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# British Regional Growth and Sectoral Trends – Global and Local Spatial Econometric Approaches

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## Abstract

This paper looks beneath the surface of British sub-regional aggregate GVA growth over the period 1995-2007, by examining how the differing growth dynamics of the secondary and services sectors have influenced the overall regional growth process. A spatial econometric analysis is undertaken which tests regional secondary and services real GVA per capita for absolute and conditional convergence at the NUTS 3 level. Both local and global spatial analysis techniques are utilised in order to gain a detailed insight into the growth process over the period 1995-2007.

**Keywords:** Regional Economic Growth, Britain, Spatial Econometrics

**JEL-Classification:** R11, R12

## 1. Introduction

The inherently spatial nature of the economic data underpinning regional economic analysis has received increasing levels of attention in recent years with the emergence of an impressive array of spatial econometric techniques. The impact on the regional growth process of core or peripheral location, proximity to natural resources, and spillover effects from neighbouring regions can now be vividly depicted by means of these techniques. One aspect of this spatial data configuration that has started to attract particular attention is that of spatial heterogeneity across regions: if an economic convergence or divergence process is evident in a given region, does this process exhibit contrasting patterns of spatial association across the sub-regions and does the speed of this convergence (or divergence) process vary at a local level? This issue of heterogeneous spatial relationships has seen spatial analysis move from a global perspective with spatially stable parameters to a local one where economic performance can vary from one sub-region to the next. While global spatial analysis techniques acknowledge the importance of location and proximity in the economic development process by controlling for the influence of spatial autocorrelation, they characterise the underlying process as being spatially stable i.e. the same relationship holds across the entire country. However, agglomeration of economic activity and uneven allocation of resources are common features of regional development. Local spatial analysis techniques offer an opportunity to explore the significance of these spatial disparities.

This paper builds upon the work of Henley (2005), Monastiriotis (2006), and Patacchini and Rice (2007) and employs these global and local spatial techniques to shed light on the regional growth process occurring in Britain over the 1995-2007 period. The analysis undertaken in this paper focuses on NUTS 3 real GVA per capita data spanning from 1995-2007 for the secondary and services sectors. While the time-span (1995-2007) considered in this paper is dictated by data availability, this decade is nonetheless an important one. It captures a period of time where regional growth in many developed countries has been impacted by the move towards the outsourcing of manufacturing and the absorption of phenomenal technological advances. Britain is no exception to this trend: in 2007 primary, secondary, and services as defined in Section 2, below, accounted for approximately 1%, 17% and

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2  
3 55% of British GVA, while the equivalent shares in 1995 were 2%, 27% and 47% respectively.<sup>1</sup> This  
4  
5 surge in services sector output, accompanied by a falling off of secondary output, justifies a more  
6  
7 disaggregated approach to the convergence/divergence debate.  
8

9  
10 This paper is organised as follows: Section 2 provides a description of the data used in this paper, as  
11  
12 well as a brief review of the literature on British regional growth in the years prior to 1995. Section 3  
13  
14 provides a description of how  $\beta$ -convergence analysis has been augmented to include a number of  
15  
16 global spatial econometric methods and the local spatial econometric method Geographically  
17  
18 Weighted Regression (GWR). The results yielded by these global and local spatial econometric  
19  
20 methods are reported in Section 4. Conclusions are presented in Section 5.  
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24

## 25 **2. Data Issues and Background**

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28  
29 This paper is primarily focused on NUTS 3 level gross value added (GVA) per capita data. Unadjusted  
30  
31 (constrained to headline NUTS2) aggregate GVA by NUTS3 area at current basic prices for the years  
32  
33 1995 to 2007 is available from the Office of National Statistics ([www.statistics.gov.uk](http://www.statistics.gov.uk)), as well as  
34  
35 being disaggregated for 1) agriculture, hunting and forestry; 2) Industry, which comprises of  
36  
37 manufacturing, electricity, gas and water supply, but excludes construction; and 3) service activities,  
38  
39 which comprises of business services and finance, as well as distribution, transport and  
40  
41 communications (which includes wholesale, retail and hospitality).<sup>2</sup> These three categories are  
42  
43 henceforth referred to as “primary”, “secondary”, and “services”, respectively. Estimates of  
44  
45 workplace-based GVA allocate income to the region in which commuters work. Per capita estimates  
46  
47 can then be constructed using NUTS 3 level population data available from Nomis Labour Market  
48  
49 Statistics ([www.nomisweb.co.uk](http://www.nomisweb.co.uk)). The current price GVA DATA has been deflated using the national  
50  
51 annual Retail Price Index (RPI) series (rebased to 2007=100). Unfortunately, regional weights for the  
52  
53 RPI are only available for the UK for the years 2000, 2003, and 2004. In this study, regional price  
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56  
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59 <sup>1</sup> Calculations based on National Accounts GVA data available from Office of National Statistics Office of  
60 National Statistics ([www.statistics.gov.uk](http://www.statistics.gov.uk)).

<sup>2</sup> Business services and finance accounted for 52% of national services GVA in 1995, with distribution, transport and communications accounting for the remaining 48%. By 2007, the corresponding shares were 60% and 40% respectively.

1  
2  
3 level differences have been accounted for the years 1995-99 using 2000 regional RPI weights  
4  
5 (UK=100). Similarly for 2001-2002, the 2003 regional RPI weights are used and for 2004-2007  
6  
7 regional RPI weights are used. The basket used to calculate the RPI figures include both consumer  
8  
9 goods and services such as household services, personal services, and leisure services.<sup>3</sup>

10  
11 By way of background, it should be noted that studies of British regional growth patterns over the  
12  
13 1977-1995 period, based on National Accounts GDP per capita data for the 62 British counties and  
14  
15 New Earnings Survey data, have identified a number of prominent features.<sup>4</sup> Chatterji and Dewhurst  
16  
17 (1996) conclude that regional GDP per capita data yields no evidence of convergence over this time  
18  
19 period, though they do identify some sub-periods that exhibit convergence (in periods where the  
20  
21 economy as a whole was experiencing slow growth). Bishop and Gripaios (2004) find no signs of  
22  
23 convergence over the 1977-1995 period, regardless of whether one uses National Accounts or New  
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25 Earnings Survey data. A further insight to emerge from this line of research has been the influence of  
26  
27 geographic location and spatial factors on British regional growth. Dewhurst (1998) and Bishop and  
28  
29 Gripaios (2004) both find evidence of the influence of a “north-south divide” on British regional  
30  
31 growth patterns, which acts to the detriment of the northern areas. More recently a whole range of  
32  
33 spatial economic techniques have become available, allowing for a more refined characterisation of  
34  
35 the spatial dimension in the regional growth process. When this spatial component is controlled for in  
36  
37 convergence analysis, there are signs that not only has Britain not experienced regional convergence in  
38  
39 recent decades, but there may even have been a process of divergence in action. Monastiriotis (2006),  
40  
41 using wage data from the New Earnings Survey, points to widening aggregate wage disparities  
42  
43 throughout the 1980s and 1990s when the issue of spatial dependence is taken into account. Henley  
44  
45 (2006) has undertaken a spatial econometric analysis of NUTS 3 level aggregate GVA data for the  
46  
47 1995-2001 period and concludes that British NUTS 3 sub-regions experienced divergence over this  
48  
49 time period. The transition from global to local spatial analysis of UK economic activity is evident in  
50  
51 the work of Patacchini and Rice (2007). They use local measures of spatial autocorrelation to analyse  
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53 patterns of spatial association for different indicators of British economic performance. They find that  
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<sup>3</sup> For further details of the composition of the RPI series, see the ONS publication *Economic Trends 615*, February 2005.

<sup>4</sup> For the purposes of this study, only Great Britain is considered, i.e. Northern Ireland is not included.

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2  
3 the contributions of occupational composition and productivity vary significantly across local regimes,  
4  
5 with a ‘winner’s circle’ of areas in the south and east of England benefiting from both above-average  
6  
7 levels of productivity and better-than-average occupational composition, while the low-income regime  
8  
9 in the north of England suffers from poor occupational composition.

10  
11 In order to provide a visual impression of the spatial dispersion of real GVA per capita across British  
12  
13 NUTS 3 sub-regions, a set of maps are presented (Figures 1-4). Each map is colour coded, with the  
14  
15 light shading denoting 0-100% of median real GVA per capita, medium shading denoting 100-125%,  
16  
17 and dark shading denoting over 125% of median real GVA per capita. Each sub-region is shown  
18  
19 relative to the median rather than the mean to mitigate the impact of outliers such as the services GVA  
20  
21 of London’s financial district located in the Inner London West NUTS 3 sub-region.  
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24  
25 Figure 1 presents aggregate real GVA per capita for 1995 and 2007. Salient features include the  
26  
27 apparent spatial clustering of high GVA per capita in greater London, Manchester, Liverpool,  
28  
29 Edinburgh, Glasgow, and Aberdeen (near the North Sea oil fields); a clear expansion of the greater  
30  
31 London high-GVA area over the period in question; increased GVA per capita in Scotland but no  
32  
33 consistent GVA per capita increase in Northern England. In comparison, the secondary industry  
34  
35 presents a mixed picture (Figure 2): the North of England NUTS 3 sub-regions appear to have  
36  
37 experienced mixed fortunes; there are signs of increased secondary GVA per capita in Scotland, while  
38  
39 the Midlands and South East exhibit some shuffling of regions between the three categories, but no  
40  
41 clear pattern. The business services and finance subsector (Figure 3) and the distribution, transport and  
42  
43 communications subsector (Figure 4) highlight the strength of the high-GVA greater London area but  
44  
45 continued sluggishness in Northern England and Scotland. In all it would appear that it is the services  
46  
47 industry which drives the expansion of the southern high GVA per capita in the aggregate map.  
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50  
51 **[Insert Figure 1 here]**

52  
53 **[Insert Figure 2 here]**

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55 **[Insert Figure 3 here]**

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57 **[Insert Figure 4 here]**  
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3 Summary statistics of secondary and services sector real GVA per capita developments over the 1995-  
4  
5 2007 period are provided in Table 1. The contrast between secondary and services sector GVA per  
6  
7 capita developments over the 1995-2004 period is stark. The decrease in the mean, median and  
8  
9 standard deviation of secondary GVA per capita over the 13 year period suggest that any convergence  
10  
11 experienced in the secondary sector has not been a buoyant one. The GVA per capita of the services  
12  
13 sub-sectors, on the other hand, are indicative of healthy growth, with their mean and median showing  
14  
15 marked increases over the 13 years.  
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18 **[Inset Table 1 here]**  
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22 In Section 4 a number of additional data sources are drawn upon. Explanatory variables introduced in  
23  
24 the conditional convergence analysis of Sub-section 4.3 include average primary school pupil-teacher  
25  
26 ratio per county and the average A-level pass rate achieved by pupils in each county, both of which are  
27  
28 available from the ONS publication *Regional Trends*. The number of businesses registered for Value  
29  
30 Added Tax and female employment expressed as a proportion of people aged 16+ are both available  
31  
32 from Nomis Labour Market Statistics ([www.nomisweb.co.uk](http://www.nomisweb.co.uk)). Net capital expenditure data for  
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34 British sub-regions is available from the ONS series *Regions in Figures*.<sup>5</sup>  
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<sup>5</sup> *Region in Figures* has now been discontinued. The final edition was Winter 2004/05 (volume 9). It has now been replaced by a new publication, *Regional Snapshot*.



### 3. Regional Convergence and the Spatial Dimension

This section begins with a brief description of how  $\beta$ -convergence analysis, as developed by Baumol (1986), Barro and Sala-I-Martin (1992), and Mankiw et al. (1992), has been augmented to include a number of spatial econometric methods. When considering regional convergence, various empirical approaches have been implemented in the literature: from simple plots of measures of dispersion over time to intra-distributional dynamics using Markov chains applied to GDP per capita. It is  $\beta$ -convergence analysis, however, that has lent itself most easily to spatial econometric analysis.

#### 3.1 Global Spatial Econometric Methods and the Modelling of Regional Growth

While a variety of distinct convergence concepts have emanated from the economic growth literature, one form of convergence which has received particular attention over the last two decades has been that of  $\beta$ -convergence. This form of convergence occurs when poor regions grow faster than richer regions, resulting in a catching-up process where the poor regions close the economic gap that exists between their richer counterparts. The now-standard specification of  $\beta$ -convergence can be expressed in vector form as follows:

$$(1) \quad \ln\left(\frac{y_{t+k}}{y_t}\right) = \alpha + (1 - e^{-\lambda k}) \ln(y_t) + \varepsilon_t$$

where  $y_t$  denotes the vector of per capita income of each state  $i$  in year  $t$ ;  $\alpha$  represents the intercept term, and  $(1 - e^{-\lambda k})$  is the convergence coefficient, which is usually reparametrized as  $\beta = (1 - e^{-\lambda k})$ . The  $\beta$  coefficient is then estimated using Ordinary Least Squares (OLS), and the speed of convergence,  $\lambda$ , can then be calculated. A negative estimate for  $\beta$  indicates that growth rates of per capita income over the  $k$  years is negatively correlated with initial incomes – a finding which is interpreted as a support for the hypothesis of convergence. It is assumed that the error terms from different regions are independent:

$$(2) \quad E[\varepsilon_t \varepsilon_t'] = \sigma_t^2 I.$$

This unconditional  $\beta$ -convergence specification can then be augmented, as per Barro and Sala-I-Martin (1992), to include a range of control variables (such as differences in human capital accumulation, infrastructure disparities, industrial structure, as well as dummy variables reflecting different regional characteristics) which may capture differences in the paths of steady-state income per capita.

Equations (1) and (2) can be augmented to capture interactions across space, a refinement which reflects more accurately the realities of the growth process across regions. As Henley (2006) notes, this spatial dimension can exert its influence on regional growth through numerous channels: adjustment costs and barriers to labour and capital mobility, spatial patterns in technological diffusion, the ability of regions to pursue independent regional growth policies, and the extent to which neighbouring regions interact and benefit from spillover effects. Following from Anselin (1988), spatial dependence has been incorporated into the  $\beta$ -convergence specification in two ways: (i) as an explanatory variable in the specification or (ii) as operating through the error process.<sup>6</sup> The former, known as a Spatial Autoregressive Model (SAR), depicts a region's growth as being directly affected by growth in neighbouring regions. This direct spatial effect is independent of the exogenous variables and is captured by including a spatial autoregressive parameter,  $\rho$ , and a spatial weight matrix,  $W$ , in the specification:

$$(3) \quad \ln\left(\frac{y_{i,t+k}}{y_{i,t}}\right) = \alpha + (1 - e^{-\lambda k}) \ln(y_{i,t}) + \rho W \ln\left(\frac{y_{i,t+k}}{y_{i,t}}\right) + \varepsilon_{i,t}$$

In equation (3), the growth of a given region is influenced by the growth rate of adjacent regions. However, it may be the case that rather being directly affected by the growth rate of its neighbours, a region's growth rate may be influenced by a complex set of random, unexpected shocks transmitted across space arising from spillovers associated with technology or consumer tastes. In this Spatial Error Model (SEM) case, the spatial influence does not enter the systematic component of the

<sup>6</sup> For more detailed treatment of spatial autoregressive and spatial error models, see Bernat (1996), Rey and Montouri (1999), and Fingleton and Lopez-Bazo (2006).

specification. Instead, it is captured in an error term which contains a spatial error coefficient,  $\zeta$ , and an idiosyncratic component,  $u$ , where  $u \sim N(0, \sigma^2 I)$ .

$$(4) \quad \ln\left(\frac{y_{i,t+k}}{y_{i,t}}\right) = \alpha + (1 - e^{-\lambda k}) \ln(y_{i,t}) + \varepsilon_{i,t} \quad \text{where} \quad \varepsilon_{i,t} = \zeta W \varepsilon_{i,t} + u_{i,t}$$

Section 4 reports results for cross-sectional growth equation regressions which test for absolute and conditional convergence using the SAR and SEM specifications.

### 3.2 Local Spatial Econometric Methods

As Eckey et al. (2007) note, the influence between the dependant variable and a set of independent variables often differs across regions (spatial non-stationarity). Therefore it may be desirable to utilise an econometric technique which takes account of the possibility of spatial heterogeneity in speeds of convergence across regions. One such technique is geographically weighted regression (GWR), a technique for exploratory spatial data analysis developed by Fotheringham, Brunson, and Charlton, (see, for example Brunson et al. (1996, 1998), Fotheringham et al. (1998, 2002)). GWR permits parameter estimates to vary locally as the parameters are estimated separately at each observed location. The standard OLS regression specification of (1) above can be rewritten as follows to incorporate parameters that vary locally:

$$(5) \quad \ln\left(\frac{y_{i,t+k}}{y_{i,t}}\right) = \alpha_i + \sum \beta_i \ln(y_{i,t}) + \varepsilon_{i,t}$$

where, as discussed above,  $\beta_i = (1 - e^{-\lambda k})$ . In the calibration, observations are weighted according to their proximity to region  $i$ . As the distance between two regions becomes smaller, the weight becomes greater. The Euclidian distance between to regions ( $d_{ij}$ ) is used to calculate a Gaussian weighting function. At the observed point,  $i$ , the weighting of the data point will be unity and the weighting of

the other data will decrease according to a Gaussian curve as the distance between  $i$  and  $j$  increases, so that for a data far away from  $i$  the weighting will fall close to zero, effectively excluding these observations from the estimation of parameters for location  $i$ ; Fotheringham et al. (2002).<sup>7</sup>

$$(6) \quad w_{ij} = e^{-0.5 \cdot (d_{ij}/b)^2}$$

Similar to kernel regression estimation, it is the bandwidth,  $b$ , that determines the extent to which the distances are weighted. A greater bandwidth increases the smoothing across the regions, giving regions  $i$  and  $j$  a relatively larger (smaller) weighting if they are far from (close to) each other. The bandwidth is computed by minimising the Akaike information criteria. In the GWR setting, the parameter estimate for  $\beta_i$  can then be estimated by weighted least squares, with the values of the independent variables from regions near to region  $i$  having a greater influence as they are multiplied by region  $i$ 's weighting matrix,  $\mathbf{W}_i$ :

$$(7) \quad \hat{\beta}_i = (\mathbf{X}' \cdot \mathbf{W}_i \cdot \mathbf{X})^{-1} \cdot \mathbf{X}' \cdot \mathbf{W}_i \cdot \mathbf{Y}$$

where  $\mathbf{X}$  is the matrix form of the independent variable  $\ln(y_{i,t})$  and  $\mathbf{Y}$  is the matrix form of the

$\ln\left(\frac{y_{i,t+k}}{y_{i,t}}\right)$  dependant variable.

However GWR is not without its pitfalls. Wheeler (2009) notes that empirical research and simulation studies have demonstrated that local correlation in explanatory variables can lead to estimated regression coefficients in GWR that are strongly correlated. The standard error calculations in GWR are only approximate due to reuse of the data for estimation at multiple locations (Lesage, 2004) and due to using the data to estimate both the kernel bandwidth and the regression coefficients (Wheeler and Calder, 2007). An issue related to inference of the regression coefficients is that of multiple testing in GWR, where tests of coefficient significance are carried out at many locations using the same data (Wheeler, 2007; Fotheringham et al., 2002). Following Ord and Getis (1995) a Bonferroni correction procedure is used to adjust the significance level of individual tests, where the overall significance

<sup>7</sup> A bi-square (adaptive) kernel Gaussian kernel has been used in the GWR specifications presented in the forthcoming sections.

level is adjusted by dividing by the number of observations in the sample (i.e the number of multiple tests) to get the individual significance level for each observation.

#### 4. Spatial Analysis of $\beta$ -convergence

The focus now turns to establishing the empirics of regional growth and  $\beta$ -convergence across British sub-regions, in the presence of possible spatial dependence. The first step is to statistically test for the presence of spatial autocorrelation in sub-regional secondary, services and aggregate real GVA per capita data using the well-known diagnostic for global spatial autocorrelation, Moran's  $I$  statistic. Once the presence of spatial autocorrelation has been established, the issue of convergence across sub-regions is then considered by augmenting the cross-sectional growth equations which test the hypotheses of absolute conditional convergence to incorporate spatial autoregressive (SAR) components and spatial error (SEM) components, as well as the local GWR specification.

##### 4.1. Diagnostic Test for Global Spatial Autocorrelation

The Moran's  $I$  statistic for spatial autocorrelation yields a test statistic which can be defined as follows:

$$(8) \quad I_t = \left( \frac{n}{s} \right) \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} y_{it} y_{jt}}{\sum_{i=1}^n \sum_{j=1}^n y_{it}^2}$$

where  $w_{ij}$  represents the elements of the spatial weighting matrix  $W$ ,  $n$  and  $s$  denote the total number of sub-regions and the summation of  $w_{ij}$  respectively. The results of this diagnostic test for spatial autocorrelation on secondary, services and aggregate log real GVA per capita for 1995 and 2007, as well as for real GVA per capita growth over the 1995-2007 period, are reported in Table 2.

The test has been carried out using two different types of spatial weighting matrix: i) an inverse distance spatial weighting matrix, where  $w_{ij}$  denotes the row standardized reciprocal distance between sub-regions  $i$  and  $j$ ; and ii) a fixed distance binary contiguity matrix, where  $w_{ij} = 1$  if sub-regions are geographically adjacent with a given distance threshold and  $w_{ij} = 0$  for sub-regions outside of the threshold. The fixed distance threshold (140km) for NUTS 3 level secondary and services real GVA

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3 per capita has been selected using multi-distance spatial cluster analysis (Ripley's k-function).  
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5 Ripley's k-function is a descriptive statistic used for detecting deviations from spatial homogeneity by  
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7 comparing, over different geographic intervals, the mean and variance of the spatial distribution of the  
8  
9 actual data with those generated by a homogenous Poisson process; Dixon(2002). The fixed distance  
10  
11 threshold is chosen as the distance within which deviations from spatial homogeneity are observed to  
12  
13 highest. As this spatial weight specification is intuitive and derived from the underlying data, it used in  
14  
15 the regression analysis undertaken in the following sub-section.  
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17  
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20

21 **[Insert Table 2 here]**  
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24

25 It is clear from Table 2 that secondary, services, and aggregate real GVA per capita do indeed exhibit  
26  
27 strong spatial autocorrelation across sub-regions in both 1995 and 2007. However, when one considers  
28  
29 growth rates over the 1995-2004 period, secondary real GVA per capita growth exhibits spatial  
30  
31 autocorrelation within the 140km threshold when the spatial weight specification is binary contiguous,  
32  
33 while neither business services and finance nor distribution, transport and communications growth  
34  
35 display spatial autocorrelation in this setting. This absence of spatial autocorrelation in real GVA per  
36  
37 capita growth of these services subsectors is in keeping with the visual impression provided by Figure  
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39 4, in which the London-centric spatial pattern of real GVA per capita appears to be firmly established  
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41 prior to 1995 and virtually unchanged over the 1995-2007 period.  
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#### 47 **4.2. Global Analysis of Absolute $\beta$ -convergence**

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49 Table 3 below presents spatial autoregressive (SAR) and spatial error and (SEM) cross-sectional  
50  
51 regressions of secondary, services, and aggregate GVA per capita growth on initial, 1995, log GVA  
52  
53 per capita ( $\ln GVA_{1995}$ ), as outlined in Section 3. GVA per capita data for 125 of the 128 NUT 3 sub-  
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55 regions are used in the specifications in Table 3.<sup>8</sup> In keeping with the notation of Section 3,  $\rho$  and  $\tau$   
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60 <sup>8</sup> In order to ensure consistency with the explanatory variables included in Table 4, the NUTS 3 sub-regions of East and West Cumbria have been amalgamated to form Cumbria. Similarly, East Derbyshire and South and West Derbyshire have been combined to form Derbyshire, while North and South Nottinghamshire have been combined to form Nottinghamshire.

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3 represent the spatial autocorrelation coefficient and spatial error coefficient, respectively. The spatial  
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5 weighting matrix used in throughout this section is the row standardised inverse distance matrix.  
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10 **[Insert Table 3 here]**  
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14 From Table 3 it is clear that secondary sector GVA per capita growth exhibits convergence over the  
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16 1995-2007 period, with an estimated annual speed of convergence ranging from 0.8%-1.03%.<sup>9</sup> Of the  
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18 two services sub-sectors under consideration, business services and finance exhibits neither  
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20 convergence nor divergence over the period in question. Distribution, transport and communications,  
21  
22 does experience convergence in the growth of its real GVA per capita over the 1995-2007 period, with  
23  
24 an annual convergence speed of approximately 1.2%. As for the competing spatial specifications, in  
25  
26 the case of the secondary sector and business services and finance and both yield similar  $R^2$  values and  
27  
28 log-likelihood values, while the SEM specification yields a noticeably higher  $R^2$  value for distribution,  
29  
30 transport and communications. It should also be noted that the SAR spatial autocorrelation estimate is  
31  
32 significant in the case the secondary and distribution, transport and communications sectors, while the  
33  
34 SEM spatial error estimate is significant only in the secondary sector.  
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#### 40 **4.3. Global Analysis of Conditional $\beta$ -convergence**

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42 The cross-sectional specifications used to test for absolute convergence are now augmented with a set  
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44 of explanatory variables, which may capture differences in the paths of steady-state GVA per capita.  
45  
46 Foremost amongst these are initial education levels and human capital formation, which are necessary  
47  
48 to raise productivity.<sup>10</sup> Following Henley (2005), two variables are utilised here to capture distinct  
49  
50 aspects of human capital accumulation process: (i) the county average primary school pupil-teacher  
51  
52 ratio (*Pupil\_Teacher*) and (ii) the average A-level pass rate (*grades*) achieved by pupils in each  
53  
54 county. It is this exam which enables pupils to enter university. As 1995 data is unavailable for these  
55  
56 variables, data dating from 1993 is used instead. As these variables are unavailable at sub-regional  
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<sup>9</sup> As the dependent variable is defined as average real GVA per capita growth for 1995-2004, the speed of convergence,  $\theta$ , is calculated as  $\theta = \log(1 - \beta k) / k$ , where  $k$  denotes the number of years in the time period.

<sup>10</sup> See Mankiw et al. (1992) and Barro and Sala-I-Martin (1995, pp. 420-445) for a detailed discussion regarding the inclusion of control and environmental variables in conditional convergence regressions.



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3 level, the data for each county is applied to the sub-region residing in that county. As discussed in  
4  
5 Section 2, location and geographic proximity have been identified as key drivers of the British  
6  
7 regional growth process. In order to capture this, a set of dummy variables for the eleven NUTS 1  
8  
9 regions has been constructed. Furthermore, the rural/urban orientation of each sub-region is captured  
10  
11 through the inclusion of a variable representing each sub-region's 1995 agricultural real GVA as a  
12  
13 proportion of aggregate real GVA (*Agri*). Data on the capital stock residing in each sub-region at the  
14  
15 start of the 1995-2007 period is unavailable. Instead, as per Hart and McGuinness (2003), the number  
16  
17 of businesses registered for Value Added Tax (VAT) disaggregated for secondary and services sectors  
18  
19 is used as a proxy for capital utilization. This variable (*No. of Businesses*) is expressed in per capita  
20  
21 terms with respect to the relevant sub-region. In order to control for capital investment, net capital  
22  
23 expenditure as a proportion of aggregate real GVA for each sub-region (*Capital Expenditure*) in 1997,  
24  
25 deflated as described in Section 2, is also included in the specifications.<sup>11</sup> As per Perugini and  
26  
27 Signorelli (2004), a further control variables, females in employment in 1995 expressed as a  
28  
29 proportion of people aged 16+ (*Fem Emp'ment*), is included in order capture differences in local  
30  
31 labour market conditions (such as the tightness of the labour market) at the beginning of the 1995-  
32  
33 2007 period. From a methodological perspective, one weakness of cross-region regressions is that of  
34  
35 reverse causality and endogeneity. With the exception of *Capital Expenditure*, all the explanatory  
36  
37 variables used in the conditional convergence specifications refer to 1995 or earlier – and thereby not  
38  
39 susceptible to such reverse causality. *Capital Expenditure* is assumed to be weakly exogenous, and  
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41 instrumental variable techniques have not been applied to it.  
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46 Similar to the absolute convergence case, the results reported in Table 4 are indicative of secondary  
47  
48 sector convergence and exhibit a similar estimated annual speed of convergence (1.1%-1.3%). Of the  
49  
50 services sub-sectors, distribution, transport and communications once again exhibits a convergence  
51  
52 tendency over the 1995-2007 period, with an estimated convergence speed in a range of 1.5%-1.6%.  
53  
54 Business services and finance does not exhibit a tendency towards either convergence or divergence in  
55  
56 this case. In these conditional convergence specifications, the SEM spatial error estimate is significant  
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58 across the secondary and services sectors while the SAR spatial autocorrelation estimate is only  
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<sup>11</sup> Capital expenditure data for the 11 NUTS 3 regions of Wales was unavailable for 1997. As a proxy, the capital expenditure per worker figure for the NUTS 1 region, Wales, is weighted by the real GVA of NUTS 3 region.



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3 significant for business services and finance. Furthermore, the secondary sector SEM estimate exhibits  
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5 a positive sign while the services subsector SEM and SAR estimates both carry negative signs. This  
6  
7 may be indicative of differing mechanisms through which secondary and services sectors spill over to  
8  
9 adjoining NUTS 3 areas, with services centres being more geographically bounded.  
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13 [Inset Table 4 here]  
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17 The conditional convergence regressions also provide some insights into the factors which have driven  
18 these growth trends over the 1995-2004 period. In the secondary sector, the SAR and SEM  
19 specifications point to the average primary school pupil-teacher ratio (*Pupil\_Teacher*) as  
20 positively influencing secondary sector real GVA per capita growth over the period in  
21 question. In the SAR specification, the Scotland regional dummy also appears to exert a  
22 positive significant impact on secondary sector real GVA per capita growth between 1995  
23 and 2007. The set of explanatory variables possess less explanatory power in the case of  
24 business services and finance than for the secondary sector or distribution, transport and  
25 communications. Nonetheless the business services and finance regression indicates that both  
26 the average primary school pupil-teacher ratio (*Pupil\_Teacher*) and the Scotland regional  
27 dummy once again positively influence real GVA per capita growth in that services sub-  
28 sector. Across the distribution, transport and communications SAR and SEM regression  
29 specifications, the significant positive *Fem Emp'ment* coefficient indicates that the local labour  
30 market conditions positively impacted growth over the period in question. The positive significant *No.*  
31 *of Businesses* (in the SEM specification) and the negative significant *Agri* variable are indicative  
32 of the urban orientation of distribution, transport and communications real GVA per capita  
33 growth.<sup>12</sup>  
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<sup>12</sup> Two problems often emerge in studies utilising highly disaggregated regional data: (i) neglect of the impact of commuter flows and (ii) the administrative delineation of regions may not reflect self-contained economic areas. See Fingelton (2003) and Curran (2009) for a discussion of these issues in the British context.

#### 4.4. Local Analysis of Conditional $\beta$ -convergence

The geographically weighted regression technique (GWR) is now utilised to undertake a local analysis of conditional  $\beta$ -convergence on the British NUTS 3 1995-2007 real GVA per capita data. The GWR procedure is used to estimate the local parameter values of cross-sectional regressions of secondary, business services and finance, and distribution, transport and communications GVA per capita growth on initial secondary and services log GVA per capita ( $\ln GVA_{1995}$ ) and the set of explanatory variables described above. The regional dummy variables are omitted from the GWR specification. Tables 5-7 below present the minimum, lower quartile, median, upper quartile, and maximum values of the set of local parameter value estimates and  $R^2$ . For comparison, the global SAR and SEM estimates from Table 4 are also presented. Significance levels for the global SAR and SEM estimates are indicated in Tables 5-7, while significance levels for the variables we are most interested in (the significant secondary and distribution, transport and communications  $\ln GVA_{1995}$  estimates) are presented via colour-coded maps in Figures 5 and 6.

[Inset Table 5 here]

[Inset Table 6 here]

[Inset Table 7 here]

When the secondary sector and both services sub-sector local GWR parameter estimates for  $\ln GVA_{1995}$  are compared with those of the global SAR and SEM specifications, they appear to be in the same order of magnitude and display the same sign (Tables 5-7). As with the global SAR and SEM parameter estimates, secondary sector and distribution, transport and communications sub-sector real GVA growth per capita over the 1995-2007 period exhibits convergence, while business services and finance does not exhibit any tendency towards convergence or divergence.

An inspection of the statistical significance of the local parameter estimates of secondary sector and transport and communications sub-sector  $\ln GVA_{1995}$  is presented in Figure 5, with the Bonferroni significance level (0.04%), as well as the 5%, 1%, and 0.5% significance levels illustrated. It is clear from Figure 5 that the secondary sector GWR specification yields  $\ln GVA_{1995}$  parameters statistically

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3 significant only at 5% or 1% significance levels in the Scottish NUTS 3 regions. This finding, which  
4  
5 was anticipated by the significant Scotland regional dummy variable in the SAR specifications of  
6  
7 Table 4, may be reflecting Scotland's success in the 1990s in attracting multinational computer  
8  
9 hardware manufacturers; van Egeraat and Jacobson (2004). However, as these computer hardware  
10  
11 activities began to shift towards Eastern Europe in the early 2000s, any associated convergence trends  
12  
13 may have been transitory.  
14

15  
16 The local  $\ln GVA_{1995}$  parameter for distribution, transport and communications sub-sector, on the  
17  
18 other hand, is statistically significant across the entire country and displays highest statistical  
19  
20 significance in peripheral western and northern regions. A similar trend is evident in Figure 6,  
21  
22 which illustrates the speed of secondary sector and distribution, transport and communications  
23  
24 sub-sector convergence indicated by the local  $\ln GVA_{1995}$  parameters. While the secondary  
25  
26 sector exhibits an annual convergence speed of 1%-1.5% in Scotland only, the distribution,  
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28 transport and communications sub-sector yields convergence speeds of 1-1.5% per annum in  
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30 the South East, but reside within a range of 1.5%-2% per annum across the rest of Britain.  
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38 [Insert Figure 5 here]

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41 [Insert Figure 6 here]

## 42 43 44 45 46 **5. Conclusions**

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50 This paper addresses the following question: how should the process of British regional economic  
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52 growth over the decade 1995-2007 be characterised? Disaggregating British real GVA per capita into  
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54 its secondary and services components indicates it is an oversimplification to characterize the  
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56 development process experienced in this time period as a convergence process. While economic  
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58 growth in the secondary sector and in certain services activities may well have manifested itself in a  
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60 convergent regional growth process, at the same time growth in services activities such as business

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3 services and finance appears to follow a very persistent spatial pattern that has been established prior  
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5 to 1995 and has been reinforced over the subsequent years.  
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7 While global spatial regression techniques acknowledge the importance of location and proximity in  
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9 the economic development process by controlling for the influence of spatial autocorrelation, they  
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11 characterise the underlying process as being spatially stable i.e. the same relationship holds across the  
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13 entire country. Even a cursory glance at the spatial dispersion of British services sector real GVA per  
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15 capita over the 1995-2007 period suggests that such a characterisation is unlikely to reflect actual  
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17 services sector development. What is more, the growing contribution of services sector GVA to the  
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19 aggregate GVA suggests that this issue is not confined to the services sector development process.  
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22 The main findings of this paper concerning the unevenness of real GVA per capita  
23  
24 convergence across the secondary and services sectors are evident from both global and local  
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26 spatial analysis. Once these trends are established at a global level, the local spatial analysis  
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28 techniques then provide additional insights as how these trends play out “on the ground”. In  
29  
30 this way, employing global and local spatial analysis in a complementary fashion facilitates a  
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32 more detailed characterisation of the British economic development process over time.  
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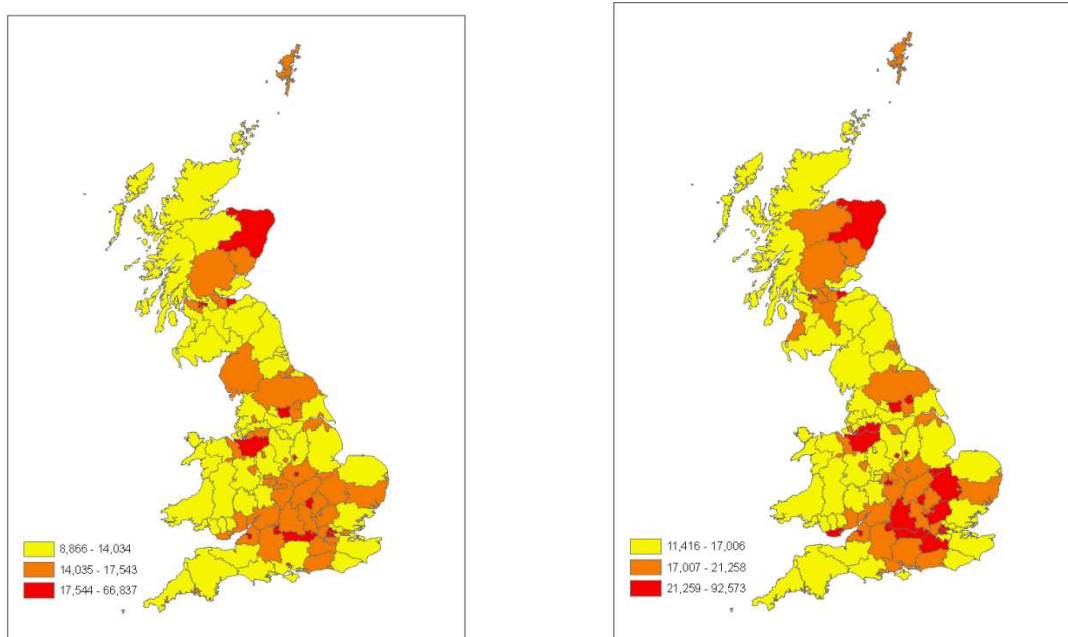
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For Peer Review



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**Figure 1: Aggregate Real GVA per Capita (2007£), 1995 (left) and 2007 (right)**



**Figure 2: Secondary Sector Real GVA per Capita (2007£), 1995 (left) and 2007(right)**

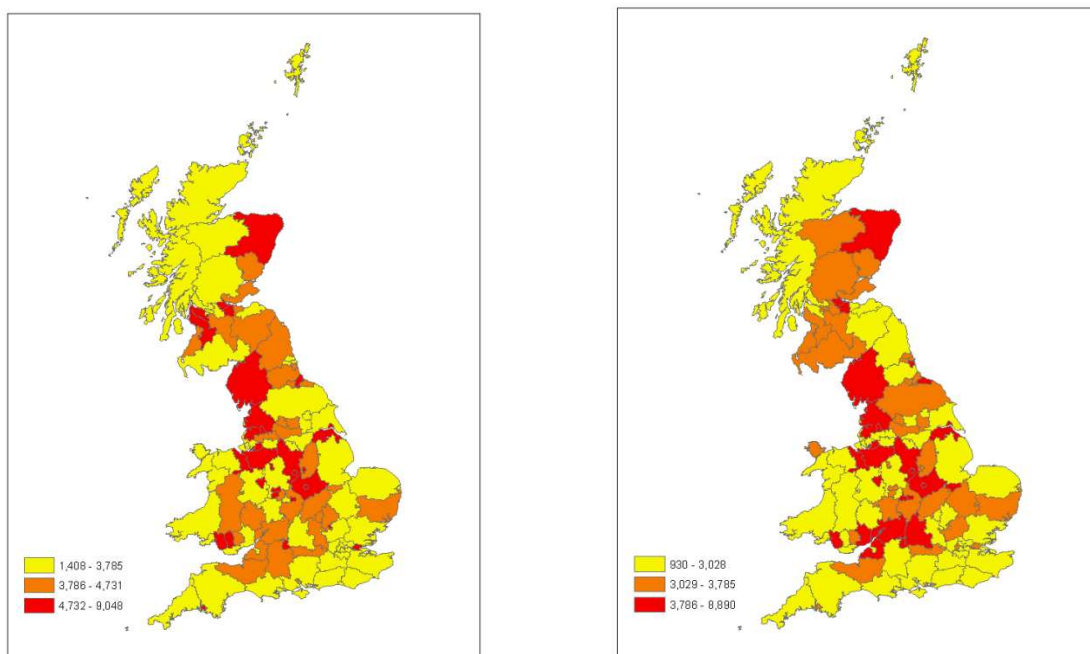


Figure 3: Business Services and Finance GVA per Capita (2007£), 1995 (left) and 2007 (right)

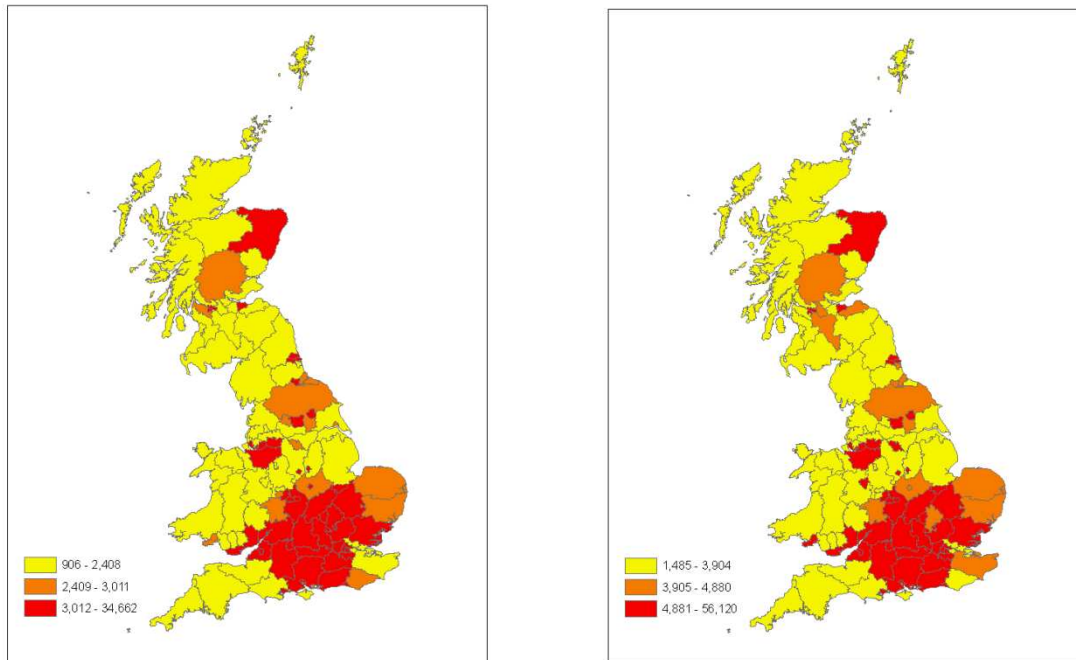
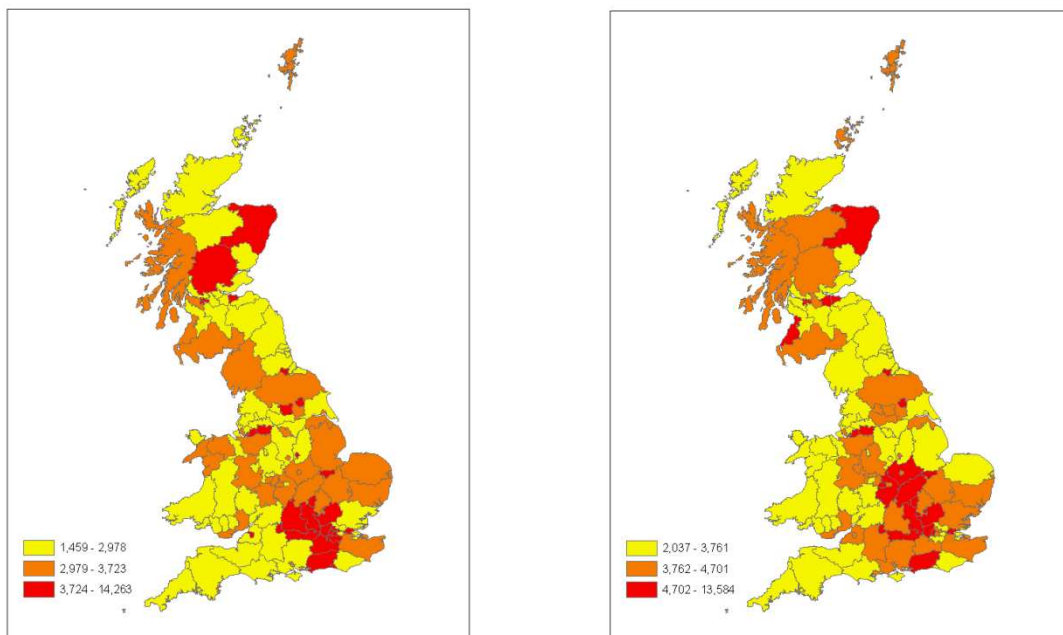
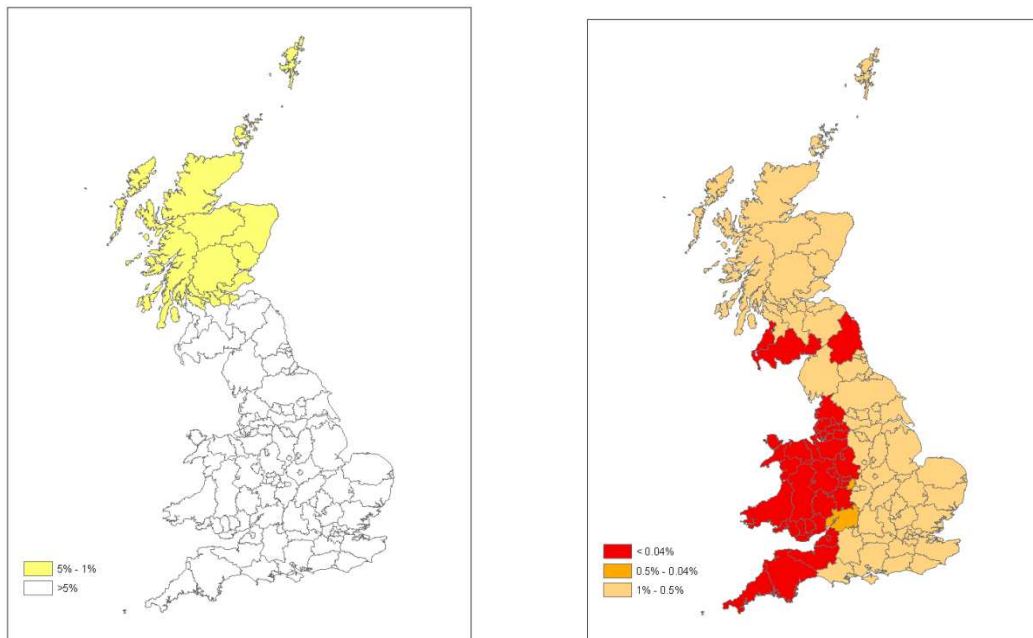


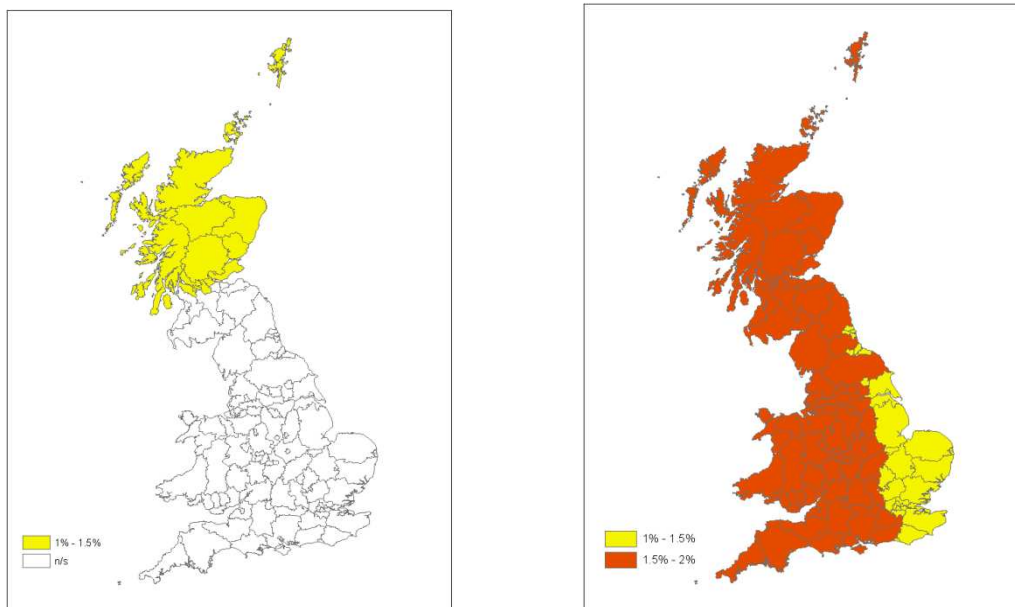
Figure 4: Distribution, transport and communications GVA per Capita (2007£), 1995 (left) and 2007 (right)



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6 **Figure 5: Local  $t$ -statistics for 1995 logged secondary real GVA per capita (left) and distribution,**  
7 **transport and communications GVA Per Capita (right) GWR parameter estimates**  
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33 **Figure 6: Convergence speeds based on 1995 logged secondary real GVA per capita (left) and**  
34 **distribution, transport and communications GVA Per Capita (right) GWR parameter estimates**  
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**Note:** All convergence speeds (shaded) correspond to significance levels of 5% or less; n/s denotes “not significant”.

**Table 1: Summary Statistics for NUTS 3 Secondary and Services real GVA per capita, 1995 -2007**

Secondary Sector GVA per capita (2007 UK£)			Business Services and Finance GVA per capita (2007 UK£)			Distribution, Transport and Communication GVA per capita (2007 UK£)		
	1995	2007		1995	2007		1995	2007
Mean	3,980	3,163	Mean	3,114.08	5,186.98	Mean	3,165.38	4,049.26
Median	3,785	3,028	Median	2,408.89	3,904.57	Median	2,978.83	3,761.01
Maximum	9,048	8,890	Maximum	34,661.66	56,119.66	Maximum	14,262.87	13,583.81
Minimum	1,408	930	Minimum	905.50	1,485.23	Minimum	1,459.05	2,037.28
Std. Dev.	1,503	1,373	Std. Dev.	3,232.33	5,417.09	Std. Dev.	1,264.55	1,360.99
Growth (%)	-	-1.49%	Growth (%)	-	3.73%	Growth (%)	-	1.94%

**Note:** Growth (%) refers to the average annual growth of GVA per capita across NUTS 3 regions over the period 1995-2007. The maximum and minimum for secondary sector average annual NUTS 3 growth are 2.51% and -6.98%, respectively. The equivalent figures for Business Services and Finance are 8.90% and -0.17% respectively, and for Distribution, Transport and Communication the equivalent figures are 5.08% and -0.48% respectively.

**Table 2: Moran's I Global Spatial Autocorrelation Statistic**

	Secondary		Business Services and Finance		Distribution, Transport and Communication	
	<i>W1</i>	<i>W2</i>	<i>W1</i>	<i>W2</i>	<i>W1</i>	<i>W2</i>
<i>Spatial weights matrix</i>						
Log real GVA per capita 1995	0.105***	0.137***	0.189***	0.219***	0.116***	0.138***
Log real GVA per capita 2007	0.111***	0.109***	0.156***	0.210***	0.084***	0.148***
GVA per capita Growth 1995-2007	0.051**	0.015	0.012	0.045*	-0.024	0.013

**Note:** Significance at \*\*\*1%, \*\*5%, and \*10% level. Spatial weights matrices used in the above calculations are row standardised fixed distance (*W1*) and row standardised inverse distance (*W2*) matrices. Fixed distance threshold (140km) selected using multi-distance spatial cluster analysis (Ripley's k-function).

**Table 3: Absolute Convergence Regressions for British NUTS 3 Sub-regions, 1995-2007**

<i>Dependent variable: Average GVA Growth per Capita (1995-2007)</i>						
	<b>Spatial Autoregressive Model (SAR)</b>			<b>Spatial Error Model (SEM)</b>		
	Secondary	Business Services and Finance	Distribution, Transport and Communication	Secondary	Business Services and Finance	Distribution, Transport and Communication
Constant	0.059 (0.038)	0.025 (0.018)**	0.132 (0.026)***	0.071 (0.040)*	0.029 (0.022)***	0.135 (0.026)***
$\ln GVA_{1995}$	-0.008 (0.005)*	0.0003 (0.003)	-0.013 (0.003)***	-0.011 (0.005)**	0.001 (0.002)	-0.014 (0.003)***
$\rho$ (SAR)	0.57 (0.126)***	0.284 (0.176)	-0.454 (0.220)**			
$\tau$ (SEM)				0.824 (0.083)***	0.208 (0.249)	0.253 (0.241)
$R^2$	0.05	0.01	0.14	0.06	0.01	0.13
Log Likelihood	313.851	336.07	396.02	314.73	335.53	395.03
Number of Obs	125	125	125	125	125	125

**Note:** Standard errors are given in parenthesis. Significance at \*\*\*1%, \*\*5%, and \*10% level

**Table 4: Conditional Convergence Regressions for British NUTS 3 Sub-regions, 1995-2007**

<i>Dependent variable: Average GVA Growth per Capita (1995-2007)</i>						
	<b>Spatial Autoregressive Model (SAR)</b>			<b>Spatial Error Model (SEM)</b>		
	Secondary	Business Services and Finance	Distribution, Transport and Communication	Secondary	Business Services and Finance	Distribution, Transport and Communication
constant	-0.013 (0.054)	-0.077 (0.038)	0.119 (0.034)***	-0.015 (0.060)	-0.032 (0.037)	0.135 (0.033)***
lnGVA <sub>1995</sub>	-0.012 (0.005)**	0.003 (0.004)	-0.016 (0.004)***	-0.014 (0.005)**	0.003 (0.004)	-0.018 (0.004)***
Grades	0.0002 (0.001)	0.000 (0.001)	0.0001 (0.0004)	0.001 (0.001)	0.000 (0.001)	0.000 (0.000)
Pupil_Teacher	0.002 (0.001)*	0.004 (0.001)***	0.001 (0.001)	0.003 (0.002)**	0.003 (0.001)***	0.000 (0.001)
Agri	0.180 (0.144)	0.003 (0.130)	-0.143 (0.074)*	0.230 (0.146)	-0.006 (0.128)	-0.173 (0.074)**
No. of Businesses	0.263 (1.141)	-0.368 (0.318)	0.294 (0.187)	-0.611 (1.093)	-0.379 (0.326)	0.329 (0.198)*
Capital Expenditure	0.102 (0.206)	0.067 (0.176)	0.173 (0.106)	0.129 (0.199)	0.088 (0.176)	0.186 (0.108)*
Female Emp'ment	0.001 (0.001)	0.001 (0.001)	0.001 (0.0004)**	0.001 (0.001)	0.001 (0.001)	0.001 (0.0004)***
NE	0.005 (0.010)	-0.013 (0.009)	-0.010 (0.005)*	0.008 (0.019)	-0.010 (0.007)	-0.005 (0.004)
NW	-0.003 (0.008)	-0.008 (0.007)	-0.008 (0.004)**	-0.002 (0.015)	-0.006 (0.006)	-0.007 (0.004)**
YH	0.008 (0.009)	-0.004 (0.007)	-0.008 (0.004)*	0.008 (0.012)	-0.005 (0.006)	-0.005 (0.004)
EM	0.009 (0.009)	0.001 (0.008)	-0.002 (0.005)	0.007 (0.012)	0.003 (0.007)	-0.0003 (0.004)
WM	-0.001 (0.008)	-0.005 (0.007)	-0.001 (0.004)	-0.001 (0.012)	-0.002 (0.006)	-0.0002 (0.004)
SE	-0.0002 (0.008)	-0.006 (0.007)	-0.003 (0.004)	0.001 (0.009)	-0.005 (0.006)	-0.002 (0.003)
L	-0.009 (0.011)	0.0002 (0.010)	-0.010 (0.006)	-0.006 (0.011)	0.0003 (0.010)	-0.011 (0.006)*
SW	0.004 (0.008)	-0.005 (0.007)	-0.002 (0.004)	0.012 (0.012)	-0.002 (0.005)	-0.001 (0.003)
W	0.005 (0.009)	-0.003 (0.008)	-0.0002 (0.005)	0.008 (0.014)	-0.001 (0.007)	-0.002 (0.005)
S	0.018 (0.010)*	0.015 (0.008)*	-0.0001 (0.005)	0.022 (0.027)	0.014 (0.006)**	-0.004 (0.004)
$\rho$ (SAR)	0.275 (0.228)	-0.339 (0.210)	-0.869 (0.239)***			
$\tau$ (SEM)				0.939 (0.035)***	-0.936 (0.327)***	-0.989 (0.323)***
R <sup>2</sup>	0.18	0.12	0.28	0.19	0.17	0.31
Log Likelihood	323.25	343.56	407.42	323.98	347.39	409.32
Number of Obs	125	125	125	125	125	125

**Note:** Standard errors are given in parenthesis. Significance at \*\*\*1%, \*\*5%, and \*10% level. The NUTS 1 level regional dummy variables included are North East (NE), North West (NW), Yorkshire and the Humber (YH), East Midlands (EM), West Midlands (WM), South East (SE), London (L), South West (SW), Wales (W), and Scotland (S). East England is the base region.



**Table 5: Secondary Sector local GWR and global SAR and SEM parameter estimates**

*Dependent variable: Average Secondary GVA Growth per Capita (1995-2007)*

	Min	Lower Quartile	Median	Upper Quartile	Max	Global SAR	Global SEM
constant	-0.099	-0.094	-0.085	-0.061	0.052	-0.013	-0.015
lnGVA <sub>1995</sub>	-0.017	-0.005	-0.003	-0.003	-0.002	-0.012**	-0.014**
Grades	0.000	0.000	0.000	0.000	0.001	0.000	0.001
Pupil_Teacher	0.000	0.001	0.002	0.003	0.003	0.002*	0.003*
No. of Businesses	-2.481	-1.863	-1.347	-1.083	0.572	0.263	-0.611
Capital Expenditure	-0.140	-0.108	-0.061	0.082	0.292	0.102	0.110
Female Emp'ment	0.000	0.001	0.001	0.002	0.002	0.001	0.001
Agri	0.183	0.300	0.314	0.331	0.391	0.180	0.230
R <sup>2</sup>	0.14	0.14	0.14	0.26	0.26	0.18	0.19

**Note:** Significance indicated for global parameters only. Figure 5 illustrates significance of local parameters. Significance of global parameters denoted as follows: \*\*\*1%, \*\*5%, and \*10% level. SAR and SEM global parameter estimates are extracted from Table 4 above.

**Table 6: Business Services and Finance GWR and global SAR and SEM parameter estimates**

*Dependent variable: Average Business Services and Finance GVA Growth per Capita (1995-2007)*

	Min	Lower Quartile	Median	Upper Quartile	Max	Global SAR	Global SEM
constant	-0.045	-0.034	-0.032	-0.030	0.026	-0.077*	-0.083
lnGVA <sub>1995</sub>	0.001	0.002	0.002	0.002	0.003	0.003	0.003
Grades	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Pupil_Teacher	0.001	0.001	0.001	0.001	0.002	0.004***	0.003***
No. of Businesses	-0.941	-0.511	-0.314	-0.269	-0.243	-0.368	-0.379
Capital Expenditure	0.025	0.047	0.067	0.106	0.203	0.067	0.088
Female Emp'ment	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Agri	-0.020	0.004	0.010	0.021	0.030	0.024	-0.006
R <sup>2</sup>	0.07	0.07	0.08	0.18	0.18	0.12	0.17

**Note:** Significance indicated for global parameters only. Significance of global parameters denoted as follows: \*\*\*1%, \*\*5%, and \*10% level.



**Table 7: Distribution, Transport and Communications GWR and global SAR and SEM parameter estimates**

*Dependent variable: Average Distribution, Transport and Communications GVA Growth per Capita (1995-2007)*

	Min	Lower Quartile	Median	Upper Quartile	Max	Global SAR	Global SEM
constant	0.089	0.099	0.110	0.122	0.157	0.119***	0.135***
lnGVA <sub>1995</sub>	-0.020	-0.018	-0.017	-0.017	-0.016	-0.016***	-0.018***
Grades	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Pupil_Teacher	-0.001	0.000	0.000	0.001	0.001	0.001	0.000
No. of Businesses	0.042	0.083	0.118	0.170	0.264	0.294	0.329*
Capital Expenditure	0.051	0.081	0.090	0.996	0.153	0.173	0.186*
Female Emp'ment	0.000	0.001	0.001	0.002	0.002	0.001**	0.001***
Agri	-0.180	-0.122	-0.097	-0.087	0.062	-0.144*	-0.173**
R <sup>2</sup>	0.20	0.23	0.25	0.29	0.29	0.28	0.31

**Note:** Significance indicated for global parameters only. Figure 5 illustrates significance of local parameters. Significance of global parameters denoted as follows: \*\*\*1%, \*\*5%, and \*10% level.