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**Testing for long-run convergence across regional house prices in the UK:
a pairwise approach***

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ABSTRACT

This paper tests for stochastic convergence in UK regional house prices using the recently developed pairwise approach. This approach allows for unit root tests to be conducted on all $N(N-1)/2$ possible pairs of house price differentials across N regions in the UK, thus avoiding the need to choose a base region or alternative national figure as the benchmark. Using mixadjusted house price data from 1973Q4 to 2008Q4, the main finding is that there is no evidence of long-run convergence among regional house prices or of an equilibrium relationship towards which UK regional house prices have a tendency to gravitate.

JEL classification: C33, R21, R31

Keywords: Regional convergence; House prices; Housing Market; Pairwise approach

* For helpful comments on an early draft of this paper we are grateful to Hashem M. Pesaran.

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6 **Testing for long-run convergence across regional house prices in the UK:**
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8 **a pairwise approach**^{*}
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12 **I Introduction**
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15 Since the house price boom of the late 1980s, substantial inter-regional differences in
16 UK house prices have been the object of continued media attention and public debate.
17
18 Research interest has followed suit, and a fairly rich research agenda – rekindled at times of
19 housing market appreciations or depreciations – has developed accordingly. The primary, and
20 still unsettled, line of investigation has been that of establishing whether the apparent regional
21 differences in UK house prices are growing steadily over time (divergence hypothesis),
22 exhibit a long-run tendency of convergence (convergence hypothesis) or simply reflect
23 cyclical behaviour, with regional house price gaps widening during house price booms and
24 narrowing during housing market downturns (cyclical gap hypothesis). The analysis is
25 complicated by two additional issues brought to the fore by previous empirical work (see,
26 among others, Alexander and Barrow, 1994; Ashworth and Parker, 1997; Giussani and
27 Hadjimatheou, 1990; Holmes, 2007; Meen, 1999; Peterson et al., 2002; Rosenthal, 1986).
28 The first relates to the possibility of regional segmentation in the UK housing market, with
29 possibly only subgroups of regions forming what could be termed ‘house price convergence
30 clubs’. The second issue is the so called ‘ripple effect’, which describes a tendency for shocks
31 to UK regional house prices to originate in the London region and then spatially diffuse
32 outward from the South East.¹
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58 ^{*} For helpful comments on an early draft of this paper we are grateful to Hashem M. Pesaran.

59 ¹ For an insightful discussion of which region ought to be taken as the best candidate to approximate the
60 geographic origin of the ripple (Greater London or the rest of the South East), see Drake’s (1995) preliminary
analysis.

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Despite intense empirical scrutiny, the evidence is still mixed and has yet to provide a conclusive answer as to whether a long-run equilibrium relationship across all regional house prices exists. For example, Macdonald and Taylor (1993) find long-run interregional stability in UK house prices but only limited evidence in support of the ripple effect in the context of weak segmentation of the housing market. Drake (1995) finds that house prices in the North and Scotland exhibit greater divergence from prices in ‘the rest of the South East’ (RSE, their benchmark region) than do the southern and Midlands regions. The latter regions show a relatively stable ‘norm differential’, albeit one which is influenced by cyclical factors and is subject to structural changes. As such, he finds no evidence of a ripple effect or of any equilibrating forces of convergence between house prices in the RSE and elsewhere in the UK. By contrast, Cook (2003, 2005) unveils the presence of a pattern of asymmetric adjustment between regions, where reversion to equilibrium occurs more rapidly (slowly) during periods in which house prices in the South of England – the Outer South East, the South West and East Anglia – decrease (increase) relative to other regions. More recently, Holmes and Grimes (2008) test convergence by means of a seemingly unrelated regression (SUR) estimator to establish whether the first principal components of the N regional house price differentials (based on regional deviations from the UK average house price) are stationary or not. They find constancy in the long-run house price ratios between all UK regions and also evidence of a ripple effect with respect to house prices originating in London (with the exception of Scotland, whose speed of adjustment towards long-run equilibrium is considerably slower than for all other regions).

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By and large, previous empirical work has mainly relied on advances in cointegration or unit root testing procedures to shed light on the nature and degree of convergence in UK regional house prices. Such procedures, however, are typically applied to a common underlying specification of N regional house prices all measured relative to a base region

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3 (often taken to be the South East or Greater London) or to the ratio of house prices for each
4 region relative to the national (aggregate or average) figure. Such an approach is sensitive to
5 the choice of benchmark (or numeraire), ignores the information in all the other cross price
6 differentials and is subject to a high degree of cross section dependence which has adverse
7 effects on estimation and inference. This paper avoids these problems by employing the
8 recently developed 'pairwise approach' (Pesaran, 2007) to the analysis of long-run
9 convergence. This approach allows for a variety of unit root tests to be conducted on all
10 possible $N(N-1)/2$ regional house price differentials between pairs of all the N regions of the
11 UK, and estimate, consistently, the proportion of the pairs that are stationary. By allowing for
12 the possibility of forming regional clusters (if any) from the test outcomes, this approach is
13 also ideally suited for investigating the hypothesis of 'club convergence'.
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29 The paper is organized as follows. In Section 2 we offer a rationale for the use of the
30 pairwise approach to the analysis of regional house price convergence by detailing the virtues
31 of this methodology vis-à-vis the statistical techniques employed in previous studies. Section
32 3 defines multi-regional stochastic convergence and describes the pairwise tests to be
33 conducted. Section 4 discusses data and the empirical results. The final section draws
34 conclusions.
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46 **II Why the Pairwise Approach?**

47 Tests of regional house price convergence within a cointegration framework fall
48 within two main approaches. One approach applies system cointegrating techniques directly
49 to the series and tests for the existence of $N-1$ cointegrating vectors among the N regional
50 series. The problem with this approach is that cointegration is necessary but not sufficient if
51 the underlying series are trend stationary. Convergence requires the regional house price
52 series to be cotrended in addition to being cointegrated with the cointegrating vector of the
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3 form (1, -1). An application of multivariate cointegration analysis can be found in Macdonald
4 and Taylor (1993) who estimate simultaneously $N-1$ linear combinations of UK regional
5 house prices using the Johansen (1991) technique. Although the system cointegration
6 technique that they employ does not require the use of a base region, they do not test whether
7 the house price series that do cointegrate might not be cointegrated. In their analysis, therefore,
8 cointegration does not necessarily imply that the house price series are convergent.
9
10 Furthermore, as they themselves acknowledge, Macdonald and Taylor (1993) did not control
11 for data dependency and relied exclusively on non mix-adjusted indices of (residential) house
12 prices. As noted by Holmes (2007), the use of non mix-adjusted series may be very
13 misleading since such series do not isolate pure price changes from changes in the mixture
14 of properties sold each quarter in terms of characteristics such as quality and design.

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30 The second approach tests for unit roots (or stationarity) in $N-1$ regional house price
31 differences with respect to a base region or in the ratio of house prices in a given region
32 relative to the national figure as the numeraire. For example, using the national UK average
33 house price as the benchmark (p_n), the house price differentials $p_{it}-p_{nt}$ for $i = 2, 3, \dots, N$ are
34 tested for unit roots. The significant limitation of this approach is that, irrespective of any
35 transformation of the original series, it is dependent on the choice of the benchmark and
36 could therefore yield misleading results. In an attempt to go beyond standard panel unit root
37 testing procedures, Holmes (2007) and Holmes and Grimes (2008) employ a seemingly
38 unrelated regression (SUR) framework. Although the SUR framework allows for the
39 determination of which series in the panel are responsible for any rejection of the null of joint
40 non-stationarity, this approach is still dependent upon the benchmark of an equilibrium
41 relationship with respect to the UK average house prices series. It follows that, in this
42 context, any evidence of segmentation, with a subset of regions exhibiting divergence from
43 the UK average (as in Holmes, 2007), is also potentially misleading since it relies on the
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3 assumption of transitivity, according to which these divergent regions are not pairwise
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5 cointegrated with any of the remaining regions that are cointegrated with the benchmark
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7 (UK) series. Evidently, such an assumption cannot be warranted *a priori*. For example, in a
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9 three region setting with region n as the benchmark, regions j and k could be convergent even
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11 if the house price differentials, $p_{jt}-p_{nt}$ and $p_{kt}-p_{nt}$ are divergent, namely contain unit roots or
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13 deterministic trends. This case would arise if $\Delta p_{jt} = \Delta p_{kt}$ and $\Delta p_{jt} \neq \Delta p_{nt}$. Similar concerns
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15 apply to Cook's (2003) application of momentum autoregressive (MTAR) unit root tests on
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17 the ratio of regional house prices relative to the national figure, in spite of the virtues of these
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19 tests in allowing for consideration of stationarity under conditions of asymmetric adjustment.
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25 It is important to emphasise at this point that the pitfalls that surround the use of a
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27 base region or national average numeraire are not unique to analyses of long-term
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29 convergence that employ unit root or stationarity tests. Even Drake's (1995) application of
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31 the Kalman filter is constrained by an econometric specification that hinges upon a UK house
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33 price index differential as the benchmark of reference in order to estimate the time varying
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35 parameter (his b coefficient) of convergence.²
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39 What is required, therefore, is a procedure that allows for the assessment of
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41 multi-regional convergence through pairwise convergence *across all* regional combinations.
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43 A procedure which: (i) considers the possibility that the regional house price series that do
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45 cointegrate might not be cointegrated; and (ii) does not rely on the stringent and potentially
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47 misleading assumption of transitivity. The recently developed pairwise approach (Pesaran,
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49 2007) is ideally suited to address the methodological challenges identified above since it
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51 allows for testing the unit root and trending properties of all $N(N-1)/2$ possible house price
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59 ² Drake's (1995) model specification to test for regional house price convergence is $[\log \text{HPUK} - \log \text{HPWM}]_{(t)}$
60 $= a_t + b_t [\log \text{HPUK} - \log \text{HPSE}]_{(t)}$, where HPUK is the index of UK house prices, HPSE is the index of house
prices in the South East, and HPWM is the index of the specified region, in this example the West Midlands.

differentials, $p_{it}-p_{jt}$, for $i = 1, 2, \dots, N-1$ and $j = i+1, \dots, N$, thus also avoiding the problems inherent in the use of any given benchmark.

III Pairwise Tests of UK Regional House Price Convergence

Two regions' house prices are converging, in a stochastic sense, when, after an exogenous shock, the limit of their expected price differential tends to zero as T (the number of time periods) increases. House price differentials are therefore transitory. However, if shocks are permanent, the differentials are integrated and diverging. More formally, the analysis that follows draws from Pesaran's (2007) definition of probabilistic convergence which, though originally developed in the context of the growth literature, can be readily applied to house price levels.³ Accordingly, regions $i = 1, 2, \dots, N$ are said to converge if for some finite constant C (reflecting, for example, climate and other area characteristics), and a tolerance probability measure $\pi > 0$,

$$\Pr \left\{ \bigcap_{i=1, \dots, N-1; j=i+1, \dots, N} |p_{i,t+s} - p_{j,t+s}| < C \mid \ell_t \right\} > \pi \quad (1)$$

for s horizons into the future, $s = 1, 2, \dots, \infty$. Hence, multi-regional convergence requires pairwise convergence across all regional combinations.

Pairwise tests for each regional pair, i and j , can be undertaken from a unit root regression of the log house price differential, $d_{ijt} = p_{it} - p_{jt}$:

$$\Delta d_{ijt} = \alpha_{ji} + \lambda t + \beta_{ij} d_{ij,t-1} + \sum_{s=1}^{p_{ij}} \delta_{ijs} \Delta d_{ij,t-s} + v_{ijt} \quad (2)$$

³ Pesaran's (2007) definition is less stringent than the earlier definitions of stochastic convergence developed in the growth literature. Bernard and Durlauf (1995, 1996) were the first to define cross-country output convergence in terms of the limit of expected output gaps, with asymptotically perfect convergence said to occur for a group of economies when forecasts of income differences tend to 0. Hobjin and Franses (2000) later introduced the notion of asymptotically relative output convergence whereby forecasts of income differences tend to a non-zero constant.

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3 When $H_0: \beta_{ij}=0$ cannot be rejected, p_{it} and p_{jt} are divergent under the null, whereas if $H_1: \beta_{ij}<0$
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5 holds, the two series are convergent. A further restriction is $H_0: \lambda = 0$, the co-trending
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7 hypothesis, which indicates that d_{ijt} is not trended but stationary around a constant mean. In a
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9 cointegrating framework, the above hypotheses represent the cointegrating and co-trending
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11 restrictions, respectively. In the present analysis, both of these conditions are tested for,
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13 through a specification which, as the one in equation (2), includes both a drift term and a
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15 linear trend. Following Pesaran (2007), only stationary pairs that cannot reject the hypothesis
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17 of the absence of a significant linear trend are converging pairs. Multi-regional convergence
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19 is expected to arise when the fraction of the stationary pairs that satisfy the co-trending
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21 restriction is larger than the chosen nominal size of the test.
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27 Two different unit root tests are employed: the standard ADF test and the ADF-GLS
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29 test statistic of Elliot et al. (2006). The ADF-GLS test makes use of GLS de-trended data and
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31 is expected to have higher asymptotic power and less size than the standard ADF test,
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33 through its more efficient estimation of the deterministic components. Two model selection
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35 criteria are used to identify the appropriate lag augmentation order: the Akaike Information
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37 Criterion (AIC) and the Schwarz Bayesian Criterion (SBC), assuming a maximum lag order
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39 of six. As a further sensitivity check, a test with ‘stationarity’ as the null hypothesis (the
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41 KPSS test developed by Kwiatkowski et al., 1992) is also reported. Under the null hypothesis
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43 of stationarity, the KPSS test statistic is given as:
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$$49 \quad \text{KPSS}_{ijT}(\ell) = \frac{T^{-2} \sum_{t=1}^T s_{ijt}^2}{s_{ijT}^2(\ell)} \quad (3)$$

50 where $s_{ijt} = \sum_{\ell=1}^t \hat{\epsilon}_{ij\ell}$, $\hat{\epsilon}_{ijt} = (d_{ijt} - \bar{d}_{ij})$ and \bar{d}_{ij} is the mean of the house price differential, d_{ijt} .

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 $s_{ijT}^2(\ell)$ is the estimate of the long-run variance of s_t , given by

$$s_{ijT}^2(\ell) = \frac{1}{T} \sum_{t=1}^T \hat{e}_{ijt}^2 + \frac{2}{T} \left[\sum_{k=1}^{\ell} w_k \left(\sum_{t=k+1}^T \hat{e}_{ijt} \hat{e}_{ij,t-k} \right) \right] \text{ with the weights defined as}$$

$w_k = 1 - \frac{k}{\ell + 1}$, $k = 1, 2, \dots, \ell$. In the case of the KPSS test, multi-regional convergence can be

measured by the fraction of house price differentials that cannot reject the null hypothesis of stationarity and satisfy the co-trending restriction.

Finally, the possibility that house price convergence may hold only for a subgroup or ‘club’ of regions is considered. In the limit, club convergence tells us if the rejection of convergence is caused by one or a few regions.

IV Data and Estimation Results

Data

UK regional house prices are measured using seasonally adjusted quarterly data published by the Halifax Bank and the Nationwide Building Society, the two largest mortgage lenders in the UK over the sample period. Both indices use observations collected from mortgage approvals and thus exclude cash house purchases and mortgage-backed sales from other lenders. These indices were chosen because they have been published for longer periods than available alternatives and adopt a mix-adjusted, volume-weighted price index. The purpose of mix adjustment is to identify pure house price changes, holding constant locational and physical characteristics. This is achieved by hedonic regressions that estimate the market value of the properties’ various attributes, from which a synthetic price is placed on each characteristic (Wood, 2005). The indices include all property types from both new housing and transactions germane to the existing stock.

To ensure consistency across the two datasets, the sample period begins in 1983Q1, the first date when the Halifax house price index (HPI) was published, and ends at 2008Q4.

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3 As can be seen from Figures 1 and 2, that plot the Halifax and Nationwide HPIs, the sample
4 period is sufficiently long to capture two UK housing market cycles: (i) the rise in property
5 prices up to 1990Q1, followed by the slump that finished in 1993Q1; and (ii) the subsequent
6 rise in property prices, peaking in 2007Q1. Data were collected for 12 regions of the UK:
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8 Greater London (LN), the South East (SE), the South West (SW), East Anglia (EA), the East
9 Midlands (EM), the West Midlands (WM), the North West (NW), Yorkshire and the Humber
10 (YH), the North (N), Scotland (SC), Wales (WL), and Northern Ireland (NI). Figure 3 shows
11 the exact location of the above regions. Regional classifications across the two datasets are
12 analogous, however, the figures for the South East using the Nationwide HPI are derived
13 from the average house price of the Outer South East and the Outer Metropolitan regions.
14 Price differentials are constructed by subtracting the natural logarithm of the average house
15 price for region j from the natural logarithm of the average house price for region i , thus
16 $d_{ijt} = \ln(p_{it}) - \ln(p_{jt})$. In total there are $12 \times 11 / 2 = 66$ distinct pairs, from which the rate of price
17 convergence across UK regions is calculated.
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36 FIGURES 1, 2 and 3 ABOUT HERE

37 *Results and Discussion*

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39 We begin by considering the unit root properties of the house price differential pairs.
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41 Unit root tests are conducted using the full sample of observations, so $T=104$ from 1983Q1-
42 2008Q4. Table 1 reports the proportion of pairs for which the unit root hypothesis is rejected
43 using the ADF and ADF-GLS test statistics, and the proportion of pairs that cannot reject the
44 null hypothesis of stationarity from the KPSS test. In total, there are 66 tests used to calculate
45 every rejection frequency and all of them are conducted at the customary 5% significance
46 level using two information criteria orders of augmentation: the AIC and SBC. Under the
47 hypothesis of non-convergence, the proportion of stationary pairs should be close to the
48 nominal size of the test (Pesaran, 2007; Pesaran et al., 2009). The results uniformly reject the
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3 convergence hypothesis. The lowest rejection rate is zero from the Halifax ADF test, and the
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5 highest rejection rate is 15.15% from the ADF-GLS-SBC test again using the Halifax dataset.
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7 Looking at the results from the ADF test, none of the pairs rejects the unit root hypothesis
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9 using the Halifax HPI, while the Nationwide dataset produces rejection frequencies of 1.52%
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11 and 12.12% using the AIC and SBC. The ADF-GLS test has a higher rejection frequency
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13 than the standard ADF test, as expected given its higher power.⁴ For the four cases reported,
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15 the average rejection frequency is 7.20%, which while higher than the average of 3.41% from
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17 the ADF, is still very close to the 5% significance level. Thus, the very limited evidence in
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19 favour of convergence emerges from only few pairs and may, therefore, have arisen just by
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21 chance. The rejection frequencies are consistent between the two house price indices and
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23 across the two information criteria. The average rejection frequency using the Halifax data is
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25 4.54%, and 5.68% from the Nationwide dataset, while the AIC and SBC produce average
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27 rejection frequencies of 3.03% and 7.57% respectively. Average lag lengths are quite low.
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29 Using the Halifax HPI, the average lag length was 3.87 from the AIC, and 2.56 from the
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31 SBC. The corresponding figures using the Nationwide dataset are 3.53 and 1.83.
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36 Further evidence against the hypothesis of convergence is provided by the KPSS tests.
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38 The proportion of pairs that cannot reject the null hypothesis of stationarity is greater than
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40 zero in only one case. Using the Nationwide dataset and choosing the lag order from the AIC,
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42 the rejection frequency is 1.52%, implying stationarity in the sole case of one house price
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44 differential.
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50 51 TABLE 1 ABOUT HERE 52

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54 Next, the analysis sought to identify the convergent pairs by investigating how many
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56 pairs are both stationary and satisfy the co-trending restriction. Table 2 shows that the
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58 proportion of pairs that can be regarded as stationary around a constant mean is low. The
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⁴ Both Pesaran (2007) and Pesaran et al. (2009) report analogous findings.

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3 proportions of converging pairs for the ADF-GLS test are very similar to the fractions of
4 stationary pairs reported in Table 1. However, the fractions of converging pairs reported for
5 the standard ADF test are lower. Using the Nationwide HPI with the SBC, the proportion of
6 converging pairs rises to only 1.52% (one case). As for the KPSS tests, all the results are
7 against the hypothesis of stochastic convergence.
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15 TABLES 2 and 3 ABOUT HERE
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17 Since unit root tests may exhibit low power when applied to a relatively short data
18 span, to test the robustness of the results presented in Table 2, we undertook additional
19 estimations using an extended Nationwide dataset of house prices, one that starts at 1973Q4
20 (approximately ten additional years, totalling 141 quarters used for estimation). We also
21 employed the Ng and Perron's (2001) Modified Akaike's Information Criterion (MAIC) as
22 an additional check since the MAIC yields tests with improved size and power properties.⁵
23 Table 3 presents the results of this exercise, which do not change the conclusions reached
24 heretofore. Convergence rates pertaining to the extended, 36-year sample, range from 0%
25 using the KPSS test, under all three selection criteria, to 12.12% using the ADF-GLS test
26 under the AIC. Interestingly, under the MAIC, the proportions of converging pairs are
27 consistently 0%, irrespective of the unit root or stationarity test considered.
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43 So how can evidence of no overall convergence in UK regional house prices be
44 rationalised? First, as convincingly demonstrated by Hwang and Quigley (2006) in their
45 comprehensive study of the effects of national and regional economic conditions on housing
46 markets in metropolitan areas of the U.S.: "*housing markets are local, and housing market*
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55 ⁵ The MAIC (Ng and Perron, 2001) is defined as $-2(\ell/T) + 2(k + \tau)/T$, where ℓ is the selected bandwidth
56 parameter, T is the number of time series observations, k is the chosen lag length and τ is a modification factor.
57 The MAIC differs from the conventional AIC through the inclusion of τ , which is defined as
58 $\tau = \alpha^2 \sum_t y_{t-1}^2 / \sigma_u^2$, where α is the slope estimate of y_{t-1} from the ADF regression and σ_u^2 is the variance of the
59 residual errors from the ADF regression.
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3 *outcomes reflect local economic conditions*” (p.425). If so, it would be difficult to even
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5 contemplate the plausibility of any evidence pointing to ‘convergence’ (rather than just
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7 stationarity) in UK regional house prices without a clearly conceived and cogent theoretical
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9 explanation as to why, and how, this finding could emerge in the presence of markedly
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11 different regional economic conditions. The UK Department for Business, Enterprise and
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13 Regulatory Reform (BERR) has recently produced Regional Economic Performance
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15 Indicators (May 2009) that highlight the persistence of significant economic disparities across
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17 UK regions, in terms of ‘input factors’ (such as R&D expenditure, business start-up rates,
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19 business density and educational qualifications), ‘output factors’ (such as gross value added
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21 per head, productivity and employment rates), and ‘outcome factors’ (for example, wages).
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23 Such disparities exist within, as well as among, UK regions, they are large and difficult to
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25 bridge. Against this backdrop, our finding of the persistence of house price differentials
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27 among UK regions appears to be not only plausible but far less controversial than it may
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29 seem *prima facie*.
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37 Of course, interregional labour migration might have an effect on the demand for
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39 housing across regions, with obvious implications for house prices and their potential
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41 tendency toward convergence. Yet, also this conceptual link to the direction of interregional
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43 labour migration flows would appear to support the evidence presented heretofore. In the
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45 UK, where limited frictions hinder the mobility of labour, such flows have traditionally
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47 followed the supply of jobs, resulting in a form of arbitrage in the labour market. Since the
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49 direction of these flows is not uniform across regions, with a pronounced differential between
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51 the labour migration from North-to-South vs. that going the opposite way, the resulting net
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53 effect of asymmetric labour migration flows on regional housing markets across the UK is
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55 one likely to reinforce existing house price differentials across regions rather than act as an
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57 equilibrating mechanism. For example, net interregional labour migration flows into the more
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3 economically prosperous southern UK regions - such as Greater London and the South East –
4 cannot but compound house price differentials vis-à-vis other UK regions by further
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6 stimulating job-led demand for housing in the areas that already record the highest house
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8 prices.
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12 As noted earlier, a virtue of the pairwise approach is that it allows for the
13 investigation of the hypothesis of club convergence from the test outcomes. This further
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15 application of the approach is justified since Pesaran (2007) shows that the rejection
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17 frequency does not vary significantly with the number of pairs, N , but does tend to rise
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19 rapidly with the number of periods, that in the present analysis remains fixed at $T = 104$.
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24 Table 4 reports the rejection frequencies of different regional groupings. Specifically,
25
26 interest centres on testing for stochastic convergence in house prices across subgroups of
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28 English regions: between the South of England, the North of England, the East Midlands and
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30 the West Midlands. Moreover, to ascertain whether a wider pool of convergence exists, ‘the
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32 North’ is interacted with the aggregated regions of the Midlands. Finally, a test for
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34 convergence adopting a wider definition of ‘the South’ that includes the East Midlands and
35
36 East Anglia is undertaken. The latter case is considered since the ‘border’ of the so-called
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38 ‘North-South’ divide in England has been re-defined recently, and the ‘Extended South’ now
39
40 is said to include East Anglia and a large part of the East Midlands (Dorling, 1997).
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46 The analysis reported in Table 4 reports only the results from the ADF-GLS test with
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48 orders of augmentation selected using the SBC (due to the high degree of consistency found
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50 between unit root test statistics and both model selection criteria). For each ‘club’ examined,
51
52 the rate of convergence is calculated from the $N(N-1)/2$ pairs of regions. For example,
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54 convergence of the ‘Extended South’ club is calculated from the $5 \times 4 / 2 = 10$ house price
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56 differentials pertaining to that regional grouping. Empirical evidence in favour of club
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58 convergence appears to be very limited at best. Using the Nationwide dataset, none of the
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3 clubs examined displays any evidence of convergence, while some evidence of partial
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5 convergence can be found using the Halifax HPI. Specifically, one fifth of the relevant pairs
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7 converge for the 'Extended South' and 'the North & Midlands' regions. However, the three
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9 remaining cases, 'the North', 'the South' and 'the Midlands' support the divergence
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11 hypothesis.
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TABLE 4 ABOUT HERE

Disaggregating the dataset further, Tables 5 and 6 present individual unit root tests for all the bivariate regional combinations under consideration. The bold figures highlight the fairly sporadic events of convergence. Using the Nationwide dataset, only two pairs are found to be convergent: the North-South East and the London-South West differentials. The Halifax HPI provides more evidence in favour of convergence, however, there appears to be no systematic pattern of spatial dependence in terms of contiguity, geographic distance or centre-periphery structure to illuminate as to why some regions' house prices converge over all other bivariate regional combinations. Convergence is found for the North West-Yorkshire and the Humber, Wales-North and North West-Yorkshire and the Humber combinations and for the East Anglia-East Midlands, East Anglia-West Midlands and East Anglia-Wales pairs. The South West region does not appear to converge with any other UK region, while house prices in the South East are found to converge with those of the East Midlands and Wales only. Finally, although the Greater London-North and Greater London-North West price differentials are found to be convergent, a rather interesting finding is the lack of convergence between house prices in Greater London and the South East. The plots for the Greater London-South East house price differential (Figures 4 and 5) corroborate the latter result, suggesting a widening price differential after 1995.

This latter finding is important and deserves further attention not only because the geographic proximity of Greater London and the South East should accentuate spatial and

1
2
3 temporal house price diffusion (see, for example, Holly et al., 2010), particularly in terms of
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5 neighbourhood characteristics (see Meen, 2001), but also because Greater London and the
6
7 South East are the two most economically successful regions of the UK, and the two regions
8
9 that have the highest house prices. One might therefore argue that arbitrage could have been
10
11 expected to lead to convergence at least in the case of these two southern regions, especially
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13 given that the supply of jobs is high in both, with bilateral flows of job matching taking place.
14
15 Yet, consistent with our previous rationalisation, the persistence of house price differentials
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17 between Greater London and the South East may be due to the contiguity of these two
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19 regions, as a result of which labour mobility translates into higher 'commuting' rather than
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21 'migration' flows, with no consequent equilibrating effect on the respective housing markets.
22
23 Indeed, 'commuting' rather than 'migrating' across these regions may tend to reinforce rather
24
25 than reduce the existing house price gap. Evidence from previous literature supports this
26
27 supposition. Jackman and Savouri (1992a, 1992b, 1996) considered the implication of the
28
29 commuting/migrating trade-off on the determinants of migration across UK regions and
30
31 found that fixed costs are much greater for migrating, while commuting costs strongly
32
33 increase with distance. Contiguity, therefore, implies that the decision of where to live can be
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35 made more independently from the decision of where to work. In the case of contiguous
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37 regions, where the commuting option is relatively cheap, people who live in the region with
38
39 somewhat lower housing costs would be inclined to stay living there and commute to the
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41 contiguous region with higher house prices for work (see also evidence from Murphy et al.,
42
43 2006). Similarly, people who already live in the region with somewhat higher house prices
44
45 may also be inclined to stay living there - thus avoiding the considerable fixed costs of
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47 relocation⁶ - and commute to the contiguous region with lower house prices for work.
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59 ⁶ In the UK, 'stamp duty' is charged depending on the purchase price of the property. The current (2010) stamp
60 duty rates are 1% for properties over £175,000 to £250,000, 3% for properties over £250,000 to £500,000, and
4% for properties with a purchase price in excess of £500,000. Additional fixed costs include estate agent

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3 TABLES 5 and 6 ABOUT HERE
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6 FIGURES 4 and 5 ABOUT HERE
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8 The results of the present analysis are in stark contradiction to those obtained by
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10 Macdonald and Taylor (1993). They found strong evidence for long-run cointegrating
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12 relationships (up to nine cointegrating vectors) in regional house prices, seemingly driven by
13
14 the convergence adjustment process of two large groups of regions, with Greater London, the
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16 South East, the South West and East Anglia forming one club, and the West and East
17
18 Midlands, the North, the North West, Yorkshire and the Humber, Wales and Scotland forming
19
20 another. The comparison acts as a reminder of the necessity to use appropriate data (they
21
22 relied exclusively upon nonmix-adjusted series of regional house prices), to employ a
23
24 sufficiently large sample for the analysis of long-run convergence (their sample period was
25
26 limited to 18 years, ending in 1979) and a suitable testing methodology (they did not ensure
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28 the satisfaction of the co-trending restriction hence failing to establish whether stationary
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30 linear combinations were, in fact, convergent).
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36 Several previous studies also found evidence in favour of the existence of a ‘ripple
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38 effect’ (see Cook, 2003, 2005; Holmes, 2007; and Holmes and Grimes, 2008). Although the
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40 present study did not set out to test the ripple effect and was not concerned with the analysis
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42 of short-run movements in regional house prices, the finding of no overall long-run house
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44 price convergence across all the regions of the UK implies that any ripple-like effects in
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46 regional house prices reflect, at best, transitory movements rather than the (symmetric or
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48 asymmetric) adjustment process towards an equilibrium relationship of house prices across
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50 all the UK regions. As such, the results of the present analysis, are more in line with the
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52 findings presented by Drake (1995), who found no evidence of ‘significant equilibrating
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54 charges (for sellers only), valuation and survey costs, and legal costs that include a solicitor’s fee, as well as
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56 Land Registry and Local Authority search fees.
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3 forces' between regional house prices, and who dismissed the 'ripple effect' as no more than
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5 a series of leads and lags in house price movements across regions. It should also be borne in
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7 mind that the findings of the studies cited above are indiscriminately affected by a model
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9 specification which, being based on regional house price ratios relative to the UK aggregate
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11 figure as the benchmark, is subject to considerable crosssection dependence with adverse
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13 effects for estimation and inference.
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20 **V Conclusions**

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22 The primary aim of this paper was to test for stochastic convergence across regional
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24 house prices in the UK using the recently developed pairwise approach. This approach avoids
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26 the problems inherent in estimation of the typical model specification found in previous
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28 studies, a specification dependent upon the choice of a base region or national house price
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30 figure as the benchmark of reference. By allowing for the possibility of forming regional
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32 clusters from the test outcomes, implementation of this methodology also permitted the
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34 investigation of the hypothesis of 'club convergence', i.e. that house price convergence may
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36 hold only for a subgroup or 'club' of regions.
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41 The empirical analysis of the unit root and trending properties of log house price
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43 differentials across all the N regions in the UK over the period 1983Q1-2008Q4, offers no
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45 evidence in support of overall convergence. Hence, there appears to be no equilibrium
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47 relationship towards which UK regional house prices have a tendency to gravitate. The
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49 hypothesis of 'club convergence' is also not supported, with only two subgroups of UK
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51 regions (the 'Extended South', and the 'North' with the 'Midlands') displaying some
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53 evidence of partial convergence. Confirmatory, bivariate, pairwise tests corroborate the rather
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55 sporadic events of convergence. These results hold across the use of two different datasets of
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57 mix-adjusted house price series (Halifax and Nationwide house price indices), three different
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3 unit root (stationarity) test statistics (the ADF, ADF-GLS and KPSS), and two alternative
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5 model selection criteria (AIC and SBC). Robustness tests undertaken using an extended
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7 sample of house prices that starts at 1973Q4, and an additional modified Akaike's information
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9 criterion (MAIC) with improved size and power properties, confirm the reliability of the
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11 results presented.
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15 The overall finding that substantial inter-regional differences in UK house prices have
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17 a tendency to persist, has important implications in terms of, for example, labour mobility,
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19 migration and commuting patterns, and social inequality across UK regions, and should prove
20
21 useful in the evaluation of national as well as region-specific housing policy.
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25 In interpreting the findings of the present study, two final caveats are in order. First,
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27 following much of the literature that investigates regional house price convergence, the
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29 analysis reported here is empirical rather than theoretical. The aim of this paper was to test
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31 for stochastic convergence in house prices across UK regions using state-of-the-art
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33 econometric techniques whilst making no attempt to identify the determinants of regional
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35 house prices. Yet, the plausibility of our findings – rationalised in terms both of the existing
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37 regional economic disparities and of the direction of the flows regulating labour market
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39 arbitrage vis-à-vis the regional supply and demand of housing – is strong. This means that
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41 should future evidence point to the convergence of UK regional house prices, work producing
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43 such evidence will be burdened with the additional onus of devising a theory that in addition
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45 to fitting to the statistical properties of the data is capable of nesting our conceptual
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47 explanation. Second, investigation of pairwise convergence is essentially an analysis germane
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49 to the long-run. The extent to which short-run house price adjustments or transitory contagion
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51 effects occur across regions, and the specific dynamics of such short-run movements, were
52
53 beyond the scope of this study.
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Table 1 Proportion of pairs rejecting the null hypothesis of a unit root (ADF, ADF-GLS) or not rejecting the null of stationarity (KPSS)

House price index	Order selection criterion	ADF	ADF-GLS	KPSS
Halifax	AIC	0	3.03	0
	SBC	0	15.15	0
Nationwide	AIC	1.52	7.57	1.52
	SBC	12.12	3.03	0

Note: ADF is the standard Augmented Dickey-Fuller test, ADF-GLS is the GLS-detrended Dickey-Fuller test of Elliot et al. (2006), KPSS is the KPSS test for stationarity of Kwiatkowski et al. (1992). Unit root tests (tests for stationarity) are conducted for every house price differential at the 5% significance level using the Mackinnon (1996) critical values for the ADF and ADF-GLS tests, and the Kwiatkowski et al. (1992) critical values for the KPSS test. There are $12 \times 11/2 = 66$ distinct pairs of regions and $T=104$ from the sample period 1983Q1 to 2008Q4. Orders of augmentation are chosen by the AIC and SBC, assuming a maximum lag order of six.

Table 2 Proportion of pairs that are both stationary and have a non-significant time trend i.e. converging pairs

House price index	Order selection criterion	ADF	ADF-GLS	KPSS
Halifax	AIC	0	3.03	0
	SBC	0	15.15	0
Nationwide	AIC	0	6.06	0
	SBC	1.52	3.03	0

Note: The proportion of all pairs that are converging is calculated from those house price differentials that reject the null hypothesis of a unit root (cannot reject the null of stationarity) and have an insignificant time trend (the co-trending restriction). ADF is the standard Augmented Dickey-Fuller test, ADF-GLS is the GLS-detrended Dickey-Fuller test of Elliot et al. (2006), KPSS is the KPSS test for stationarity of Kwiatkowski et al. (1992). The nominal size of the unit root test is set at 5% with the co-trending restriction being rejected whenever the t-ratio of the time trend coefficient exceeds the 5% critical values.

Table 3 Proportion of pairs that are both stationary and have a non-significant time trend i.e. converging pairs (extended sample, 1973Q4-2008Q4)

House price index	Order selection criterion	ADF	ADF-GLS	KPSS
Nationwide	AIC	10.61	12.12	0
	SBC	7.58	6.06	0
	MAIC	0	0	0

Note: The proportion of all pairs that are converging is calculated from those house price differentials that reject the null hypothesis of a unit root (cannot reject the null of stationarity) and have an insignificant time trend (the co-trending restriction). ADF is the standard Augmented Dickey-Fuller test, ADF-GLS is the GLS-detrended Dickey-Fuller test of Elliot et al. (2006), KPSS is the KPSS test for stationarity of Kwiatkowski et al. (1992). The MAIC is the Ng and Perron (2001) modified Akaike's information criterion, defined as $-2(\ell/T) + 2(k + \tau)/T$, where ℓ is the selected bandwidth parameter, T is the number of time series observations, k is the chosen lag length and τ is a modification factor. The nominal size of the unit root test is set at 5% with the co-trending restriction being rejected whenever the t-ratio of the time trend coefficient exceeds the 5% critical values.

Table 4 Convergence clubs

House price index	Convergence club	Regions	Rate of convergence
Halifax	The South	LN, SE, SW	0
	Extended South	LN, SE, SW, EA, EM	20
	The North	N, NW, YH	0
	The North & Midlands	N, NW, YH, EM, WM	20
	Midlands	EM, WM	0
Nationwide	The South	LN, SE, SW	0
	Extended South	LN, SE, SW, EA, EM	0
	The North	N, NW, YH	0
	The North & Midlands	N, NW, YH, EM, WM	0
	Midlands	EM, WM	0

Note: Convergence clubs are defined for different groups of English regions based on their geographical proximity to one another. Each club consists of $N \times (N-1)/2$ pairs. So for example, there are $3 \times 2/2 = 3$ pairs used to calculate the rejection frequency of 'the South' but $5 \times 4/2 = 10$ pairs used for the 'North & Midlands'. Rejection frequencies are calculated using the results from the ADF-GLS test including both intercept and linear trend, with lag order selected by the SBC. The rate of house price convergence is calculated from the stationary pairs that have an insignificant time trend. The nominal size of the unit root test is set at 5% and the co-trending restriction is tested with 5% critical values.

Table 5 Bivariate unit root tests using the Halifax HPI

	LN	SE	SW	EA	EM	WM	N	YH	NW	WL	NI	SC
LN	—											
SE	-2.316	—										
SW	-1.906	-2.464	—									
EA	-1.821	-1.629	-1.944	—								
EM	-1.932	-3.087	-2.738	-3.055	—							
WM	-2.738	-2.989	-2.471	-3.205	-1.637	—						
N	-3.166	-2.791	-2.809	-2.180	-2.127	-2.819	—					
YH	-2.516	-2.293	-2.682	-2.569	-2.199	-2.030	-2.001	—				
NW	-3.071	-2.203	-2.748	-2.126	-2.570	-3.202	-1.639	-3.048	—			
WL	-2.930	-3.112	-2.864	-3.206	-2.269	-1.945	-3.235	-1.582	-2.457	—		
NI	-2.473	-2.577	-2.817	-2.948	-2.710	-2.163	-2.682	-2.553	-2.011	-2.709	—	
SC	-2.644	-2.713	-1.891	-2.203	-1.705	-1.985	-2.089	-2.822	-2.101	-2.522	-2.362	—

Note: Figures are values of the ADF-GLS test for a unit root, with order of augmentation chosen using the SBC. Both intercept and linear trend are included in the regression. Bold figures indicate those pairs which are converging i.e. the house price differential is stationary and has a non-significant time trend.

Table 6 Bivariate unit root tests using the Nationwide HPI

	LN	SE	SW	EA	EM	WM	N	YH	NW	WL	NI	SC
LN	—											
SE	-2.089	—										
SW	-2.284	-1.484	—									
EA	-2.437	-2.117	-2.257	—								
EM	-2.311	-2.588	-2.033	-1.786	—							
WM	-2.156	-2.257	-1.693	-2.629	-1.766	—						
N	-2.724	-3.054	-3.026	-2.750	-1.635	-1.699	—					
YH	-2.842	-2.540	-2.736	-2.732	-1.722	-1.215	-2.479	—				
NW	-3.128	-2.455	-2.678	-2.264	-1.536	-2.235	-1.898	-2.069	—			
WL	-2.477	-2.358	-2.389	-2.306	-1.285	-1.429	-1.551	-2.968	-1.551	—		
NI	-2.032	-1.979	-1.955	-2.622	-2.069	-2.363	-2.832	-2.092	-2.832	-2.588	—	
SC	-2.142	-2.123	-2.003	-2.412	-1.422	-1.774	-1.422	-2.131	-1.990	-1.606	-2.492	—

Note: Figures are values of the ADF-GLS test for a unit root, with order of augmentation chosen using the SBC. Both intercept and linear trend are included in the regression. Bold figures indicate those pairs which are converging i.e. the house price differential is stationary and has a non-significant time trend.

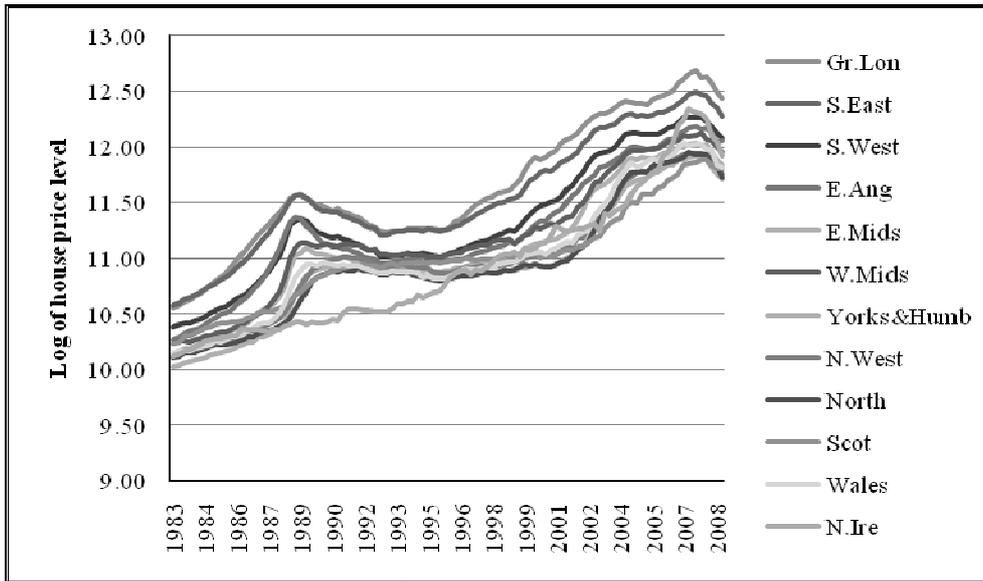


Figure 1 Log of regional house price level (Halifax HPI)

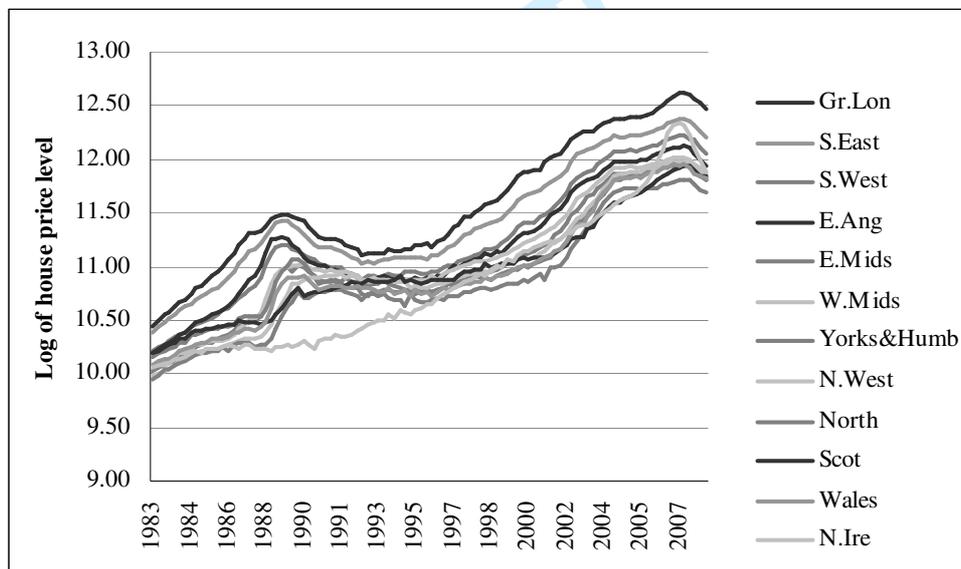


Figure 2 Log of regional house price level (Nationwide HPI)



Source: able.co.uk

Note: The regions come from the definitions provided by the Halifax House Price Index. To ensure strict comparability, for the Nationwide house price index, the series for the South East region is derived from the house prices indices of both the Outer Metropolitan and Outer South East regions.

Figure 3 Map of UK regions

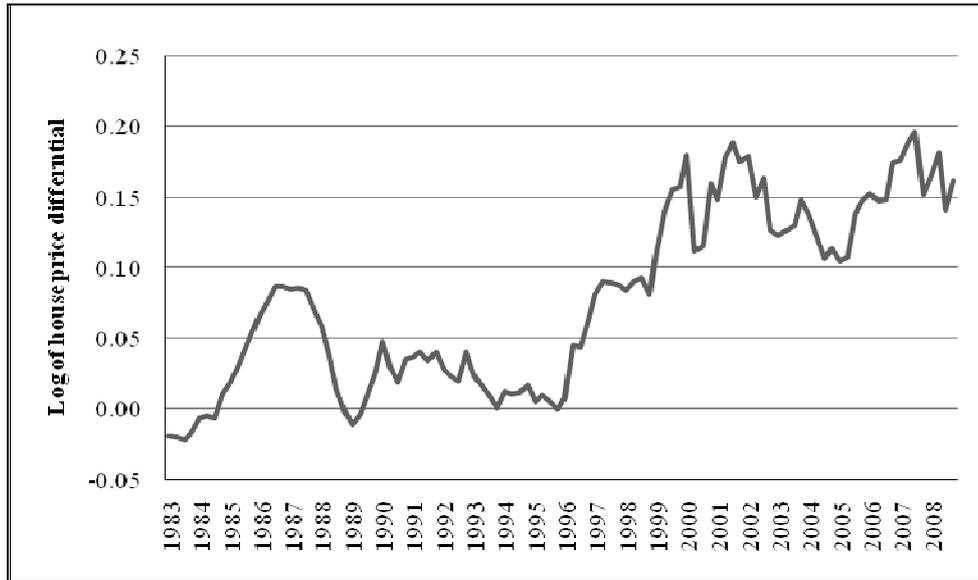


Figure 4 Log house price differential for Greater London-South East (HalifaxHPI)

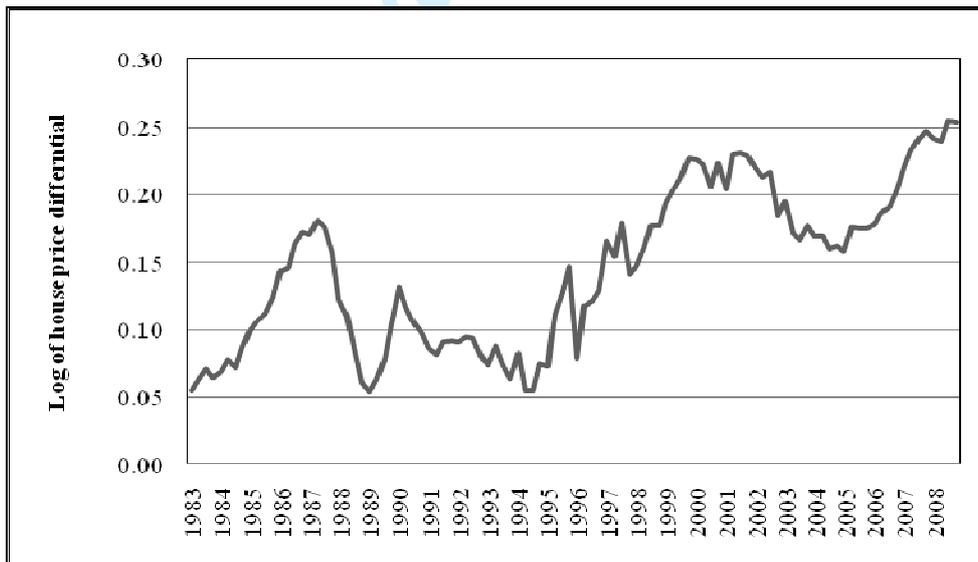


Figure 5 Loghouse price differential for Greater London-South East (Nationwide HPI)