Akaike's information criteria used to identify the appropriate lags in the ARMA(p,q) structure. The typical structure is shown in equation 2.

$$R_{t,i} = \mu + \varphi_1 R_{t-1,i} + \ldots + \varphi_p R_{t-p,i} + u_{t,i} + \theta_1 u_{t-1,i} + \ldots \theta_q u_{t-q,i} \quad (2)$$

For every region, the residuals are tested for evidence of AutoRegressive Conditional Heteroskedasticity with one lag (the most common in finance). The results are shown in Table 3.

Table 3: ARCH tests by region

Region	**ARMA (p,q)**	**F statistic**	**nR^2**	**ARCH?**
East Anglia	5,6	0.693885	0.700928	no
East Midlands	1,2	12.58484*	11.66352*	yes
London	5,3	0.480617	0.486300	no
North	5,1	1.672660	1.676882	no
Northern Ireland	4,3	18.63321*	16.53389*	yes
North West	6,4	0.051037	0.051820	no
Outer Metropolitan	3,5	3.735519	3.687043	no
Outer South East	3,2	18.52888*	16.46692*	yes
Scotland	3,3	0.086934	0.088212	no
South West	4,3	37.45664*	29.47807*	yes
Wales	3,1	23.65196*	20.31903*	yes
West Midlands	4,3	21.05540*	18.38159*	yes
Yorkshire & Humberside	0,4	12.27488*	11.40671*	yes

* significant at 5%

The results show that seven regions reject the null of no ARCH and can be viewed as having a conditional variance. The remaining six regions are assumed to have a constant variance.

Conditional variances by region

The seven regions where their residuals from the ARMA formats show evidence of ARCH are now re-modelled using their original ARMA mean process combined with Exponential GARCH in mean (based on standard deviation). Use of E GARCH allows an asymmetric component to be identified and removes the requirement to artificially set non-negative constraints. The generic formats for the mean process and conditional variance are set out in Equation 3.

$$R_t = ARMA(p,q) + \sigma_t + \varepsilon_t \quad (3.1)$$
$$\log\sigma^2_t = \omega + \alpha|\varepsilon_{t-1}/\sigma_{t-1}| + \gamma(\varepsilon_{t-1}/\sigma_{t-1}) + \beta\log\sigma^2_{t-1} \quad (3.2)$$

To ensure the regions' data generating processes are appropriate, each set of standardised residuals from this process is tested for an independent identical distribution (iid) via the BDS test (based on 6 dimensions and a correlation integral of 0.7). The tests indicate that there is "nothing else there" for five of the regions, but reject the null of iid for East Midlands and West Midlands. These are re-run with basic GARCH and Threshold GARCH but still reject the null of iid, thus any consideration of relationships involving these two must be treated with some scepticism as they are not fully explained.

Table 4A Coefficients for EGARCH mean process and BDS statistics

Region	In mean coefficient	BDS test Z statistic, Dimension				
		2	3	4	5	6
E Midlands	42.487	12.0941*	12.5632*	13.0740*	13.8001*	14.8060*
N Ireland	0.042148	-1.18143	-1.35181	-0.46642	0.00714	-0.59710
Outer SE	0.215201	1.01124	0.77428	1.30316	1.93382	1.67247
South West	0.710021	1.83320	1.57657	1.49188	1.42464	1.61582
Wales	1.071670	1.00824	0.50423	1.61038	2.31395	2.48814
W Midlands	2.590161*	3.95229*	4.53522*	4.75314*	5.10568*	5.13875*
York Hside	0.791406*	0.38406	0.54131	0.85337	0.97235	1.27654

* significant at 5%

Table 4B Coefficients for EGARCH variance regression

Region	**Variance coefficients**			
	Constant ω	**¦ARCH¦** α	**ARCH** γ	**EGARCH** β
East Midlands	-5.322598*	-0.002780	0.015020	0.276545
N Ireland	-3.673590*	1.377899*	0.247607	0.640290*
Outer SE	-5.882937*	0.753627*	-0.095120	0.322041
South West	-5.796411*	0.599018*	0.091072	0.310311
Wales	-3.822461*	0.510048*	0.126008	0.532180*
W Midlands	-7.501809*	0.467694*	-0.033823	0.044070
York & Hside	-3.723134*	0.682236*	-0.062678	0.560335*

* significant at 5%

There are a variety of initial observations on these results set out in Table 4. Two of the seven mean equations' data generating processes (West Midlands and Yorkshire & Humberside) have the conditional standard deviation's coefficient as significant at 5%. All seven have a significant constant in the conditional variance regression, but East Midlands has no significant other coefficients. The other six all have significant coefficients for the modulus coefficient α and no significance for the leverage effect γ. Northern Ireland, Wales and Yorkshire & Humberside have significant coefficients for the autoregressive "generalised" coefficient of the variance. A new set of series of conditional variances is now generated for these seven regions using the coefficients from Table 4 above. These form the basis for subsequent analysis.

Analysis of conditional variances

Table 5 shows the results of ADF tests on the seven conditional variances series. The conditional variance series are all stationary. (Although the statistics are not shown here, it is worth noting that the original attempt to generate conditional variances utilised Threshold GARCH rather than E GARCH. In this format several of the conditional variance series were either mis-specified and failed to produce a statistic or had a unit root.)

Table 5: ADF(4) with intercept tests on conditional variances

Region	**Test statistic**	**Comment**
East Midlands	-9.161612*	Stationary
Northern Ireland	-3.992643*	Stationary
Outer South East	-4.309758*	Stationary
South West	-3.540981*	Stationary

Wales	-3.582514*	Stationary
West Midlands	-4.154742*	Stationary
Yorks & H'side	-3.572131*	Stationary

* significant at 5%

Contemporaneous correlation of the seven conditional variances set out in Table 6 shows a variety of pairwise coefficients. The most significant correlations are between Outer South East with the South West, Wales and Yorkshire & Humberside, the South West with Wales and Yorkshire & Humberside and Wales with Yorkshire & Humberside. At a slightly lower but still significant level is East Midlands with both Wales and Yorkshire & Humberside. West Midland's correlation with Yorkshire & Humberside is only significant at 10%. These correlations continued for up to four lags. There was no significant contemporaneous, lead or lagged correlation for Northern Ireland.

Table 6: Pairwise correlation coefficients for conditional variances

	EM	NI	OSE	SW	W	WM	YH
EM	1.0	-0.00404	0.09053	0.10102	0.19687*	-0.06334	0.21285*
NI		1.0	0.071751	-0.01120	0.08592	0.01495	0.03424
OSE			1.0	0.45180*	0.61667*	0.13958	0.30745*
SW				1.0	0.50311*	0.12257	0.38357*
W					1.0	0.07760	0.49027*
WM						1.0	0.19051
YH							1.0

* significant at 5%

With no region having a conditional variance with a unit root there can be no consideration of cointegration. The seven regions can however be analysed by a vector autoregressive process (VAR). Two different information criteria (Schwarz and Hannan-Quinn) both suggest a lag of one and the basic structure is therefore assumed to be a constant plus a one lag autoregressive process across all seven variables. Results from this VAR produce diagnostic statistics indicating that this structure is mis-specified and consequently of limited use; showing high levels of autocorrelation, heteroskedasticity and serial correlation. The Akaike, LR test statistic and the Final Prediction error information criteria alternatively suggest a lag structure of three and in this format the diagnostics indicate a higher degree of specification. In particular, at 5% significance, there is no autocorrelation, no residual serial correlation and no residual heteroskedasticity. There is evidence of lack of normality in the residuals, but this is to be expected with the GARCH structure used to generate the series. Results are set out below, with only those parameters (and their t statistics) significant at 5% shown. For ease of interpretation the variables EM et al are the conditional variances for that region at time t and EM(1) for time t-1.

Equations 4.1 to 4.7 Conditional Variances VAR coefficients [t statistics]

EM=0.000131+0.360858EM(1)+0.225197EM(2)+0.196459EM(3)-0.013489SW(3)
[8.32993] [3.74138] [2.34280] [2.40500] [-2.74377]

NI = 0.208095NI(1) + 0.497154NI(2)

[2.13175] [5.76894]

OSE = 0.255162OSE(2) + 0.482890SW(3) – 0.141098WM(2)
[2.25205] [3.36116] [-2.16217]

SW = 0.140935OSE(2) + 0.133377OSE(3) + 0.121114YH(1)
[1.81515] [1.67847] [3.10186]

W = 0.271761OSE(2) + 0.290124W(1) -0.335170W(2) + 0.205700W(3)
[2.88861] [2.50749] [-2.86473] [1.77700]

WM = 0.002545 + 0.476221SW(3) – 0.197264WM(1)
[3.90403] [2.33428] [-2.01933]

YH = 7.199600EM(3) + 0.730148OSE(3) + 0.434462YH(1) + 0.176239YH(3)
[1.80872] [3.77617] [4.57286] [1.75268]

Initial observations on the VAR are that East Midlands (EM) has the highest adjusted R^2 at 0.9577 and is chiefly autoregressive, although there is a low but significant link to the South West running with a lag of three quarters. Northern Ireland has a modest R^2 of 0.1833 and is solely based on its own prior values. Outer South East is partly autoregressive but is also linked with both the South West and West Midlands. Adjusted R^2 is very low at 0.0884 suggesting that other exogenous factors are more important. South West has obvious links with the Outer South East and a three quarters lag with Yorkshire & Humberside, its r^2 is 0.1871, a fairly low value similar to that of Northern Ireland. Wales is predominantly autoregressive but also has a link to the Outer South East and has an R2 of 0.2894. West Midland's R2 is 0.0368, suggesting the regression is of virtually no use. Finally, Yorkshire & Humberside has not insignificant autoregression combined with lagged links to East Midlands and the Outer South East and an R2 of 0.3218.

Discussion

Time series analysis is generally seen as a-theoretical so any discussion or interpretation of these results is limited, an issue that is exacerbated by the inclusion of ARCH, in itself also a-theoretic. Despite this, certain limited observations can be made; commencing with a UK/USA comparison. Miller and Peng (2006) identified 17% of US metropolitan regions where there was a conditional variance, a result that is mirrored in this study for the UK market, albeit at a greater scale, with over 50% of the regions showing some evidence. Structural analysis of housing markets has over the years identified similarities between the US and UK, perhaps best exemplified by Mean (2002) who concluded that "the similarities are more striking than the differences". The results obtained here support this conclusion in that the mix of constant and time-varying variances is evident in both markets.

This raises the second area of interest, namely are they just single national markets? Much research on US housing supports the hypothesis that it is not a single market but a series of subnational spatially adjacent markets. Regional analysis within the UK has tended to focus on the ripple effect rather than structural models, so the existence of regional differences in conditional variances shown here supports the need to give greater consideration to the UK also being a set of subnational regions. It is not suggested that each of the Nationwide's sub-indices identifies a unique market, rather that there seems to be a small number of groups that may be considered as markets in their own right. For instance, within the six regions where the variance is constant, they form two groups where the three regions in each group are spatially adjacent. Firstly there is Northern England, North West England and Scotland; a grouping that possibly supports the concept of a north / south divide. Secondly there is London, Outer Metropolitan and East Anglia. TEST = SDEVS

Within the seven regions with conditional variances, Northern Ireland stands out as having no significant link with the other regions. The estimated process is solely autoregressive. If adjacent regions are important to conditional variances, then it may be the case that Northern Ireland is more influenced by the Republic of Ireland rather than other UK regions.

The remaining six regions are less clear. The VAR results set out in equation 4 show that each of these six has strong autoregressive components; in particular East Midlands, Wales and to a slightly lesser extent Yorkshire & Humberside. The two most frequent independent regions are Outer South East and South West, with both of these depending on lagged values of each other. A possible conclusion could be to group these two spatially adjacent regions together as a single meta region in the south. The other four remaining regions all have an autoregressive component and part of this meta region as an independent variable with only Yorkshire and Humberside linked elsewhere, in particular to the adjacent East Midlands. Thus the UK could be seen as comprising a variety of housing markets: Scotland and the north; greater London and East Anglia; the south; Northern Ireland and central England and Wales.

The third aspect to consider is that of asymmetries, as evidenced by the need to use a non-symmetrical GARCH process in Willcocks (2008). Asymmetries have long been identified in various models of the UK market. For instance Cook (2003) uses asymmetric unit root tests and finds that speed of movement towards equilibrium in certain regions depends on whether it is upwards or downwards. He concludes that "the failure of previous studies to detect convergence is due to significant asymmetry in the convergence process". Unfortunately there is not a close match between his asymmetric regions and the results in this paper: in fact it is interesting that (from Table 4B above) none of the seven E GARCH conditional variance processes has the asymmetry (or leverage) coefficient as significant at 5%. The results (set out in Table 4B above) do however indicate that a shock or innovation to a region's return as in equation 3A will generate a large error which in turn will increase the conditional variance in the next period. This is most pronounced in Northern Ireland where the ARCH coefficient is greater than one and is insignificant only in the East Midlands. Whether this innovation "echoes" over several periods depends on the Generalised ARCH coefficient β, where it can be seen that this is largest for (yet again) Northern Ireland and only significant for this plus Wales and Yorkshire & Humberside.

The fourth and perhaps most important question is why some regions have a conditional variance whilst others have a constant one. Economic models of the UK market tend to use independent variables such as inflation, interest rates, credit market constraints, population, consumption, disposable income, house prices and tax. Any attempt to duplicate these models at the regional level suffers immediately from a lack of data at the regional level. Some variables obviously are constant across the country, others do vary and are available whilst others are likely to vary but are not available. One variable that is available for similar regions but over a shorter period than used in this study is unemployed claimant rates. Although the data is not given here, a fairly simple time series analysis of the claimant rates showed that ARCH was present in some regions but not others. Thus it may be the case that the regions where there is conditional variance map onto underlying economic factors that also exhibit ARCH. Hence the conditional variance in a region's housing market is not intrinsic to that region, but is merely a function of the underlying economic factors. The alternative is that it is the region's housing market per se that causes the conditional variance.

Conclusion

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