SERC DISCUSSION PAPER 78

Investigating Agglomeration Economies in a Panel of European Cities and Regions

Marianne Sensier (IPEG, School of Social Sciences, University of Manchester)
Declan Curran (DCU Business School, Dublin City University, Dublin)
Michael Artis (SERC, IPEG, University of Manchester, Swansea University)

April 2011

This work is part of the research programme of the independent UK Spatial Economics Research Centre funded by the Economic and Social Research Council (ESRC), Department for Business, Innovation and Skills (BIS), the Department for Communities and Local Government (CLG), and the Welsh Assembly Government. The support of the funders is acknowledged. The views expressed are those of the authors and do not represent the views of the funders.

Investigating Agglomeration Economies in a Panel of European Cities and Regions

Marianne Sensier*
Declan Curran**
Michael Artis***

April 2011

* Institute of Political and Economic Governance, School of Social Sciences, University of Manchester
** DCU Business School, Dublin City University, Dublin
*** SERC, IPEG, University of Manchester, Swansea University

Acknowledgements
This work was funded by a European Spatial Planning Observation Network grant entitled "The Case for Agglomeration Economies in Europe". We would like to thank Martyn Andrews for his advice. Our results are preliminary, please do not cite without permission from authors.

Abstract

This paper investigates agglomeration economies in an annual panel of NUTS 2 and NUTS 3 city regions across France, Germany, Ireland, Italy, Spain and the UK over 1980-2006 and comparing three sub-samples to see if the effects have changed over time. We uncover evidence of long run agglomeration effects of around 6% for NUTS 2 and NUTS 3 city regions for the full sample. The underlying pattern that this data reflects is changing sectoral composition in which manufacturing was declining, to be largely replaced by services; then more recently a period of city-based economic growth with the financial and business services-led boom at its heart.

JEL Classifications: C22, E32, E37, E40
Keywords: agglomeration, system dynamic panel data estimations

1. Introduction

Theories of agglomeration economies posit that the concentration of economic activities leads to the emergence of positive externalities, which are transmitted both within and between industries through channels such as technological spillovers, an increasingly skilled labour pool, and firm-supplier networks (Fujita et al., 1999; Fujita and Thisse, 2002). However, while empirical studies have generally confirmed the presence of a positive agglomeration effect, estimates of this positive externality have tended to vary in magnitude (Melo et al., 2009). Empirical research estimating the extent to which agglomeration economies influence the development of areas has tended to focus on how these positive externalities manifest themselves in a given region's labour productivity. The relationship is usually expressed in terms of how much a doubling of employment density would increase labour productivity. While US and EU estimates of this relationship have varied, most estimates have fallen within a range of 4.5% (Ciccone, 2002) to 13% (Brülhart and Mathys, 2008) for Europe.

In this quantitative analysis we aim to establish the presence and strength of agglomeration economies observed across European NUTS 2 areas and NUTS 3 city-regions[1]. This comparison of agglomeration forces at play in NUTS administrative areas also allows us to assess the extent to which the choice of geographic unit of analysis affects the observed estimates of European agglomeration economies. We also investigate whether distinct agglomeration trends are present in the secondary and services sectors (localisation economies) and whether agglomeration economies operate across sectors (urbanisation).

We estimate the effect of agglomeration economies by regressing employment density on labour productivity utilising a range of dynamic panel data techniques. The countries we analyse include France, Germany, Ireland, Italy, Spain and the UK. We use a similar approach to Brülhart and Mathys (2008), who use a dataset that covers the majority of Europe's NUTS 2 areas and they transform their data into three year averages. While our analysis focuses on a smaller group of Western European countries, we include the countries that Ciccone (2002) studied in cross-section at the NUTS 3 area level. Our analysis departs from both these studies in that we investigate the data at an annual frequency over the sample 1980-2006 and three

[1] We define large city regions as those Nuts 3 regions with population greater than 500,000.

further sub-samples which are close to the decade split (1981-1989, 1990-1998 and 1999-2006) this allows us to assess whether the observed agglomeration effects are changing over time. At the NUTS 2 level we also include a Eurostat variable capturing the amount of human resources in science and technology (HRST) in a region to proxy an education control.

To preview our results we find a greater agglomeration effect for total labour productivity at the NUTS 2 area level in that a doubling of employment density would increase productivity by 6.3% compared to 6.1% at the NUTS 3 city-region level. We find strong localisation agglomeration economies for industry in the 1980s and 1990s but this is not significant for the latest sample though urbanisation economies have emerged. Services in city-regions have strong urbanisation agglomeration economies over the full sample whereas financial intermediation in NUTS 2 areas has exhibited greater localisation economies than urbanisation in the last decade.

In the next section we review the literature on agglomeration economies. In Section 3 we detail the methodology used in this study, Section 4 presents the datasets used in our estimations and some summary statistics. Section 5 discusses the results from our panel data estimation. Finally, Section 6 offers some conclusions.

2. Agglomeration Literature Review

The economics of agglomeration, whose origins can be traced back to the work Marshall (1898; 1919; 1930), tend to be summarised into a triad of external economies – a pooled market for workers with specialised skills, a growing number of increasingly specialised input suppliers and technological spillovers. The local pool of labour can provide an efficiency gain for both workers and firms by maximising job-matching opportunities and thus reducing search costs (Gordon and McCann, 2000; Simpson, 1992), while the associated accumulation of human capital can enhance both labour skills (Arrow, 1962) and firm productivity (Romer, 1987; Scott, 1988). As regards input relations, a localised industry can support more suppliers, which increases the level of specialisation and efficiency of the supply base, which, in turn, presents an efficiency gain for the customers (Harrison, 1992). The actual driver for geographical proximity between firms is the desire to reduce the costs of transactions across space (Krugman, 1991). This may involve transport/logistics costs and/or the cost of intentional information exchange between the two firms (van Egeraat and Jacobson, 2006). The third advantage that is commonly distilled from Marshall's work, technological spillovers, involves informational or knowledge externalities which result from the concentration of (both vertically and horizontally) related firms, facilitating processes of learning and innovation in the locality (Malmberg and Maskell, 1997 and 2002). Technological spillovers are believed to be intensified by proximity in "untraded interdependencies" (Storper, 1995) and independent of the degree of intentional interaction. Knowledge tends to become embedded in the local milieu (Malmberg, 1996) – "the mysteries of trade (…) are in the air" (Marshall, 1898, p.350). This unintentional interaction (Oerlemans and Meeus, 2005) within a group of firms involves the acts of observation and comparison by firms (Malmberg and Maskell, 2002) which are facilitated by non-geographical forms of proximity, notably social, cultural and institutional proximity (although these other forms of proximity can indirectly be augmented by geographical proximity) (Boschma, 2005).

Hoover (1937) further refined the theory of agglomeration economies by dividing such economies into two distinct types: localisation and urbanisation economies. Localisation economies, as identified by Marshall (1890), are advantages that firms in a single industry (or set of closely related industries) gain from being located in the same location while urbanisation economies are advantages gained by all firms, regardless of sector, from being located together. Urbanisation economies are partially based on economies of scope and are related to the phenomenon that people and economic activity in general tend to concentrate in cities or core industrial areas (Malmberg and Maskell, 2002). Urbanisation economies, in particular, offer agents located in densely populated markets the opportunity to take advantage of positive externalities, such as those associated with knowledge spillovers across firms both within and between industries the presence of a more extensive division of labour or increasing returns owing to firm-level economies of scale and improved firm-worker matching (Wheeler, 2001), as well as improved access to inter-industry information flows, better access to specialised services, and access to general public infrastructure and facilities (see Melo et al., 2009; Fujita and Thisse, 2002; Fujita et al., 1999). Of course, negative externalities such as congestion may also arise, though Ciccone and Hall (1996) find that for densely populated areas in the US agglomeration effects more than offset the associated congestion effects.

Empirical research estimating the extent to which agglomeration economies influence labour productivity generally find a positive relationship, though the estimates tend to vary in magnitude; Melo, et al. (2009). Ciccone (2002) estimates agglomeration effects in a cross-section of NUTS 3 areas in France, Germany, Italy, Spain and the UK. Ciccone (2002) finds that a doubling of employment density increases labour productivity by 4.5% - compared to a corresponding elasticity of 5% estimated for the United States (Ciccone and Hall, 1996). Ciccone (2002) also finds that agglomeration effects, education, and country-dummies explain 64 percent of the variation in productivity across European regions; agglomeration effects do not appear to differ significantly between France, Germany, Italy, Spain, and the UK; and production in neighbouring NUTS 3 areas has a significant effect on regional productivity. Further European estimates come from Cingano and Schivardi (2004), who estimate a long-run elasticity of plant productivity to Italian city employment of 6.7%, and Rice et al. (2006), who estimate the effect of proximity to economic mass (controlling for occupational composition) on regional productivity to yield an elasticity of 3.5% for the UK. However, when Brülhart and Mathys (2008) employ a panel data approach estimating the effect of employment density on productivity across the majority of European countries they find elasticity estimates in the region as high as 13%. The wide range of agglomeration-productivity elasticity estimates is greatly influenced by the estimation techniques employed and how these techniques tackle the potential sources of endogeneity or reverse causality in empirical studies of agglomeration effects. The problem of endogeneity, and the empirical approaches utilised to handle it, are now discussed.

It has been well documented in empirical studies of agglomeration effects that, when regressing regional productivity on a measure of regional agglomeration, there is a risk of causality running from productivity to the agglomeration measure i.e. reverse causality. A range of different estimation procedures have been employed to account for this possible source of endogeneity. The general approach is to replace the agglomeration variable (be it employment density or employment mass) with an instrumental variable that is correlated with the agglomeration variable but not correlated with productivity. In a cross-sectional study Ciccone (2002) instruments employment density with regional land area. The underlying idea is that regional boundaries drawn mostly in the 19th century are correlated with 19th century population (and with current population and employment) but not with current productivity. Artis, Miguelez and Moreno (2009) incorporate both a spatial component and instrumental variables into a cross-sectional 2 stage least squares approach. Two external instruments are used: (i) the population in 1801 for regions whose centre is within two travel time bands as per Rice et al. (2006) and (ii) total land area of regions as per Ciccone (2002). Brülhart and Mathys (2008) exemplify the movement away from this type of "external" instrument by using past levels and past changes of the agglomeration variable ("internal instruments") in a dynamic panel setting which is the methodology used in this study and discussed in the next section.

3. Methodology

We outline our theoretical model and estimation approach in this section to quantify the effect of agglomeration.

Brülhart and Mathys (2008) utilise a dynamic version of Ciccone's (2002) static log-linear model of regional labour productivity. Mathys (2007) proposes the dynamic regional productivity model by adding a Cobb-Douglas capital accumulation function to the supply side of the model, combined with an infinitely-lived representative consumer with a constant inter-temporal elasticity of substitution. As investment takes time then we assume that capital stock adjustment evolves slowly (in our case over a year) so labour productivity this year (P_{nt}) is a function of productivity last year ($P_{n,t-1}$) and contemporaneous employment density (D_{nt}). This results in a autoregressive distributed lag ADL(1,0) panel model:

$$P_{nt} = \alpha P_{n,t-1} + \beta D_{nt} + \gamma' X_{nt} + \varepsilon_n + \rho_{ct} + v_{nt} \qquad (1)$$

X_{nt} is a column vector of $k \in (1....K)$ control variables; *α*, *β* and *γ* are coefficients to estimated; ε_n is a region-specific effect; ρ_{ct} is a period-specific effect which varies with country, *c*, and v_{nt} is a stochastic error term. X_{nt} contains the HRST variable representing human resources in science and technology of each NUTS 2 region *n*. It could also contain variables reflecting the time-varying component of the regional business climate or the political environment. In our case we are analysing NUTS 2 and NUTS 3 city region's productivity separately and their sectoral components.

The effects of agglomeration are quantified by testing the long-run equilibrium relationship between employment density and productivity in equation (1) given by the elasticity $\beta_{LR} = \frac{\beta}{1-\alpha}$ so we can gauge the change within the year. We compute this nonlinear combination with a Wald test. If the restrictions are rejected we can conclude that density has a statistically significant long-run effect on region/city productivity. If the restrictions are not rejected but the parameters are individually statistically significantly different from zero, the interpretation is that changes in density have short-run effects on region/city productivity without impacting on the long-run productivity level.

Brülhart and Mathys (2008) compare a number of different dynamic panel estimation methods: OLS, fixed effects, differenced Generalised Method of Moments (DIFF-GMM) and system GMM estimator (SYS-GMM). While the Arellano and Bond (1991) DIFF-GMM estimator uses first differences as instruments, this was found to behave poorly in small samples (Windmeijer, 2005). The SYS-GMM method of Arellano and Bover (1995) uses both lagged levels and first differences as instruments and is seen to perform better in small samples. Brülhart and Mathys (2008) note that SYS-GMM estimation has the ability to control for reverse causality, the approach is also more robust to error than cross-sectional approaches as time-invariant additive measurement error is absorbed into the region-specific effects of the panel specification.

We also compute different estimators to benchmark our results. We compare OLS (with residuals clustered by region), fixed effects and the system GMM model and include year*country dummies in each panel. We utilise Stata 10 and the xtabond2 routine to estimate our SYS-GMM models and compute the Hansen instrument test. Density is assumed to be endogenous[2]. Intuitively, not only might higher density in a given region lead to higher regional productivity, but higher regional productivity could also contribute to higher density as people are attracted into a region. We use as instruments lagged levels of productivity and density in the difference equation and first differences in the levels equation. We follow Brülhart

[2] We save the residuals from our OLS regression and check if the differenced residuals are correlated with first differenced density. We generally find a correlation between 0.3 and 0.5 so this leads us to conclude that density is endogenous. When estimating urbanisation agglomeration effects with other sector density we find this correlation to be closer to zero so other sector density is treated as exogenous in the instrument set.

and Mathys (2008) in testing whether the instruments are performing well by running OLS regressions of density on two lags of first differenced density and two lags of first differenced productivity and then first differences on the level. The combinations of lags that are tested for as instruments are lags(2 3), lags(2 4) and lags(3 5).

Two further diagnostic tests are computed: (1) the Arellano and Bond (1991) test for zero autocorrelation in first-differenced errors and (2) the cross-sectional dependence test of Pesaran (2004) which is written as a Stata routine by De Hoyos and Sarafidis (2006) to follow a fixed effects panel regression and is suitable in dynamic panels when $T<N$ (with T the number of years in the time series and N the number of regions). This tests the null hypothesis of no cross-sectional dependence which if rejected could indicate spatial dependencies are present. We also test different cross-section years with the Moran's *i* statistic for spatial autocorrelation (see Appendix B).

To get a handle on whether it is localisation or urbanisation agglomeration effects that are important we analyse different sectors and estimate own and other sector density effects in separate panel regressions by testing the long-run relationship in the same way as described above.

4. Data and Summary Statistics

We investigate NUTS 2 areas and NUTS 3 city regions in France, Germany (excluding East German regions), Ireland, Italy, Spain and the UK (we eliminate extremes from our dataset by excluding less productive small island regions and highly productive Aberdeen, NUTS 2 region ukm5, due to North Sea oil revenues) for a sample from 1980 to 2006. The dataset we use in this study has been purchased from Cambridge Econometrics[3]. In Chapter 4 of their manual detailing the European regional economic model and the data they describe how "the data completion process for NUTS 2 areas involves deflation, interpolation and summation constraints to ensure consistency across different levels of aggregation", p.4-4. The Eurostat REGIO database is the prime source for the European data produced by Cambridge

[3] See: http://www.camecon.com/AboutUs/Economic_Intelligence_Services/European_forecasts_by_city_region_and_sector/european_forecasts_city_reg_sector.aspx.

Econometrics. They are able to produce deflated GVA series for areas by utilising sectoral price deflators from AMECO.

We analyse a total of 122 NUTS 2 areas (see Appendix Table A.1 for full list) and 172 NUTS 3 city regions we include NUTS 3 areas that have a population greater than 500 thousand (we use Cambridge Econometrics NUTS 3 region population estimates in 2006 to decide which areas to include) these areas are listed in the Appendix Table A.2.

We transform constant price GVA (in millions of Euros with 2000 as the base year) and divide it by employment for the areas to arrive at our dependent variable of labour productivity (GVA per worker). To calculate our employment density variable we divide employment by total land area for each region (in square kilometres). The land areas are downloaded from Eurostat's Regional Statistics Database[4], within regional demographics we can access area tables.

The variable for human resources in science and technology (HRST) as a share of the economically active population in the age group 15-74 is also downloaded from Eurostat's Regional Statistics Database within regional science and technology statistics. This indicator gives the percentage of the total labour force in the age group 15-74, that is classified as HRST, i.e. having either successfully completed an education at the third level or is employed in an occupation where such an education is normally required. HRST are measured mainly using the concepts and definitions laid down in the Canberra Manual, OECD, Paris, 1995. We use this in our panel regression with total productivity in NUTS 2 areas.

When checking for localisation or urbanisation agglomeration effects we use the sector breakdown prepared by Cambridge Econometrics in their European regional dataset. At the NUTS 3 region level three sectors are reported: agriculture, industry and services. At the NUTS 2 area level we can get a finer sector breakdown and we focus on manufacturing and energy production within the industry sector and financial intermediation within the services sector.

Table 1 reports the summary statistics for the NUTS 2 areas over the full sample 1980-2006, with the HRST series reported over a shorter sub-sample of 1999-2006. Table 2 contains the summary statistics for the NUTS 3 city regions. In Tables

[4] See: http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/regional_statistics/data/database.

1 and 2 we present the mean, median and coefficient of variation (calculated as the standard deviation/ mean which gives and indication of the variables degree of dispersion) for total productivity, density and HRST (only available for NUTS 2 areas) over all countries and then by individual country. Within each country we also present the region with the sample average maximum and minimum productivity and density.

From Tables 1 and 2 we can see that the NUTS 2 and 3 areas of Ireland have the greatest dispersion for productivity. The UK has the greatest dispersion of employment density at the NUTS 2 level but France has greater density dispersion at the NUTS 3 level. Over all countries the NUTS 2 region with maximum average productivity of 61.03 is Île de France within this the Haut-de-Seine region has the greatest productivity for the NUTS 3 city regions at 72.55. At the other end of the spectrum Spain has the lowest reported productivity with the NUTS 3 region of Badajoz having an average of 24.68 over the full sample. The UK has the greatest dispersion of employment density at the NUTS 2 level with the densest region being Inner London, also having the highest level of human resources in science and technology. At the NUTS 3 level the highest coefficient of variation for employment density is found for France which has the greatest extreme between Paris and Côte-d'Or. Spain has the smallest average employment density at the NUTS 3 level at 59.62 and the smallest employment density region of Ciudad Real at 7.66.

Tables 3 and 4 report the changes in productivity and employment density means for the full sample and over time to match our estimation samples and also show the change by country within our sample. In Table 3 total and manufacturing productivity increases for the NUTS 2 regions for all countries. For the financial intermediation sector there are falls in productivity for France and Italy in 1990s and in the most recent sample for France. Employment density for all sectors increases in each sample overall but this conceals drops for UK and Italian in the 1990s. Manufacturing employment density actually declines in each decade overall and for all countries apart from Ireland and Spain in the last sample. Ireland has experienced delayed industrialisation with growth particularly in the high tech sectors driven by foreign direct investment since the 1980s.

Table 4 presents the sample means for the NUTS 3 densely populated regions. Again total and industrial productivity grow over time, this is the case for the service sector productivity overall but Spain and Germany experience small drops in the most recent sub-sample. Total employment density actually contracts over the "all countries" measure in the 1990s reflecting the fact that city regions may be more prone to the effects of recessions - but when looking at the country level this is only experienced by France and the UK. Again employment density for industry falls between each sub-sample but within this Ireland and Spain are growing. Employment density for the service sector increases for all large NUTS3 regions, showing this sector is more resilient to the economic downturns within this sample.

5. Agglomeration Effect at differing regional levels

Next we will present the results from our panel regression models and we will discuss the different geographical grouping in separate sections. Table 5 summaries the agglomeration effects of all our estimates (the full results of which are in Tables 6-11), which are the estimated change to productivity from a doubling of employment density. In this table the full sample results are from the OLS panels and the sub-sample results are from the SYS-GMM estimates.

5.1 Results of NUTS 2 Panel Regression Model

The results of the panel data estimations are for total productivity in 122 NUTS 2 areas is shown in Table 6 these include year*country dummies to account for the differences in productivity between countries. We report the OLS estimates (clustered by region) for the full sample as our results from the Pesaran (2004) test with null of no cross-sectional dependence is rejected over the full sample which could indicate that we have problems with spatial dependence, but this test is not rejected for the sub-samples. The issue of spatial autocorrelation in the labour productivity and employment density variables is also explored using global and local Moran's i statistics and maps (presented in Appendix B). While the global Moran's i statistic identify the presence of spatial autocorrelation in the dataset, the local Moran's i statistic and maps are not indicative of strong spatial dependence in the underlying data. We report the OLS and fixed effects parameter estimates to benchmark the SYS-GMM regression results for the sub-samples as the OLS results for an autoregressive panel model are known to be biased upwards and for the fixed effects model biased downwards.

Table 5: Summary of the Agglomeration Effect

	Full Sample	**1980s**	**1990s**	**00s**
Regional Grouping:	**1981-2006**	**1981-1989**	**1990-1998**	**1999-2006**
NUTS 2 Total	6.33%***	8.85%***	5.12%	13.35%***
NUTS 2 Manufacturing Own Sector	3.89%**	15.15%**	9.86%**	-201.88%
NUTS 2 Manufacturing Other Sector	5.67%***	2.64%*	5.94%**	6.30%***
NUTS 2 Financial Intermediation Own Sector	2.83%***	3.58%	3.56%	13.12%***
NUTS 2 Financial Intermediation Other Sector	3.53%***	2.64%*	5.12%	4.17%***
NUTS 3 City-regions Total	6.10%***	12.85%**	0.16%	9.05%***
NUTS 3 Industry Own Sector	6.94%***	12.47%**	11.75%***	3.38%
NUTS 3 Industry Other Sector	7.01%***	5.94%***	4.90%***	5.47%***
NUTS 3 Services Own Sector	5.73%***	3.49%	4.02%	9.70%***
NUTS 3 Services Other Sector	6.36%***	4.95%***	4.38%***	6.93%**

Note: the agglomeration effect is the estimated increase in productivity from a doubling of employment density.

In Table 6 for total productivity at the NUTS 2 level we see that most parameters are significant for the full sample and sub-samples, with a high coefficient on lagged productivity and a small coefficient on density. In our last sub-sample 1999 to 2006 we are able to include the human resources in science and technology variable (proxy to education controls) and find this to be significantly contributing to productivity in the OLS panel regression. We test the long-run elasticity restrictions with a Wald test which uses the "delta method" approximation in Stata. Over the full sample we have a positive elasticity of 0.0886 which is the marginal change. To transform the marginal change into the long-run agglomeration effect we calculate (2^0.0886-1) = 0.0633 so that a doubling of employment density would increase productivity by 6.33% as shown above in Table 5.

When we analyse the agglomeration effect over time we find that it was significant in the 1980s estimated to be 8.85% and becomes insignificant in the 1990s. During this decades all countries experienced classical recessions and Germany had a prolonged recession due to reunification from 1991-94[5]. Over the latest sub-sample 1999 to 2006 most countries were experiencing strong growth with only Germany (2001-3 recession) and France (2002-3 recession) experiencing downturns. Here we estimate a positive and significant agglomeration effect at 13.35% (which falls to 8.15% when the HRST variable is included). So productivity over the last decade has increased when most nations were growing but when taking account in the increase of skills in the labour force the productivity increase is more muted.

The results for NUTS 2 manufacturing productivity are presented in Table 7 and those for the NUTS 2 financial intermediation sector are in Table 8, we regress the productivity variable on own sector employment density and then in a separate regression on other sector density[6]. From Table 7 we see that over the full sample manufacturing productivity exhibits a significant localisation agglomeration effect of 3.89% and when regressed against other sector employment density we get a larger significant urbanisation agglomeration effect of 5.67%. When analysing the sub-samples we find strong significant manufacturing sector localisation effects in the 1980s and 1990s of 15.15% and 9.86%, respectively. During the last decade we find a negative and insignificant agglomeration effect for own sector manufacturing, probably due to industrial decline across Western Europe. The urbanisation agglomeration effect increases for this sector over time and for the most recent sample it is 6.3% so the manufacturing sector has benefitted from locating near other sectors.

The financial intermediation results of Table 8 show a sector that has grown more rapidly over the last decade. The urbanisation agglomeration effect for financial services is significant in the 1980s but for both panels in this sample we have problems with serial correlation. This sector has exhibited a stronger localisation agglomeration effect of 13.12% for the last sub-sample than the urbanisation effect at 4.17%, showing that this sector benefits most from locating near other firms in the financial intermediation sector.

[5] For a list of classical recessions dates see the Economic Cycle Research Institute's web-site: at www.businesscycle.com/resources/cycles.

[6] Brülhart and Mathys (2008) include both own and other sector density in the panel regression specification but we find that own and other sector density are quite highly correlated around 0.93 for the manufacturing sector and 0.98 for financial intermediation.

5.2 Results of Large NUTS 3 City Panel Regression Model

Table 9 presents the results of the panel of 172 NUTS 3 large city regions (with population greater than 500,000) for total productivity. All parameters are significant for the full sample and for the sub-samples the diagnostic tests are satisfactory. The NUTS 3 city region OLS estimates show an agglomeration effect of 6.1% over the full sample. Here the cross-sectional independence and error autocorrelation tests are rejected over the full sample but accepted for the sub-samples. When we analyse the sub-samples the agglomeration effect is strongest for the 1980s at 12.85% (larger than the 8.85% estimated for the NUTS2 grouping of regions), insignificant for the 90s decade (with more classical recessions) and then significant at 9.05% for the latest sample 1999 to 2006.

The industry productivity results for the large NUTS 3 areas are presented in Table 10 for own and other sector. Here strong localisation effects exist for industry in densely populated regions in the 1980s (12.47%) and 1990s (11.75%). Ciccone (2002) estimated this effect to be 4.5% for a 1980s cross-section of industry productivity in this group of countries (excluding Ireland) this is close to our OLS estimates for the 1980s of 5.75%. Own sector localisation agglomeration effects disappear in the recent sub-sample but urbanisation effects are found for all samples, these agglomeration effects are important for the industry sector in city regions.

Finally Table 11 shows the service sector results for large city regions with a strong localisation effect emerging in the most recent sub-sample of 9.7%. Urbanisation effects are found over the full sample and each in sub-sample, with the greatest effect reported most recently of 6.93%.

6. Conclusions

This paper investigates agglomeration economies in European NUTS 2 areas and NUTS 3 city regions across France, Germany, Ireland, Italy, Spain and the UK. The effect of agglomeration economies across these European areas over the period 1980-2006 is estimated utilising system GMM dynamic panel data techniques. While our analysis focuses on a smaller group of Western European countries than Brülhart and Mathys (2008) the dataset used in this study includes the countries contained in the Ciccone (2002) cross-sectional study of European NUTS 3 areas. In this way, our method and results can be situated in terms of existing empirical research in this area but have contributed to the literature in investigating agglomeration economies at an annual frequency in a dynamic panel, observing how these results change over time and monitoring for spatial dependence in our models.

In the quantitative analysis undertaken in this study we uncover evidence of strong long run agglomeration effects over all countries of 6.3% at the NUTS 2 area level and 6.1% at the NUTS 3 city region level. When we split our sample period into decade-long sub-samples we find that the agglomeration effect for NUTS 3 city-regions is stronger in the 1980s and for the NUTS 2 areas is greatest over the last decade. Total productivity at both levels does not show significant agglomeration effects for the 1990s due to many countries experiencing economic downturns.

We investigated if localisation or urbanisation agglomeration economies were important by analysing sector data at the broad level of industry and services for NUTS 3 city regions and for the sectors of manufacturing and financial intermediation for NUTS 2 areas. Our results are consistent with indications emanating from recent research that the last thirty years has seen a significant shift from the late industrial period, in which manufacturing industries benefited from localisation economies, to evidence of urbanisation effects for industry in the last decade. Knowledge based economic activities, dominated by service industries in terms of employment, have benefited more from urbanisation economies, particularly in the most densely populated city regions. This result is reinforced by Sensier and Curran (2010) in a study of large urban zones.

Taken as a whole, the findings of our quantitative analysis reiterate the presence of agglomeration economies across European NUTS 2 and NUTS 3 city regions in recent decades, and indicate that previous empirical studies may actually have underestimated the strength of these forces in the European context.

References

Anselin, L. (1995) Local indicators of spatial association – LISA, *Geographical Analysis* 27, 93–115.

Arellano, M., and Bond, S. 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations, *Review of Economic Studies* **58**, 277-297.

Arellano, M., and Bover, O. 1995. Another look at instrumental variable estimation of error-component models. *Journal of Econometrics* **68** 29-51.

Arrow, K. J. 1962 The economic implications of learning by doing, *Review of Economic Studies* **29**, 155–173.

Artis, M.J., Miguelez E., and R. Moreno, 2009. Assessing agglomeration economies in a spatial framework with endogenous regressors, *CEPR Working Paper* No. 7267.

Boschma, R. 2005. Proximity and innovation: a critical assessment. *Regional Studies* **39** 61 – 74.

Brülhart, M. and N. A. Mathys 2008. Sectoral agglomeration economies in a panel of European regions, *Regional Science and Urban Economics* 38, 348-62.

Ciccone, A. and Hall, R. 1996. Productivity and the Density of Economic Activity American Economic Review, *American Economic Association*, 86(1), 54-70.

Ciccone, A. 2002. Agglomeration effects in Europe *European Economic Review*, Elsevier, vol. 46(2), 213-227.

Cingano F., and Schivardi F. 2004. Identifying sources of local productivity growth. *Journal of the European Economic Association* **2**(4) 720-742.

De Hoyos, R.E. and Sarafidis, V. 2006. Testing for cross-sectional dependence in panel-data models. *The Stata Journal*, 6(4), pp. 482-496.

Egeraat, C. van, and Jacobson, D. 2006. The geography of linkages in the Irish and Scottish computer hardware industry: the role of information exchange. *Journal of Economic and Social Geography*, **97**(4) pp. 45-18.

Fujita, M.M and Thisse, J.-F., 2002 *Economics of agglomeration-cities, industrial location, and regional growth*. Cambridge University.

Fujita, M.M., Krugman, P., and Venables, A.J. 1999. *The spatial economy-cities, regions and international trade*. The MIT press. England.

Gordon, I., and McCann, P. 2000. Industrial clusters: complexes, agglomeration and/or social networks? *Urban Studies* **37** 513 – 532.

Harrison, B, 1992. Industrial districts: old wine in new bottles? *Regional Studies* **26** 469 – 483.

Hoover, E. 1937. *Location Theory and the Shoe and Leather Industry* (Harvard University Press, Cambridge).

Krugman, P. 1991. *Geography and Trade* (Leuven University Press/The MIT Press, Leuven/Cambridge).

Malmberg, A. 1996. Industrial geography: agglomeration and local milieu. *Progress in Human Geography* **20** 392-403

Malmberg, A., and Maskell, P. 1997. Towards an explanation of regional specialization and industry agglomeration. *European Planning Studies* **5** 25 – 41.

Malmberg, A., Malmberg, B., and Lundquist, P. 2000. Agglomeration and firm performance: economies of scale, localisation and urbanisation among Swedish export firms. *Environment and Planning A* **32** 305-321.

Malmberg, A., and Maskell, P. 2002. The elusive concept of localization economies: towards a knowledge-based theory of spatial clustering. *Environment and Planning A* **34** 429-449.

Marshall, A. 1898. *Principles of Economics* (4th ed. First published 1890) (Macmillan, London).

Marshall, A. 1919. *Industry and Trade* (Macmillan, London).

Marshall, A. 1930. *The Pure Theory of Domestic Values* (London School of Economic and Political Science, London).

Mathys, N.A. 2007. A dynamic model of sectoral agglomeration effects, Mimeo, University of Lausanne. (http://works.bepress.com/nicole_mathys/5/)

Melo, P., Graham, D. and Noland, R. 2009. A meta-analysis of estimates of urban agglomeration economies, *Regional Science and Urban Economics* 39 332-342.

Ord J. K. and Getis, A. 1995. Local spatial autocorrelation statistics; distributional issues and an application, *Geographical Analysis* 27, 286–305.

Oerlemans, L.A.G., and Meeus, M.T.H. 2005. Do organizational and spatial proximity impact of firm performance? *Regional Studies* **39**(1), 89-104.

Parr, J. 2002. Agglomeration economies: ambiguities and confusions. *Environment and Planning A* **34** 717 – 731.

Patacchini E. and Rice, P. (2007) Geography and economic performance: exploratory spatial data analysis for Great Britain, *Regional Studies* **41**, 489-508.

Pesaran, M.H. 2004. General diagnostic tests for cross section dependence in panels. University of Cambridge, Faculty of Economics, *Cambridge Working Papers in Economics* No. 0435.

Phelps, N. 1991. External economies, agglomeration and flexible accumulation. *Transactions of the Institute of British Geographers* **17** 35 – 46.

Rice, P., Venables, A.J. and Patacchini, E. 2006. Spatial determinants of productivity: analysis for the regions of Great Britain *Regional Science and Urban Economics* 36 727–752.

Romer, P. M. 1987. Growth based on increasing returns due to specialisation, *American Economic Review* **77**, 56–72.

Scott, A. J. 1988. *New Industrial Spaces*. London:Pion.

Sensier, M. and Curran, D. 2010. Agglomeration Economies in Large Urban Zones, working paper University of Manchester.

Simpson, W. 1992. *Urban Structure and the Labour Market: Worker Mobility, Commuting and Underemployment in Cities*. Oxford: Clarendon Press.

Storper, M. 1995. The resurgence of regional economies, ten years later: the region as a nexus of untraded interdependencies. *European Urban and Regional Studies*, **2** 191-221.

Wheeler, Christopher H. 2001. “Search, Sorting, and Urban Agglomeration” Journal of Labor Economics, 19, No. 4 pp. 879-899 University of Chicago Press.

Windmeijer, F. 2005. A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics*, **126** 25-51.

Table 1: Summary Statistics for NUTS 2 Areas in Ireland, Spain, France, the UK, Italy and Germany

Variables Country (# regions)	Mean	Median	Coefficient of Variation	Max.	Region with maximum of average 1980-2006	Min.	Region with minimum of average 1980-2006
Labour Productivity (122)	40.76	40.71	0.1900				
Ireland (2)	42.17	38.60	0.3058	48.57	Southern and Eastern (ie02)	35.77	Border, Midlands and Western (ie01)
Spain (15)	31.51	31.91	0.1451	37.46	Comunidad de Madrid (es3)	24.98	Extremadura (es43)
France (21)	44.26	44.77	0.1590	61.03	Île de France (fr1)	39.47	Limousin (fr63)
UK (35)	39.54	38.86	0.1749	53.14	Inner London (uki1)	30.89	Cornwall and Isles of Scilly (ukk3)
Italy (19)	40.31	40.21	0.1625	49.54	Valle d'Aosta/Vallée d'Aoste (itc2)	32.61	Calabria (itf6)
Germany (30)	44.56	44.14	0.1372	57.28	Hamburg (de6)	39.81	Trier (deb2)
Employment Density	209.19	73.88	3.3295				
Ireland	19.50	18.91	0.5238	28.32	Southern and Eastern (ie02)	10.68	Border, Midlands and Western (ie01)
Spain	50.50	31.31	1.3007	261.5	Madrid (es3)	7.31	Castilla-la Mancha (es42)
France	55.61	30.98	1.5172	419.0	Île de France (fr1)	16.61	Limousin (fr63)
UK	466.16	147.76	2.6424	7322.5	Inner London (uki1)	34.76	Cumbria (ukd1)
Italy	72.36	66.36	0.6199	182.26	Lombardia (itc4)	16.97	Valle d'Aosta/Vallée d'Aoste (itc2)
Germany	195.54	104.01	1.4000	1336.3	Hamburg (de6)	38.93	Lüneburg (de93)
HRST average 1999-2006	0.342	0.338	0.1786		**Maximum value**		**Minimum value**
Ireland	0.315	0.315	0.1720	0.387	Southern and Eastern (ie02)	0.22	B., M. & Western (ie01)
Spain	0.340	0.331	0.2087	0.549	Pais Vasco (es21)	0.211	Extremadura (es43)
France	0.329	0.309	0.1637	0.54	Île de France (fr1)	0.248	Champagne-Ard. (fr21)
UK	0.345	0.332	0.1650	0.582	Inner London (uki1)	0.248	E.Yorks &N.Lincs (uke1)
Italy	0.287	0.287	0.1313	0.396	Liguria (itc3)	0.199	Basilicata (itf5)
Germany	0.387	0.383	0.1046	0.518	Oberbayern (de21)	0.283	Niederbayern (de22)

Table 2: Summary Statistics for NUTS 3 city regions in Ireland, Spain, France, the UK, Italy and Germany average for 1980-2006

Variables Country (# regions)	Mean	Median	Coefficient of Variation	Maximum	Region with maximum of average 1980-2006	Minimum	Region with minimum of average 1980-2006
Labour Productivity (172)	41.94	41.63	0.2374				
Ireland (2)	52.73	51.47	0.3238	56.42	Dublin (ie021)	49.04	South-West (ie025)
Spain (27)	31.46	31.75	0.1393	37.76	Tarragona (es514)	24.68	Badajoz (es431)
France (50)	46.99	46.62	0.1921	72.55	Hauts-de-Seine (fr105)	37.28	Côte-du-Nord (fr521)
UK (44)	40.20	40.21	0.2212	55.37	Inner London - West (uki11)	30.89	Cornwall and Isles of Scilly (ukk3)
Italy (31)	40.04	39.88	0.1745	49.54	Milano (itc45)	31.60	Cosenza (itf61)
Germany (18)	49.98	48.90	0.1504	60.66	Düsseldorf, Kreisfreie Stadt (dea11)	43.08	Rhein-Sieg-Kreis (dea2c)
Employment Density	552.34	101.10	3.1003				
Ireland	252.19	194.53	1.0050	487.64	Dublin (ie021)	16.73	South-West (ie025)
Spain	59.62	33.52	1.1703	261.5	Madrid (es3)	7.66	Ciudad Real (es422)
France	555.25	48.12	4.2491	16257.24	Paris (fr101)	24.02	Côte-d'Or (fr261)
UK	892.99	193.52	2.3252	13418.5	Inner London - West (uki11)	32.69	North Yorkshire CC (uke22)
Italy	168.77	121.26	1.1962	973.01	Milano (itc45)	28.74	Foggia (itf41)
Germany	1144.6	1009.09	0.7254	2878.77	München, Kreisfreie Stadt (de212)	152.07	Rhein-Sieg-Kreis (dea2c)

Table 3: Sample Averages for NUTS 2 Areas in Ireland, Spain, France, the UK, Italy and Germany

Sector	All Sectors				Manufacturing				Financial Intermediation sector			
Sample Country (# regions)	**1981-2006**	**1981-1989**	**1990-1998**	**1999-2006**	**1981-2006**	**1981-1989**	**1990-1998**	**1999-2006**	**1981-2006**	**1981-1989**	**1990-1998**	**1999-2006**
Labour Productivity												
All Countries (122)	41.08	36.02	41.92	45.83	45.28	35.42	45.51	56.11	76.71	67.71	74.91	88.87
Ireland (2)	42.82	32.30	41.84	55.77	65.70	35.91	56.17	109.91	93.24	81.01	95.47	104.49
Spain (15)	31.74	28.82	32.93	33.67	34.32	29.21	35.12	39.16	71.33	64.42	73.93	76.17
France (21)	44.63	38.64	45.95	49.89	41.98	31.21	41.54	54.60	77.44	86.32	**72.90**	**72.57**
UK (35)	39.90	34.69	39.75	45.93	53.06	40.66	54.89	64.94	91.57	68.83	88.94	120.12
Italy (19)	40.56	35.55	42.29	44.25	39.05	32.05	40.94	44.79	74.96	75.86	**72.81**	76.37
Germany (30)	44.86	39.89	45.90	49.28	46.57	37.44	44.72	58.91	61.57	48.99	60.40	77.04
Employment Density												
All Countries	209.14	201.87	203.64	223.51	37.67	45.01	**36.45**	**30.78**	10.92	10.46	10.97	11.38
Ireland	19.61	15.84	17.87	25.82	3.80	3.35	3.75	4.36	0.75	0.55	0.65	1.08
Spain	50.80	42.41	48.24	63.11	10.85	10.52	**10.36**	11.76	1.43	1.33	1.44	1.52
France	55.62	53.68	54.34	59.26	11.17	12.89	**10.78**	**9.67**	1.98	1.91	1.97	2.06
UK	465.66	453.23	**447.87**	499.68	69.50	89.62	**64.36**	**52.63**	28.51	26.55	28.78	30.42
Italy	72.47	71.26	**71.13**	75.28	17.43	18.95	**17.04**	**16.17**	1.88	1.73	1.98	**1.95**
Germany	195.69	187.20	197.20	203.55	47.56	51.96	**49.38**	**40.57**	7.81	8.44	**7.66**	**7.28**

Note: bold font in the averages signifies decline between decades in productivity or density.

Table 4: Sample Averages for NUTS 3 city regions in Ireland, Spain, France, the UK, Italy and Germany

Sector	**All Sectors**				**Industry**				**Service Sector**			
Sample **Country (# regions)**	**1981-2006**	**1981-1989**	**1990-1998**	**1999-2006**	**1981-2006**	**1981-1989**	**1990-1998**	**1999-2006**	**1981-2006**	**1981-1989**	**1990-1998**	**1999-2006**
Labour Productivity												
All Countries (172)	42.29	36.85	43.17	47.42	42.65	34.23	43.40	51.27	44.16	41.00	44.69	47.12
Ireland (2)	53.61	38.78	50.41	73.90	73.33	35.61	61.84	128.69	47.26	40.96	46.93	54.72
Spain (27)	31.68	28.97	32.93	33.32	31.57	28.54	32.71	33.68	34.79	34.74	35.22	**34.37**
France (50)	47.36	41.76	48.48	52.41	44.47	35.48	44.87	54.13	50.14	47.52	50.83	52.30
UK (44)	40.61	34.29	40.42	47.93	46.60	35.79	48.72	56.39	39.24	34.25	38.17	46.06
Italy (31)	40.35	34.52	41.96	45.11	37.00	30.24	38.79	42.60	45.51	42.22	46.74	47.84
Germany (18)	50.30	45.08	51.75	54.53	50.87	42.25	48.23	63.51	50.96	46.73	53.96	**52.34**
Employment Density												
All Countries	551.92	540.70	**537.13**	581.18	118.45	143.08	**114.54**	**95.13**	429.35	392.53	418.65	482.80
Ireland	254.43	192.91	239.82	340.07	58.63	50.17	56.86	70.15	193.08	139.95	180.33	267.19
Spain	59.94	50.23	57.00	74.17	19.15	16.83	17.94	23.13	36.85	28.18	35.64	47.94
France	554.04	557.68	**538.68**	567.21	103.44	133.55	**98.81**	**74.76**	448.02	420.82	437.56	490.38
UK	892.19	866.72	**857.01**	960.43	166.29	206.15	**154.99**	**134.14**	722.48	656.61	698.50	823.54
Italy	169.10	164.80	166.46	176.46	56.30	61.12	**54.90**	**52.44**	106.10	94.84	105.20	119.78
Germany	1144.57	1118.32	1142.48	1176.46	305.83	356.28	**313.32**	**240.65**	832.69	755.72	822.89	930.31

Note: bold font in the averages signifies decline between decades in productivity or density.

Table 6: Total Productivity Agglomeration Estimates for Nuts 2 Areas in France, Germany Ireland, Italy, Spain and the UK

	Full Sample	1980s	1990s	2000s	2000s +HRST
Sample Period for annual data	1981-2006	1981-1989	1990-1998	1999-2006	1999-2006
Log labour prod (*t-1*) OLS	0.9707*** (0.0047)	0.9702*** (0.0078)	0.9628*** (0.0081)	0.9813*** (0.0089)	0.9604*** (0.0098)
SYS-GMM		0.8813*** (0.0556)	0.9688*** (0.0239)	0.8884*** (0.0541)	0.8747***(0.0546)
FE	0.8541*** (0.0091)	0.5196*** (0.0267)	0.5742*** (0.0233)	0.4277*** (0.0245)	0.4278*** (0.0246)
Log emp. density(*t*) OLS	0.0026*** (0.0007)	0.0023***(0.0009)	0.0032***(0.0008)	0.0021***(0.0010)	0.0016* (0.0009)
SYS-GMM		0.0145***(0.0070)	0.0023 (0.0030)	0.0202*** (0.0097)	0.0142 (0.0097)
FE	-0.0789*** (0.0088)	-0.2030***(0.0303)	-0.2945***(0.0243)	-0.4182***(0.0292)	-0.4202*** (0.0292)
HRST OLS					0.0691*** (0.0189)
SYS-GMM					0.0775 (0.0861)
FE					0.0393 (0.0350)
Constant OLS	0.1180*** (0.0199)	0.0750*** (0.0263)	0.1351*** (0.0298)	0.0961*** (0.0332)	0.1395*** (0.0364)
SYS-GMM		0.3531** (0.1812)	0.1822*** (0.0806)	0.4023*** (0.1993)	0.4456*** (0.1860)
FE	0.8938*** (0.0563)	2.6258*** (0.1684)	2.8945*** (0.1567)	4.0827*** (0.1723)	4.0698*** (0.1727)
$(\beta_0)/(1-\alpha)$: OLS	0.0886***	0.0778***	0.0855***	0.1110**	0.0414**
SYS-GMM		0.1223***	0.0721	0.1808***	0.1130*
FE	*-0.5413****	*-0.4225****	*-0.6917****	*-0.7308****	*-0.7344****
Cross-section Dependence test	0.001	0.068	0.051	0.097	0.112
AR(2)	0.198	0.772	0.778	0.283	0.288
Hansen Test for instruments		0.308 lags(2 3)	0.169 lags(3 5)	0.950 lags(2 4)	0.909 lags(2 4)
Observations	3172	1098	1098	976	970

Notes: Dependent variable = Log labour productivity(*t*) with 122 NUTS 2 regions. Two-step SYS-GMM is performed with corrected standard errors in brackets. Parameter restrictions are performed by a Wald test and *, ** and *** indicate 10, 5 and 1% significance levels respectively. The probability values are reported for Pesaran's cross-section dependence test of and the AR(2) which is the Arellano-Bond test for zero autocorrelation in first differenced errors. All regressions include year*country dummies.

Table 7: Manufacturing Sector Agglomeration Estimates for Nuts 2 Areas in France, Germany Ireland, Italy, Spain and the UK

Sample Period	Full Sample: 1981-2006		1980s: 1981-1989		1990s: 1990-1998		2000s: 1999-2006	
Sector:	Own	Other	Own	Other	Own	Other	Own	Other
Log labour productivity(*t-1*) OLS	0.9468*** (0.0084)	0.9418*** (0.0089)	0.9145*** (0.0144)	0.9120*** (0.0149)	0.9560*** (0.0100)	0.9499*** (0.0106)	0.9775*** (0.0073)	0.9733*** (0.0079)
SYS-GMM			0.8681*** (0.0385)	0.8825*** (0.0545)	0.9369*** (0.0383)	0.9117*** (0.0591)	0.9093*** (0.0281)	0.8363*** (0.0577)
FE	0.7687*** (0.0104)	0.7992*** (0.0102)	0.6182*** (0.0237)	0.6598*** (0.0239)	0.5278*** (0.0247)	0.5866*** (0.0260)	0.5065*** (0.0288)	0.5301*** (0.0292)
Log employment density(*t*) OLS	0.0029*** (0.0011)	0.0046*** (0.0011)	0.0011 (0.0018)	0.0031* (0.0018)	0.0036*** (0.0013)	0.0053*** (0.0013)	0.0034*** (0.0010)	0.0039*** (0.0012)
SYS-GMM			0.0269*** (0.0100)	0.0044 (0.0030)	0.0086* (0.0050)	0.0073* (0.0040)	-0.0024 (0.0045)	0.0144*** (0.0054)
FE	-0.0999*** (0.0093)	0.0136 (0.0164)	-0.2775*** (0.0344)	-0.0891 (0.0766)	-0.3007*** (0.0256)	-0.0037 (0.0455)	-0.2016*** (0.0287)	-0.1793*** (0.0541)
Constant OLS	0.2939*** (0.0483)	0.3080*** (0.0495)	0.3270*** (0.0571)	0.3299*** (0.0579)	0.2840*** (0.0420)	0.3000*** (0.0431)	0.1942*** (0.0314)	0.2059*** (0.0329)
SYS-GMM			0.4316*** (0.1483)	0.4394** (0.1974)	0.3245** (0.1450)	0.4105* (0.2162)	0.4937*** (0.1243)	0.7621*** (0.2350)
FE	1.1646*** (0.0519)	0.7119*** (0.0741)	2.2011*** (0.1448)	1.6067*** (0.3211)	2.6493*** (0.1304)	1.5961*** (0.2109)	2.5710*** (0.1471)	2.7055*** (0.2597)
$(\beta_0)/(1-\alpha)$: OLS	0.0550**	0.0796***	0.0125	0.0351*	0.0819**	0.1050***	0.1513***	0.1474***
SYS-GMM			**0.2035****	**0.0376***	**0.1357****	**0.0832****	**-0.0269**	**0.0881*****
FE	*-0.4317****	*0.0678*	*-0.7268****	*-0.2619*	*-0.6368****	*-0.0089*	*-0.4085*	*-0.2602****
Cross-section Dependence test	0.003	0.004	0.215	0.180	0.052	0.086	0.151	0.147
AR(2)	0.094	0.095	0.158	0.168	0.178	0.179	0.549	0.576
Hansen Test lags(2 4)			0.211	0.241	0.502	0.580	0.295	0.874
Observations	3172	3172	1098	1098	1098	1098	976	976

Notes: see Table 4.

Table 8: Financial Intermediation Agglomeration Estimates for Nuts 2 Areas in France, Germany Ireland, Italy, Spain and the UK

Sample Period	Full Sample: 1981-2006		1980s: 1981-1989		1990s: 1990-1998		2000s: 1999-2006	
Sector:	Own	Other	Own	Other	Own	Other	Own	Other
Log labour productivity(*t-1*) OLS	0.9334***	0.9337***	0.9431***	0.9428***	0.9226***	0.9229***	0.9250***	0.9269***
	(0.0065)	(0.0066)	(0.0092)	(0.0091)	(0.0130)	(0.0127)	(0.0160)	(0.0159)
SYS-GMM			0.8514***	0.7716***	0.8793***	0.9181***	0.7963***	0.8499***
			(0.0733)	(0.1446)	(0.0624)	(0.0924)	(0.0607)	(0.0456)
FE	0.8521***	0.8544***	0.6034***	0.6091***	0.6959***	0.7177***	0.4275***	0.4575***
	(0.0100)	(0.0100)	(0.0263)	(0.0264)	(0.0268)	(0.0269)	(0.0282)	(0.0295)
Log employment density(*t*) OLS	0.0027***	0.0033***	0.0016	0.0019	0.0033**	0.0042**	0.0038**	0.0046**
	(0.0009)	(0.0011)	(0.0011)	(0.0014)	(0.0017)	(0.0019)	(0.0018)	(0.0023)
SYS-GMM			0.0076	0.0043	0.0061	0.0059	0.0362**	0.0088**
			(0.0056)	(0.0032)	(0.0078)	(0.0046)	(0.0154)	(0.0037)
FE	-0.0504***	-0.0414**	-0.1308***	-0.2074***	-0.1457***	-0.0271	-0.2815***	-0.3542***
	(0.0090)	(0.0201)	(0.0279)	(0.0545)	(0.0274)	(0.0652)	(0.0280)	(0.0983)
Constant OLS	0.3511***	0.3389***	0.2073***	0.2018***	0.2930***	0.2771***	0.4289***	0.4049***
	(0.0319)	(0.0322)	(0.0413)	(0.0434)	(0.0616)	(0.0577)	(0.0705)	(0.0694)
SYS-GMM			0.6319*	0.9651	0.4979*	0.2845	1.0097***	0.7390***
			(0.3328)	(0.6737)	(0.2978)	(0.4344)	(0.2714)	(0.1940)
FE	0.7285***	0.9081***	1.7859***	2.5576***	1.4131***	1.3218***	2.8515***	4.0714***
	(0.0435)	(0.0985)	(0.1151)	(0.2637)	(0.1227)	(0.3117)	(0.1332)	(0.4702)
$(\beta_0)/(1-\alpha)$: OLS	0.0403***	0.0501***	0.0274	0.0329	0.0432**	0.0549**	0.0513**	0.0633*
SYS-GMM			**0.0508**	**0.0376***	**0.0504**	**0.0721**	**0.1779*****	**0.0589*****
FE	*-0.3411****	*-0.2849***	*-0.3299****	*-0.5306****	*-0.4792****	*-0.0959*	*-0.4085*	*-0.6529****
Cross-section Dependence test	0.005	0.005	0.097	0.116	0.255	0.330	0.120	0.096
AR(2)	0.274	0.292	0.021	0.022	0.109	0.107	0.102	0.096
Hansen Test lags(3 5)			0.250	0.331	0.184 (2 4)	0.172	0.398 (2 4)	0.342 (2 4)
Observations	3172	3172	1098	1098	1098	1098	976	976

Notes: see Table 4.

Table 9: Total Productivity Agglomeration Estimates for LARGE Nuts 3 Areas in France, Germany Ireland, Italy, Spain and the UK

	Full Sample	1980s	1990s	2000s
Sample Period for annual data	1981-2006	1981-1989	1990-1998	1999-2006
Log labour productivity (*t-1*) OLS	0.9505*** (0.0050)	0.9399*** (0.0058)	0.9492*** (0.0081)	0.9849*** (0.0090)
SYS-GMM		0.9320*** (0.0151)	0.9116*** (0.0237)	0.9099*** (0.0453)
FE	0.9031*** (0.0047)	0.7500*** (0.0149)	0.7666*** (0.0158)	0.4088*** (0.0224)
Log employment density(*t*) OLS	0.0042*** (0.0008)	0.0052*** (0.0008)	0.0042*** (0.0010)	0.0013*** (0.0008)
SYS-GMM		0.0119*** (0.0031)	0.0002 (0.0045)	0.0113*** (0.0056)
FE	-0.0757*** (0.0071)	-0.2765*** (0.0214)	-0.2417*** (0.0206)	-0.3302***(0.0261)
Constant OLS	0.2122*** (0.0266)	0.1651*** (0.0250)	0.2388*** (0.0300)	0.0711** (0.0347)
SYS-GMM		0.2384*** (0.0585)	0.3903*** (0.0947)	0.3612* (0.1955)
FE	0.7502*** (0.0431)	2.2716*** (0.1313)	2.0760*** (0.1299)	3.9460*** (0.1705)
$(\beta_0 + \beta_1)/(1-\alpha)$: OLS	0.0854***	0.0870***	0.0821***	0.0883*
SYS-GMM		**0.1744****	**0.0023**	**0.1250*****
FE	*-0.7807****	*-1.1059****	*-1.0354****	*-0.5585****
Cross-section Dependence test	0.006	0.056	0.212	0.190
AR(2)	0.048	0.950	0.077	0.169
Hansen Test for inst. lags(2 4)		0.094	0.059 (lag 2 3)	0.304
Observations	4472	1548	1548	1376

Notes: Dependent variable = Log labour productivity(t) with 172 NUTS 3 large regions with population > 500K (apart from Cardiff, Edinburgh and Belfast). For further details see Notes for Table 4.

Table 10: Industry Agglomeration Estimates for Large Nuts 3 Areas in France, Germany Ireland, Italy, Spain and the UK

Sample Period	Full Sample: 1981-2006		1980s: 1981-1989		1990s: 1990-1998		2000s: 1999-2006	
Sector:	Own	Other	Own	Other	Own	Other	Own	Other
Log labour productivity(*t-1*) OLS	0.9343*** (0.0051)	0.9338*** (0.0052)	0.9245*** (0.0061)	0.9254*** (0.0059)	0.9438*** (0.0092)	0.9433*** (0.0094)	0.9521*** (0.0103)	0.9496*** (0.0105)
SYS-GMM			0.9180*** (0.0199)	0.9223*** (0.0170)	0.8480*** (0.0432)	0.8300*** (0.0787)	0.8662*** (0.0353)	0.8962*** (0.0416)
FE	0.8765*** (0.0056)	0.8978*** (0.0053)	0.7246*** (0.0166)	0.7827*** (0.0161)	0.7246*** (0.0171)	0.7809*** (0.0174)	0.4741*** (0.0224)	0.5146*** (0.0234)
Log employment density(*t*) OLS	0.0064*** (0.0009)	0.0065*** (0.0009)	0.0061*** (0.0009)	0.0065*** (0.0009)	0.0065*** (0.0013)	0.0065*** (0.0013)	0.0046*** (0.0014)	0.0047*** (0.0013)
SYS-GMM			0.0139*** (0.0044)	0.0065*** (0.0012)	0.0244*** (0.0060)	0.0115*** (0.0040)	0.0064 (0.0066)	0.0080** (0.0037)
FE	-0.0859*** (0.0079)	-0.0145 (0.0114)	-0.2395*** (0.0232)	-0.1042*** (0.0387)	-0.2741*** (0.0219)	0.0688*** (0.0327)	-0.3485*** (0.0290)	-0.0275*** (0.0454)
Constant OLS	0.3264*** (0.0348)	0.3210*** (0.0360)	0.3350*** (0.0202)	0.3246*** (0.0194)	0.3205*** (0.0539)	0.3152*** (0.0545)	0.2389*** (0.0455)	0.2447*** (0.0450)
SYS-GMM			0.3340*** (0.0730)	0.3588*** (0.0589)	0.7146** (0.2196)	0.8293** (0.3360)	0.6224*** (0.1515)	0.4758*** (0.1749)
FE	0.7723*** (0.0408)	0.4632*** (0.0582)	1.8870*** (0.1198)	1.2716*** (0.1826)	2.0180*** (0.1135)	0.5171*** (0.1646)	3.3012*** (0.1453)	2.0341*** (0.2363)
$(\beta_0)/(1-\alpha)$: OLS	0.0968***	0.0978***	0.0806***	0.0871***	0.1156***	0.1155***	0.0962***	0.0937***
SYS-GMM			**0.1695****	**0.0832*****	**0.1603*****	**0.0679*****	**0.0480**	**0.0768*****
FE	*-0.6953****	*-0.1414*	*-0.8695****	*-0.4794****	*-0.9953****	*0.3140***	*-0.6627****	*-0.0566*
Cross-section Dependence test	0.020	0.011	0.749	0.644	0.846	0.572	0.063	0.055
AR(2)	0.721	0.798	0.135	0.058	0.016	0.015	0.723	0.701
Hansen Test lags(2 4)			0.084 (2 3)	0.484	0.043 (2 3)	0.014	0.507	0.411
Observations	4472	4472	1548	1548	1548	1548	1376	1376

Notes: see Table 7.

Table 11: Service Sector Agglomeration Estimates for Large Nuts 3 Areas in France, Germany Ireland, Italy, Spain and the UK

Sample Period	Full Sample: 1981-2006		1980s: 1981-1989		1990s: 1990-1998		2000s: 1999-2006	
Sector:	Own	Other	Own	Other	Own	Other	Own	Other
Log labour productivity(*t-1*) OLS	0.9486***	0.9500***	0.9385***	0.9376***	0.9375***	0.9393***	0.9893***	0.9931***
	(0.0056)	(0.0057)	(0.0059)	(0.0061)	(0.0100)	(0.0100)	(0.0088)	(0.0084)
SYS-GMM			0.9319***	0.9277***	0.9154***	0.7954***	0.9004***	0.9599***
			(0.0188)	(0.0224)	(0.0350)	(0.0513)	(0.0519)	(0.0387)
FE	0.8899***	0.8997***	0.7197***	0.7860***	0.6687***	0.7331***	0.4526***	0.5277***
	(0.0052)	(0.0053)	(0.0154)	(0.0158)	(0.0164)	(0.0175)	(0.0219)	(0.0224)
Log employment density(*t*) OLS	0.0041***	0.0045***	0.0047***	0.0053***	0.0047***	0.0051***	0.0012	0.0007
	(0.0008)	(0.0009)	(0.0008)	(0.0010)	(0.0010)	(0.0012)	(0.0007)	(0.0009)
SYS-GMM			0.0034	0.0050***	0.0048***	0.0126***	0.0133*	0.0039
			(0.0030)	(0.0015)	(0.0037)	(0.0042)	(0.0069)	(0.0029)
FE	-0.0930***	-0.0175***	-0.3377***	-0.0512***	-0.3208***	0.0043	-0.3084***	-0.0862***
	(0.0075)	(0.0049)	(0.0229)	(0.0158)	(0.0202)	(0.0136)	(0.0242)	(0.0180)
Constant OLS	0.2004***	0.1976***	0.2092***	0.2139***	0.2657***	0.2606***	0.0456	0.0336
	(0.0232)	(0.0232)	(0.0215)	(0.0225)	(0.0431)	(0.0436)	(0.0326)	(0.0312)
SYS-GMM			0.2335***	0.2603***	0.2818**	0.7275***	0.3605*	0.1629
			(0.0722)	(0.0757)	(0.1311)	(0.1885)	(0.1893)	(0.1509)
FE	0.8674***	0.4581***	2.5354***	1.0014***	2.7176***	1.0069***	3.5632***	2.1440***
	(0.0430)	(0.0303)	(0.1307)	(0.0895)	(0.1224)	(0.0890)	(0.1578)	(0.1070)
$(\beta_0)/(1-\alpha)$: OLS	0.0804***	0.0890***	0.0764***	0.0843***	0.0753***	0.0845***	0.1125	0.1036
SYS-GMM			**0.0495**	**0.0697*** **	**0.0569**	**0.0618*** **	**0.1336*** **	**0.0967** **
FE	*-0.8445****	*-0.1741****	*-1.2049****	*-0.2391****	*-0.9685****	*0.0160*	*-0.5634****	*-0.1825****
Cross-section Dependence test	0.002	0.002	0.060	0.053	0.078	0.086	0.114	0.133
AR(2)	0.095	0.060	0.926	0.980	0.778	0.780	0.064	0.062
Hansen Test lags(2 4)			0.071	0.122 (3 5)	0.075	0.103	0.190	0.731
Observations	4472	4472	1548	1548	1548	1548	1376	1376

Notes: see Table 7.

Appendix A: Listing of Nuts Areas used in analysis

Appendix Table A1: List of 122 Nuts 2 Areas

Code	**Ireland (2)**	Code	Region
ie01	Border, Midlands and Western	ie02	Southern and Eastern
	Spain (15)		
es11	Galicia	es41	Castilla y León
es12	Principado de Asturias	es42	Castilla-la Mancha
es13	Cantabria	es43	Extremadura
es21	Pais Vasco	es51	Cataluña
es22	Comunidad Foral de Navarra	es52	Comunidad Valenciana
es23	La Rioja	es61	Andalucia
es24	Aragón	es62	Región de Murcia
es30	Comunidad de Madrid		
	France (21)		
fr10	Île de France	fr51	Pays de la Loire
fr21	Champagne-Ardenne	fr52	Bretagne
fr22	Picardie	fr53	Poitou-Charentes
fr23	Haute-Normandie	fr61	Aquitaine
fr24	Centre	fr62	Midi-Pyrénées
fr25	Basse-Normandie	fr63	Limousin
fr26	Bourgogne	fr71	Rhône-Alpes
fr30	Nord - Pas-de-Calais	fr72	Auvergne
fr41	Lorraine	fr81	Languedoc-Roussillon
fr42	Alsace	fr82	Provence-Alpes-Côte d'Azur
fr43	Franche-Comté		
	UK (35)		
ukc1	Tees Valley and Durham	ukh2	Bedfordshire, Hertfordshire
ukc2	Northumberland, Tyne and Wear	ukh3	Essex
ukd1	Cumbria	uki1	Inner London
ukd2	Cheshire	uki2	Outer London
ukd3	Greater Manchester	ukj1	Berkshire, Bucks and Oxfordshire
ukd4	Lancashire	ukj2	Surrey, East and West Sussex
ukd5	Merseyside	ukj3	Hampshire and Isle of Wight
uke1	East Yorkshire and Northern Lincolnshire	ukj4	Kent
uke2	North Yorkshire	ukk1	Gloucestershire, Wiltshire and Bristol/Bath area
uke3	South Yorkshire	ukk2	Dorset and Somerset
uke4	West Yorkshire	ukk3	Cornwall and Isles of Scilly
ukf1	Derbyshire and Nottinghamshire	ukk4	Devon
ukf2	Leicestershire, Rutland and Nrthnts	ukl1	West Wales and The Valleys
ukf3	Lincolnshire	ukl2	East Wales
ukg1	Herefordshire, Worcs and Warks	ukm2	Eastern Scotland
ukg2	Shropshire and Staffordshire	ukm3	South Western Scotland
ukg3	West Midlands	ukn	Northern Ireland
ukh1	East Anglia		
	Italy (19)		
itc1	Piemonte	ite2	Umbria
itc2	Valle d'Aosta/Vallée d'Aoste	ite3	Marche
itc3	Liguria	ite4	Lazio
itc4	Lombardia	itf1	Abruzzo
itd1	Provincia Autonoma Bolzano-	itf2	Molise

	Bozen		
itd2	Provincia Autonoma Trento	itf3	Campania
itd3	Veneto	itf4	Puglia
itd4	Friuli-Venezia Giulia	itf5	Basilicata
itd5	Emilia-Romagna	itf6	Calabria
ite1	Toscana		
	Germany (30)		
de11	Stuttgart	de73	Kassel
de12	Karlsruhe	de91	Braunschweig
de13	Freiburg	de92	Hannover
de14	Tübingen	de93	Lüneburg
de21	Oberbayern	de94	Weser-Ems
de22	Niederbayern	dea1	Düsseldorf
de23	Oberpfalz	dea2	Köln
de24	Oberfranken	dea3	Münster
de25	Mittelfranken	dea4	Detmold
de26	Unterfranken	dea5	Arnsberg
de27	Schwaben	deb1	Koblenz
de5	Bremen	deb2	Trier
de6	Hamburg	deb3	Rheinhessen-Pfalz
de71	Darmstadt	dec	Saarland
de72	Gießen	def	Schleswig-Holstein

Appendix Table A2: List of 172 Nuts 3 city regions (with population > 500,000 used in Tables 9-13)

Code	Ireland (2)	Populatio n	Code	Region	Population
ie021	Dublin	1193.72	ie025	South-West (IE)	626.57
	Spain (27)				
es111	La Coruña	1113.11	es511	Barcelona	5225.82
es114	Pontevedra	927.40	es512	Gerona	665.93
es12	Principado de Asturias	1058.20	es514	Tarragona	715.85
es13	Cantabria	560.42	es521	Alicante	1735.84
es212	Guipúzcoa	685.43	es522	Castellón de la Plana	548.75
es213	Vizcaya	1132.51	es523	Valencia	2415.67
es22	Comunidad Foral de Navarra	592.27	es611	Almería	617.65
es243	Zaragoza	909.29	es612	Cadiz	1177.97
es3	Comunidad de Madrid	5995.49	es613	Córdoba	783.50
es418	Valladolid	511.86	es614	Granada	874.34
es422	Ciudad Real	502.23	es616	Jaén	655.78
es425	Toledo	603.79	es617	Málaga	1450.98
es431	Badajoz	664.80	es618	Sevilla	1810.50
			es62	Región de Murcia	1353.08
	France (50)				
fr101	Paris	2155.29	fr431	Doubs	515.48
fr102	Seine-et-Marne	1282.47	fr511	Loire-Atlantique	1220.84
fr103	Yvelines	1404.72	fr512	Maine-et-Loire	758.76
fr104	Essonne	1198.61	fr514	Sarthe	554.00
fr105	Hauts-de-Seine	1526.81	fr515	Vendée	593.39
fr106	Seine-Saint-Denis	1475.45	fr521	Côte-du-Nord	568.09

fr107	Val-de-Marne	1287.19	fr522	Finistère	878.27
fr108	Val-d'Oise	1160.46	fr523	Ille-et-Vilaine	940.74
fr213	Marne	567.37	fr524	Morbihan	693.91
fr221	Aisne	535.04	fr532	Charente-Maritime	597.09
fr222	Oise	792.41	fr612	Gironde	1388.89
fr223	Somme	558.55	fr615	Pyrénées-Atlantiques	630.71
fr231	Eure	567.50	fr623	Haute-Garonne	1175.14
fr232	Seine-Maritime	1243.50	fr711	Ain	567.17
fr244	Indre-et-Loire	571.76	fr714	Isère	1173.50
fr246	Loiret	646.62	fr715	Loire	729.32
fr251	Calvados	667.52	fr716	Rhône	1663.76
fr261	Côte-d'Or	515.12	fr718	Haute-Savoie	697.18
fr263	Saône-et-Loire	544.68	fr724	Puy-de-Dôme	624.12
fr301	Nord	2583.03	fr812	Gard	684.36
fr302	Pas-de-Calais	1459.97	fr813	Hérault	994.86
fr411	Meurthe-et-Moselle	723.88	fr823	Alpes-Maritimes	1070.50
fr413	Moselle	1040.24	fr824	Bouches-du-Rhône	1910.18
fr421	Bas-Rhin	1077.62	fr825	Var	979.15
fr422	Haut-Rhin	739.38	fr826	Vaucluse	533.38
	UK (44)				
ukc22	Tyneside	812.96	ukh33	Essex CC	1348.77
ukd22	Cheshire CC	682.26	uki11	Inner London - West	1099.11
ukd31	Greater Manchester South	1370.25	uki12	Inner London - East	1890.00
ukd32	Greater Manchester North	1179.81	uki21	Outer London - East and North East	1620.41
ukd43	Lancashire CC	1159.40	uki22	Outer London - South	1192.27
uke22	North Yorkshire CC	586.30	uki23	Outer London - West and North West	1798.29
uke31	Barnsley, Doncaster and Rotherham	766.17	ukj11	Berkshire	810.54
uke32	Sheffield	521.99	ukj14	Oxfordshire	629.08
uke42	Leeds	736.41	ukj22	East Sussex CC	506.69
uke43	Calderdale, Kirklees and Wakefield	909.89	ukj23	Surrey	1077.60
ukf22	Leicester CC and Rutland	667.39	ukj24	West Sussex	771.21
ukf23	Northamptonshire	662.28	ukj33	Hampshire CC	1259.65
ukf3	Lincolnshire	685.49	ukj42	Kent CC	1379.47
ukg12	Worcestershire	564.73	ukk12	Bath and NE Somerset, North Somerset and South Gloucestershire	626.09
ukg13	Warwickshire	532.05	ukk13	Gloucestershire	575.01
ukg24	Staffordshire CC	820.28	ukk23	Somerset	520.92
ukg31	Birmingham	1003.65	ukk3	Cornwall and Isles of Scilly	523.23
ukg34	Dudley and Sandwell	592.50	ukk43	Devon CC	741.83
ukh12	Cambridgeshire CC	587.97	ukl22	Cardiff and Vale of Glamorgan	440.91
ukh13	Norfolk	832.16	ukm25	City of Edinburgh	467.60
ukh14	Suffolk	699.92	ukm34	Glasgow City	584.99
ukh23	Hertfordshire	1051.37	ukn01	Belfast	265.20
	Italy (31)				
itc11	Torino	2245.89	itd54	Modena	667.72

itc16	Cuneo	572.70	itd55	Bologna	952.33
itc33	Genova	889.00	ite14	Firenze	968.91
itc41	Varese	851.99	ite21	Perugia	642.64
itc42	Como	569.60	ite43	Roma	3922.53
itc45	Milano	3876.77	ite44	Latina	526.60
itc46	Bergamo	1039.29	itf31	Caserta	889.11
itc47	Brescia	1189.09	itf33	Napoli	3084.73
itc48	Pavia	518.50	itf35	Salerno	1090.31
itd2	Provincia Autonoma Trento	504.75	itf41	Foggia	682.90
itd31	Verona	875.19	itf42	Bari	1595.90
itd32	Vicenza	841.39	itf43	Taranto	580.40
itd34	Treviso	853.39	itf45	Lecce	808.20
itd35	Venezia	834.49	itf61	Cosenza	729.01
itd36	Padova	894.39	itf65	Reggio di Calabria	564.71
itd42	Udine	530.72			
	Germany (18)				
de111	Stuttgart	593.18	de929	Region Hannover	1128.69
de113	Esslingen	514.18	dea11	Düsseldorf, Kreisfreie Stadt	576.01
de115	Ludwigsburg	513.68	dea12	Duisburg, Kreisfreie Stadt	500.31
de128	Rhein-Neckar-Kreis	534.11	dea13	Essen, Kreisfreie Stadt	584.31
de212	München, Kreisfreie Stadt	1277.09	dea1c	Mettmann	504.21
de254	Nürnberg, Kreisfreie Stadt	500.04	dea23	Köln, Kreisfreie Stadt	986.59
de501	Bremen, Kreisfreie Stadt	547.42	dea2c	Rhein-Sieg-Kreis	598.29
de6	Hamburg	1748.91	dea36	Recklinghausen	645.00
de712	Frankfurt am Main, Kreisfreie Stadt	652.30	dea52	Dortmund, Kreisfreie Stadt	587.90

Appendix B: Global Moran's *i* measure of spatial autocorrelation

The global Moran's *i* statistic for spatial autocorrelation yields a test statistic which can be defined as follows:

$$I_t = \left(\frac{n}{s}\right)\frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} y_{it} \; y_{jt}}{\sum_{i=1}^{n} y_{it}^{2}} \tag{B1}$$

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, and the y observations are demeaned values. The results of this diagnostic test for spatial autocorrelation on NUTS 2 labour productivity and employment density in 1980, 1992, and 2006 are reported in Table B1. The test has been carried out using an inverse distance spatial weighting matrix, where w_{ij} denotes the row standardised reciprocal distance between sub-regions i and j.

Table B1: Moran's* I *Global Spatial Autocorrelation Statistic

	1980	**1992**	**2006**
Labour Productivity	0.129***	0.133***	0.105***
Employment Density	0.148***	0.129***	0.149***

Note: Significance at ***1%, **5%, and *10% level.

Table B1 suggests that labour productivity and employment density do indeed exhibit spatial autocorrelation across NUTS 2 areas in 1980, 1992, and 2006. However, in order to gain a fuller understanding of the spatial patterns inherent in the NUTS 2 labour productivity and employment density data, we calculate local Moran's *i* statistics. These are presented in colour-coded maps (Figures B1 and B2). Unlike its global counterpart, the local Moran's *i* statistic describes the association between the value of the variable at a given location and that of its neighbours, and between the value within the neighbourhood set and that for the sample as a whole; Patacchini and Rice (2007).

The local Moran's *i* maps presented in Figures B1 and B2 shows the NUTS 2 areas for which the local statistics are significant at the 0.05 level. The four colour-coded categories of the local Moran's *i* maps correspond to the four types of local spatial association between a location and its neighbours: HH (upper right), contains areas with a high value surrounded by areas with high values; HL (lower right) consists of high value areas with relatively low value neighbours; LL (lower left) consists of low value areas surrounded by other areas with low values; and LH (upper left) contains low value areas with high value neighbours.

The local Moran's i statistics illustrated by in Figures B1 and B2 indicate that spatial autocorrelation may be less of an issue in the underlying data than the global measure would suggest. [7] In the labour productivity maps, there are two clear clusters of spatial correlation: one in and around the Netherlands (HH) and another in Spain (LL). While the LL cluster is present throughout the 1980-2006 time period, the HH cluster diminishes considerably by the end of the time period. In the maps of employment density, the spatial autocorrelation detected appears to be driven by the Greater London NUTS 2 area.[8]

[7] Ord and Getis (1995) have shown that the local statistics for any pair of locations, i and j, are correlated whenever their neighbourhood sets contain common elements Given this, Ord and Getis suggest using a Bonferroni bounds procedure to assess significance such that for an overall significance level of α, the individual significance level for each observation is taken as α /n, where n is the number of observations in the sample. In what follows with a sample of 156 observations (Belgium and Holland are included here but not included in the panel regressions), an overall significance level of 0.05 implies an individual significance level for each observation of just 0.00032. However, Patacchini and Rice (2007) note that in practice, for any given location the number of other locations in the sample with correlated local statistics is likely to be considerably small than n, and so this procedure is expected to be overly conservative. Using such a procedure in Figures B1and B2 above would result in less NUTS 2 areas exhibiting spatial correlation. For example, in Figure B1 the number of NUTS 2 areas exhibiting HH spatial autocorrelation in 2006 labour productivity would fall from 8 to 5, while LL regions would fall from 15 to 6.

[8] A further issue with local measures of autocorrelation statistics is that they are affected by the presence of global spatial association, and hence inference based on the normal approximation (as is the case in Figures B1 and B2) is likely to be hindered; Anselin (1995). See Patacchini and Rice (2007) for a detailed discussion of limitations associated with local autocorrelation statistics.

Figure B1: Local Moran's *i* measure of spatial autocorrelation - labour productivity of NUTS 2 areas 1980 (top left), 1992 (top right) and 2006 (bottom right)

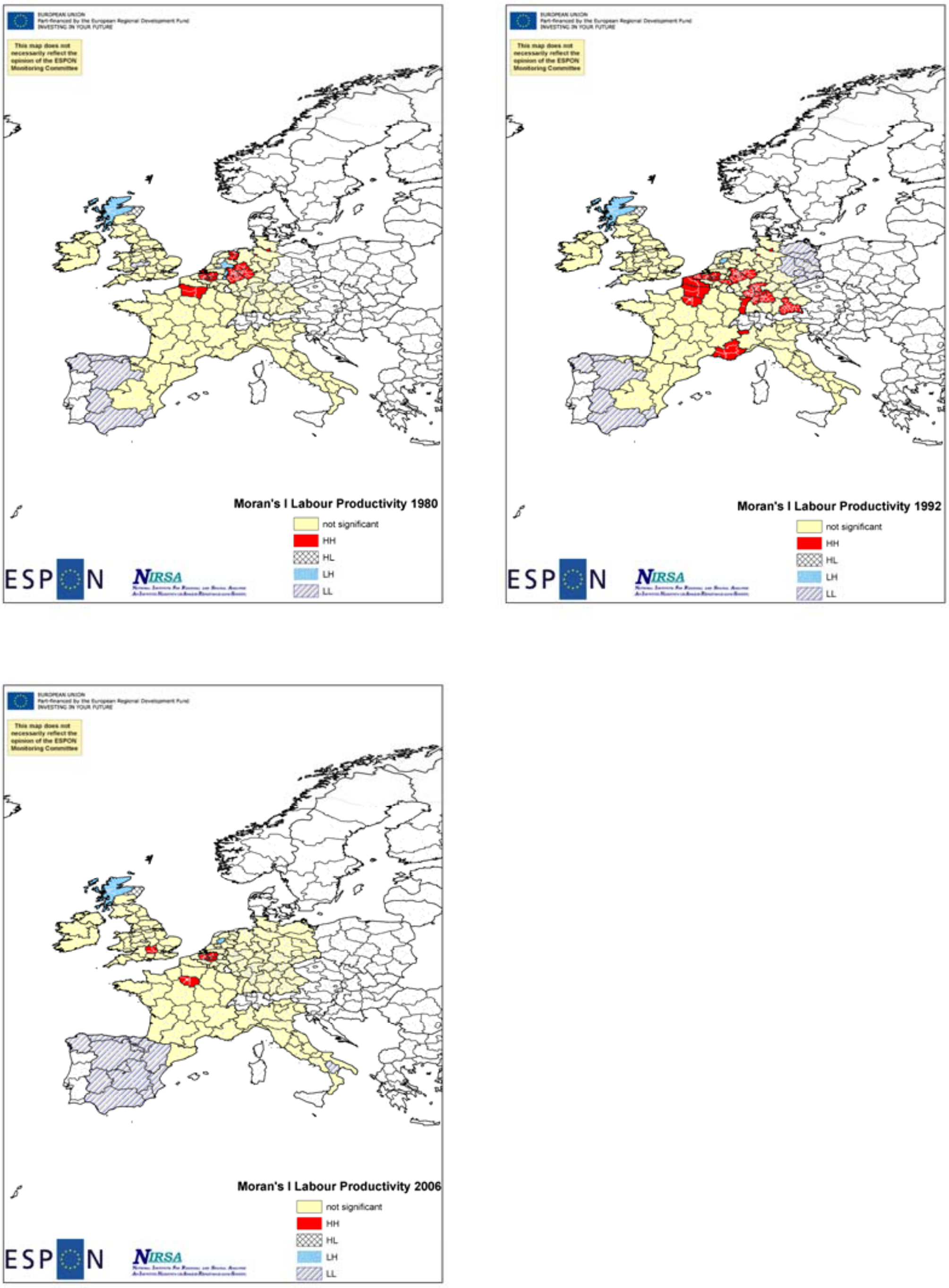
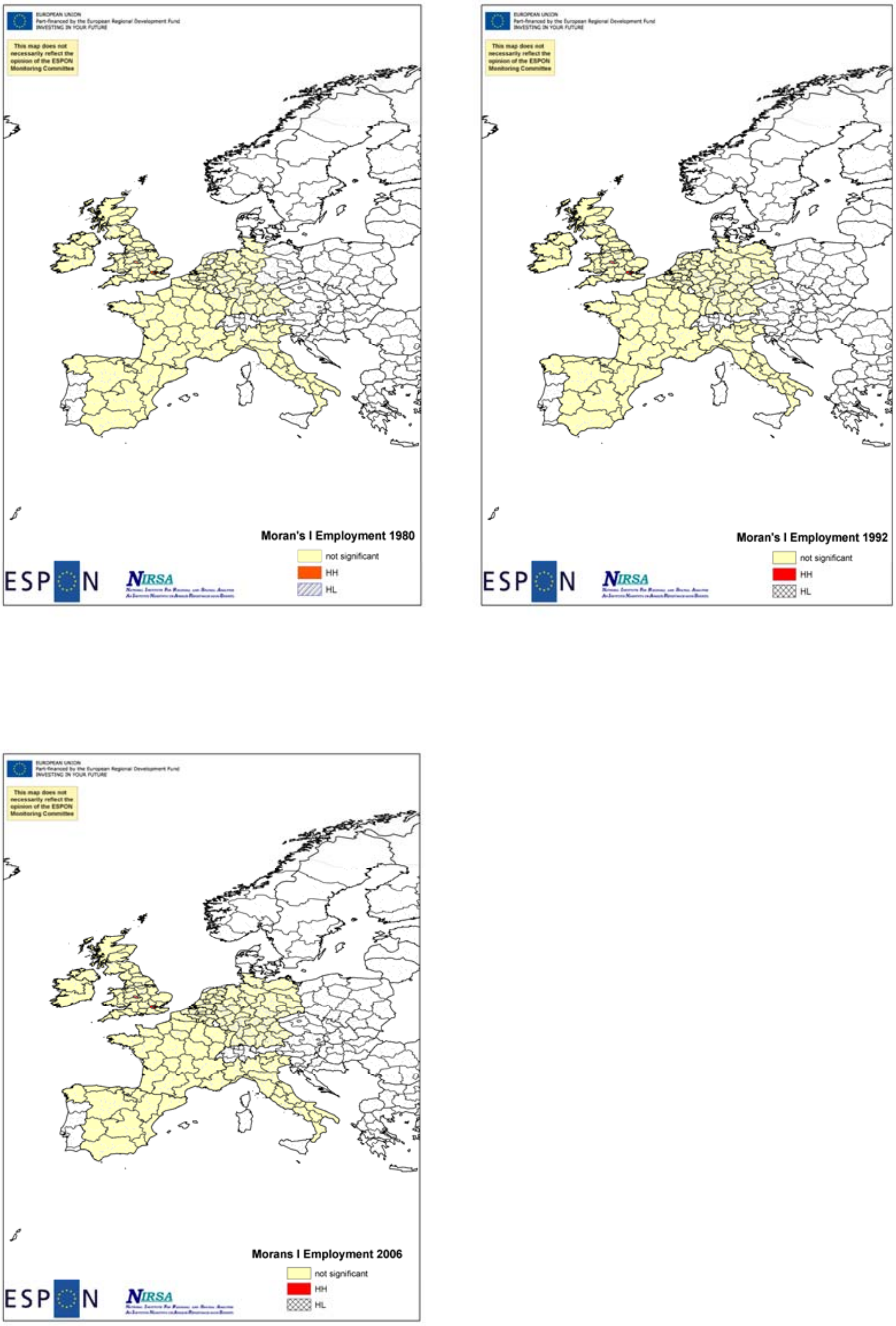


Figure B2: Local Moran's *i* measure of spatial autocorrelation – employment density of NUTS 2 areas, 1980 (top left), 1992 (top right) and 2006 (bottom right)



Spatial Economics Research Centre (SERC)
London School of Economics
Houghton Street
London WC2A 2AE

Tel: 020 7852 3565
Fax: 020 7955 6848
Web: www.spatialeconomics.ac.uk

SERC is an independent research centre funded by the Economic and Social Research Council (ESRC), Department for Business Innovation and Skills (BIS), the Department for Communities and Local Government (CLG) and the Welsh Assembly Government.