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Neil Foster and Robert Stehrer

Sectoral Productivity, Density and Agglomeration in the Wider Europe

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Abstract

In this paper we extend the agglomeration model of Ciccone (2002) to the level of industry. We then test this model using panel data for six sectors on regional level data for 27 EU member states. Our results for the aggregate economy confirm the estimates of Ciccone (2002). For our full sample of countries the sectoral level results also indicate significant agglomeration effects, with the exception of agriculture. Considering differences in the extent of agglomeration effects between new and old EU member states, however, leads to the conclusion that agglomeration effects tend to be stronger at both the aggregate and the sectoral level for new member states.

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1 Introduction

The agglomeration of economic activities in a few locations has been a distinctive feature of the world economy for many years. Despite early attempts at accounting for such agglomeration effects (see for example Marshall, 1920; Mills, 1967; Henderson, 1974) it is only recently that economists have been able to explain such effects (see for example Krugman, 1991; Ciccone, 1992; Krugman and Venables, 1995; Fujita and Thisse, 1996).

Understanding the forces of agglomeration is important since there exists a strong positive correlation between output or productivity growth and geographical agglomeration (see for example Hohenberg and Lees, 1985). In Europe, for instance, output growth during the industrial revolution was accompanied by the formation of industrial clusters in the core of Europe that largely still remain (Baldwin and Martin, 2004). The results of De la Fuente and Vives (1995) suggest that while convergence has taken place within Europe, regions inside countries have either failed to converge or have diverged, results again suggestive of the important complementarities between growth and agglomeration.

Explanations for the observed relationship between agglomeration economies and productivity within countries relate to spatial externalities and to increasing returns at the firm level combined with non-tradabilities or transport costs. Ciccone and Hall (1996) for example develop two models in which the spatial density of economic activity is the source of aggregate increasing returns. The models are based upon either local geographic externalities or upon the variety of local intermediate services. Density is assumed to affect productivity through a number of channels. Firstly, positive transport costs may lead to increasing returns within a geographical area, enhancing productivity in denser regions. Secondly, externalities associated with the physical proximity of production tend to increase productivity in regions with greater density. Such externalities include the possibility of labour market pooling, input sharing and localized technological spillovers. Thirdly, a higher degree of specialization is possible in areas of dense activity.

Few direct tests of agglomeration effects and the relationship between agglomeration and growth exist. Rosenthal and Strange (2003), however, examine the effect of existing employment on both the birth of new firms and employment in new establishments using US data at the zip code level. They find that agglomeration economies decline rapidly with distance, with the effect of own industry employment in the first mile up to 1000 times larger than the effect 2 to 5 miles away. Further evidence is provided by Dekle and Eaton (1999) who find for a sample of Japanese regions that the density of an industry in a region has a significant impact on productivity in that region, while Rice et al. (2006) find that labour productivity in British regions increases with proximity to economic mass. Most related to the current paper however are the papers by Ciccone and Hall (1996) and Ciccone (2002) to which we now turn.

Ciccone and Hall (1996) use 1988 US county level data to test their model. They construct a measure of state level labour productivity, regressing this variable on a measure of the density of employment in counties within the state and measures of education. The results indicate that doubling the employment density in a county increases labour productivity by 6 per cent on average. Ciccone (2002) conducts a similar exercise for 628 NUTS-3 regions in Germany, Italy, France, Spain and the UK. He regresses a measure of labor productivity, constructed by using data on non-agricultural private value added and salaried employment at the regional level, on the density of employment, education variables, and country and regional dummies. Ciccone finds substantial agglomeration effects for the five European countries, with the results suggesting that a doubling of the employment density increases labour productivity by approximately five per cent, a result similar to that found for the US by Ciccone and Hall (1996).

The current paper closely follows the approach of Ciccone (2002), but adds to this earlier work in a number of ways. Firstly, we extend the country coverage to include information on 255 regions in 26 European countries. Our sample also includes Central and East European countries[1], which allows us to examine whether the agglomeration effects found in the core advanced countries of Europe are also present for a wider range of European countries. Secondly, rather than concentrating on total output, or total output minus agriculture and the public sector, we consider agglomeration effects using sectoral data on six sectors, thus allowing us to examine differences in agglomeration effects across sectors. One should note, however, that from the extension of the model we provide in this paper we cannot hypothesize on the magnitude of the density and spillover effects across various sectors. For this we rely on empirical assessment, though one should also note that there is little empirical evidence on similarities or differences in density and spillover effects across sectors. This paper thus provides some initial insights into this

[1]Included are all current EU members with the exception of Malta for data reasons.

issue. Thirdly, while time series data at the regional level on the variables of interest are only available for a short period of time, we do make use of panel data considering agglomeration effects using annual data over the period 1998-2004. Before moving on to discuss the model and the results, it should be mentioned that one recent paper, Brülhart and Mathys (2008), also considers the issue of agglomeration using sectoral panel data. The paper differs from the current one in a number of respects, notably by the use of a dynamic panel model to deal with the issue of endogeneity. In addition, while the paper by Brülhart and Mathys (2008) uses data over a longer period, the current paper has a broader country coverage. The results of Brülhart and Mathys (2008) suggest stronger agglomeration effects at the aggregate level than those found by Ciccone (2002). The authors choose to concentrate on the results from manufacturing and financial services and find in the case of manufacturing that own-sector density lowers productivity, while other-sector density increases productivity. For financial services the reverse is true, with own-sector density raising productivity in the financial sector, but other-sector density reducing it.

Our results for the full sample of countries indicate significant agglomeration effects at the aggregate level. Significant agglomeration effects are also found for five of the six sectors (the exception being agriculture). These results are largely unchanged when we account for endogeneity using Instrumental Variable (IV) techniques. Of perhaps greater interest are the results obtained when we split our sample into 'old' and 'new' Europe. We find agglomeration effects in new Europe to be large and significantly larger than those in old Europe both at the aggregate and sectoral levels. The results suggest that dense regions in new Europe, such as capital cities, may have better prospects for productivity growth when compared with less dense regions. This may reflect the uneven levels of transport and business infrastructure in new Europe as compared to old Europe.

The remainder of the paper is organized as follows. Section 2 describes the theoretical model of Ciccone (2002), and extends it to the case of more than one sector. We then move on to a brief description of our data sources and classifications in Section 3. Section 4 presents results for the aggregate economy and the different sectors, while Section 5 reports results from an instrumental variable approach that deals with a potential endogeneity problem. Section 6 reports results for two country sub-samples, the Western European economies and the Eastern European transition economies. Section 7 concludes.

2 The model

2.1 Externalities within regions

In this section we introduce the basic model used in Ciccone (2002), but extend it to the case of more than one sector. We denote the production function for a particular sector i on an acre of land in a particular region s contained in country c by,

$$q_{isc} = \Omega_{isc} f_i(n_{isc} H_{isc}, k_{isc}, Q_{isc}, A_{sc})$$

where q_{isc} denotes output, n_{isc} the number of workers, H_{isc} the average level of human capital of these workers and k_{isc} the stock of physical capital used on this acre of land in this particular sector. We assume that the average level of human capital differs across sectors. In addition the capital stock is also assumed to be sector-specific which may be explained by differences in sectoral intensities with respect to asset types. This allows us to implicitly model the sector-specific use of particular factors such as land, etc. or sector-specific capital requirements. The other three parameters are specific to the region and sector with Ω_{isc} denoting an index of total factor productivity, Q_{isc} total output of the region and A_{sc} total acreage of the region. The sector-specific density of the region is then defined as Q_{isc}/A_{sc}. It is assumed that spatial externalities are driven by the density of production. In our disaggregated framework we assume that it is the sector-specific density of production that matters for agglomeration, which may arise due to sector-specific spillovers or sector-specific labour qualifications, for example. Agglomeration effects in this framework are thus not due to other regional specific effects, such as overall production density or the level of general infrastructure within a region (see Ciccone and Hall, 1996).[2] Our paper thus considers the importance of localization economies, that is, the benefit a firm gains from locating in close proximity to firms in the same sector, rather than urbanization economies, which are the benefits derived from firms locating in close proximity to other firms from all sectors. This choice is justified by noting that in the existing literature most studies have found that localization effects tend to be most prevalent (see for example the review article of Rosenthal and Strange, 2004).

Under the assumption that the elasticity of output per acre with respect to density is constant,

[2]These overall effects are captured to an extent by country and regional NUTS-1 dummies in the econometric specification below.

we obtain the following specification,

$$q_{isc} = \Omega_{isc} f_i(n_{isc}H_{isc}, k_{isc}, Q_{isc}, A_{sc}) = \Omega_{isc}\big((n_{isc}H_{isc})^{\beta_i} k_{isc}^{1-\beta_i}\big)^{\alpha_i}\big(\tfrac{Q_{isc}}{A_{sc}}\big)^{(\gamma_i-1)/\gamma_i}.$$

where $0 \leq \alpha_i \leq 1$ captures the returns to capital and labour and $0 \leq \beta_i \leq 1$ is a distribution parameter. The parameter γ_i denotes sector-specific spatial externalities. Positive spatial externalities are present if and only if $\gamma_i > 1$.

Assuming that labour and capital are distributed equally among the acres in each region, the production function of the region is $Q_{isc} = q_{isc}A_{sc}$ or,

$$Q_{isc} = A_{sc}\Omega_{isc}\big[\big(\tfrac{N_{isc}H_{isc}}{A_{sc}}\big)^{\beta_i}\big(\tfrac{K_{isc}}{A_{sc}}\big)^{1-\beta_i}\big]^{\alpha_i}\big(\tfrac{Q_{isc}}{A_{sc}}\big)^{(\gamma_i-1)/\gamma_i}.$$

Here N_{isc} is total employment, H_{isc} is the average human capital level of workers employed in sector i, and K_{isc} denotes the total amount of capital in region s and sector i. Solving the latter equation for average labour productivity gives,

$$\tfrac{Q_{isc}}{N_{isc}} = \Omega_{isc}^{\gamma_i}\left(H_{isc}^{\beta_i}\big(\tfrac{K_{isc}}{N_{isc}}\big)^{1-\beta_i}\right)^{\alpha_i\gamma_i}\big(\tfrac{N_{isc}}{A_{sc}}\big)^{\alpha_i\gamma_i-1}.$$

The appearance of the capital stock K_{isc} in this equation is troublesome since data for this variable are not available. To get around this problem we follow Ciccone (2002) and assume that the rental price of capital r_{ic} is equalized within a country. The capital demand function is then given by,

$$K_{isc} = \tfrac{\alpha_i(1-\beta_i)}{r_{ic}}Q_{isc}.$$

Substituting this into the expression above and again solving for labour productivity yields,

$$\tfrac{Q_{isc}}{N_{isc}} = \Gamma_{ic}\Omega_{isc}^{\omega_i}H_{isc}\big(\tfrac{N_{isc}H_{isc}}{A_{sc}}\big)^{\theta_i}$$

where $\Gamma_{ic} = \big(\tfrac{\alpha_i(1-\beta_i)}{r_{ic}}\big)^{\frac{(1-\beta_i)\alpha_i\gamma_i}{1-(1-\beta_i)\alpha_i\gamma_i}}$ and $\omega_i = \frac{\gamma_i}{1-(1-\beta_i)\alpha_i\gamma_i}$ are constants. The first is country- and sector-specific as long as the rental price of capital differs across countries for each sector.[3] The second constant is sector-specific and the same across countries. The effect of regional density arises through the parameter,

$$\theta_i = \frac{\alpha_i\gamma_i - 1}{1 - \alpha_i\gamma_i(1-\beta_i)}$$

[3] Note that we assume the rental price of capital to be country- and sector-specific. This may be justified in the way that the capital stock differs across industries in its intensity with respect to asset types. If the rental prices of these asset types differ (but are equalized across the country) these are sector-specific. If we assume $r_{ic} = r_c$, i.e. rental prices are equalized across sectors within a country, we would reach the same conclusions as Γ_{ic} would still be sector- and country-specific.

to which we will refer as the 'agglomeration effect'.[4] Finally, taking logs yields,

$$\ln \frac{Q_{isc}}{N_{isc}} = \ln \Gamma_{ic} + \omega_i \ln \Omega_{isc} + (\theta_i + 1) \ln H_{isc} + \theta_i \ln(\frac{N_{isc}}{A_{sc}}). \tag{2.1}$$

Thus sectoral labour productivity is a function of sectoral total factor productivity, the average level of sectoral human capital and the sector-specific employment density in the particular region. In the econometric implementation we follow Ciccone (2002) and use the share of high- and low-skilled workers in the particular sectors as a measure of the level of human capital.[5] The constants in equation (2.1) are accounted for by including country and NUTS-1 regional dummies. We also include a set of time dummies in our equation to account for time-specific effects and include sector dummies when estimating the model at the sectoral level. Our econometric specification which is estimated for each particular sector is thus,

$$\ln \frac{Q_{isc}}{N_{isc}} = D_c\beta_c + D_t\beta_t + D_r\beta_r + \textstyle\sum_{e=H,L} \delta_{ei} h_{eisc} + \theta_i \ln(\frac{N_{isc}}{A_{sc}}) + u_{isc}. \tag{2.2}$$

where $D_j(j = c, t, r)$ denote dummies for countries, time periods and NUTS-1 regions, and β_j denote the coefficients to be estimated. The share of workers with tertiary $(e = H)$ and primary $(e = L)$ educational attainment levels are denoted by h_{eisc} with the coefficients denoted by δ_{ei}. θ_i is the coefficient capturing the agglomeration effect.

2.2 Externalities across regions

The model thus far only captures sectoral level externalities within regions. As Ciccone (2002) noted however, there are goods reasons to believe that spillovers may extend beyond regions. Indeed, research has shown that the process of convergence in European regions displays spatial dependence. Ertur and Baumont (2006) for example show that spatial dependence is important in the estimation of β convergence among 138 European regions. To account for cross regional spillovers Ciccone (2002) allowed total factor productivity in a region to be dependent upon the density of production in neighbouring regions. We follow this approach assuming that total factor productivity Ω_{isc} is a function of production density in 'neighbouring' regions. Formally, this means that,

$$\Omega_{isc} = \Phi_{isc} \left(\frac{Q^n_{isc}}{A^n_{sc}}\right)^{\mu_i}.$$

[4] Ciccone (2002) discusses in detail the conditions under which $\theta_i > 0$.

[5] From our data we can only distinguish three types of educational attainment levels.

where Φ_{isc} denotes total factor productivity which is assumed to be exogenous. Output in the neighbouring regions is denoted by $Q^n_{isc} = \sum_{r,d} d_{rd,sc} Q_{ird}$ and the total acreage of neigbouring regions is $A^n_{sc} = \sum_{r,d} d_{rd,sc} A_{rd}$. Here $d_{rd,sc}$ denotes a distance measure of region s in country c to all other regions. Inserting $\ln \Omega_{isc} = \ln \Phi_{isc} + \mu_i \ln \left(\frac{Q^n_{isc}}{A^n_{sc}} \right)$ into equation (2.1) above yields

$$\ln \frac{Q_{isc}}{N_{isc}} = \ln \Gamma_{ic} + \omega_i \ln \Phi_{isc} + \omega_i \mu_i \ln \left(\frac{Q^n_{isc}}{A^n_{sc}} \right) + (\theta_i + 1) \ln H_{isc} + \theta_i \ln \left(\frac{N_{isc}}{A_{sc}} \right).$$

This results in an econometric specification similar to equation (2.2) above,

$$\ln \frac{Q_{isc}}{N_{isc}} = D_c \beta_c + D_t \beta_t + D_r \beta_r + \sum_{e=H,L} \delta_{ei} h_{eisc} + \theta_i \ln(\frac{N_{isc}}{A_{sc}}) + \varphi_i \ln \left(\frac{Q^n_{isc}}{A^n_{sc}} \right) + u_{isc} \tag{2.3}$$

which differs only by the appearance of the effect of production density in 'neighbouring' regions with $\varphi_i = \omega_i \mu_i$ being the coefficient to be estimated.

Rather than only considering spillovers among regions sharing a common border, as is done in Ciccone (2002), we also consider alternative weighting matrices. Apart from a common border matrix, we apply an exponential decay function with different decay parameters ϕ,

$$d_{ij} = \begin{cases} exp^{-\phi \text{ dist}_{ij}} & \text{for } i \neq j \\ 0 & \text{for } i = j \end{cases}$$

Here dist_{ij} denotes the great circle distance between regions i and j. The distance between two regions is measured from the centre of each region in kilometres and is divided by 1000 to allow us to calculate the exponential. We report results for decay parameters $\phi = 10, 5, 2.5, 1, 0.25$. The larger the decay parameter, the less weight is given to regions further away. The product of each of these weighting matrices and the density of the production matrix provides us with a variable measuring cross-regional spillovers.[6]

3 Data

The data we are using are taken from the Eurostat Regio database. We use value added and (total) employment data from Regional National Accounts over the period 1998-2003. For some countries and years we had to impute missing values by linear interpolation to give a balanced

[6]In the specifications reported below we set $d_{ii} = 0$. We also experimented, however, by including internal distances (measured by replacing zero with an internal distance measure given by $\text{dist}_{ii} = \sqrt{A_i/\pi}$). These results are not reported for brevity, but are available upon request.

panel. The value added data, which are in nominal terms, have been deflated (base year 2003) using country- and sector-specific deflators since no regional deflators are available. The data were also converted to a common currency using 2003 PPPs. The National Accounts employment data are collected according to the 'principle of working condition', that is, people are counted in the region where they are working and not where they are living. Given data on output by region and sector this allows one to calculate labour productivity levels. We also include the shares of high- and low-skilled workers (defined by educational attainment levels) by sector and region in the regressions. These data are taken from the Labour Force Survey (LFS), which is (consistently) available for the period 1998-2005.[7] The LFS data provide information on educational attainment levels according to the International Standard Classification of Education (ISCED) categories and allow for three types of worker (high-, medium- and low-skilled). As mentioned previously, we include the share of high- and low-skilled as measures of the level of human capital.

In the analysis we are restricted to six sectors according to the NACE classification. These are: Agriculture, Forestry and Fishing (AtB), Mining, Manufacturing and Energy (CtE), Construction (F), Wholesale and Retail Trade, Transport (GtI), Business Services (JtK) and Public Services (LtQ) (see appendix Table 7 for a more detailed description). Finally, the number of regions considered according to the NUTS-2 classification is 255, with data from 26 European countries included.[8] Data on geographical area are taken from Eurostat. Compared with the study of Ciccone (2002) the current paper thus has a broader coverage of countries within Europe as well as more disaggregated data, considering the importance of agglomeration across six broad economic sectors.[9] On the other hand, the data in the present paper are less detailed with respect to the regional classification as Ciccone (2002) applies data at the NUTS-3 level whereas we use data at the NUTS-2 level.

[7]LFS data are collected according to the 'principle of living condition', that is, people are counted in the region where they are living. This introduces a slight inconsistency in our dataset which cannot be resolved. Using employment levels from the LFS data (instead of employment levels from Regional National Accounts data), however, yields similar results.

[8]The countries considered in our analysis are: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Spain, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Sweden, and the UK.

[9]Ciccone (2002) did not consider the non-agricultural and private economy in his aggregate data on value-added.

4 Results

In this section we present our basic results. We do this using aggregate data first and then for the sectoral data.

4.1 Results for the total economy

The model given by equations (2.2) and (2.3) is estimated, first, for the total economy and for the total economy minus agriculture, forestry and fishing (AtB) and public services (LtQ), which we refer to as the 'total market economy'. This allows us to compare the results of Ciccone (2002) using NUTS-3 level data with our results using data at the NUTS-2 level. The results are reported in Table 1. The top half of this table reports the results for the total economy, while the lower half reports the results for the total market economy. The column headings refer

Variable	Intra Spillovers	Common Border	$\phi = 10.00$	$\phi = 5.00$	$\phi = 2.50$	$\phi = 1.00$	$\phi = 0.25$
				Total economy			
Density	0.050 ***	0.049 ***	0.048 ***	0.048 ***	0.049 ***	0.049 ***	0.051 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
High skill	0.495	0.506	0.554	0.526	0.504	0.508	0.507
	(0.239)	(0.230)	(0.191)	(0.219)	(0.240)	(0.237)	(0.235)
Low skill	-0.935 ***	-0.937 ***	-0.964 ***	-0.947 ***	-0.937 ***	-0.937 ***	-0.932 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Spillovers		0.020 **	0.067 ***	0.045 **	0.023	0.115	0.866
		(0.027)	(0.000)	(0.045)	(0.548)	(0.340)	(0.101)
F	437.361	402.359	425.717	432.487	433.109	434.310	437.091
R^2	0.933	0.933	0.934	0.933	0.933	0.933	0.933
Obs.	1530	1506	1530	1530	1530	1530	1530
				Total market economy			
Density	0.048 ***	0.048 ***	0.047 ***	0.047 ***	0.049 ***	0.048 ***	0.048 ***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
High skill	0.439	0.447	0.459	0.444	0.433	0.437	0.441
	(0.463)	(0.456)	(0.445)	(0.461)	(0.470)	(0.467)	(0.463)
Low skill	-0.312	-0.292	-0.340	-0.318	-0.302	-0.307	-0.316
	(0.202)	(0.239)	(0.164)	(0.190)	(0.210)	(0.203)	(0.192)
Spillovers		0.011	0.037 **	0.012	-0.035	-0.057	0.303
		(0.271)	(0.026)	(0.619)	(0.396)	(0.654)	(0.587)
F	489.042	485.633	488.118	484.740	482.733	482.330	486.680
R^2	0.913	0.913	0.913	0.913	0.913	0.913	0.913
Obs.	1530	1506	1530	1530	1530	1530	1530

All regressions include time, country and NUTS1 dummies; p-values in brackets are based on heteroscedasticity consistent standard errors; ***,**, * denote significance at the 1, 5, and 10 % level.

Table 1: Agglomeration and spillover effects at the aggregate level

to the different weighting schemes considered when accounting for cross-regional spillovers. The results on our main variable of interest, density, are largely consistent across specifications and for the two aggregates. In particular, we find a coefficient around 0.05 for both the total and the total market economy. As with Ciccone (2002) we find the results on the density variable to be robust to the different weighting schemes for regional spillovers. Despite the problems in comparing results at different spatial levels, the coefficients on density at the NUTS-2 level are remarkably similar to those found by Ciccone (2002) at the NUTS-3 level and suggest that a doubling of employment density increases labour productivity by about 5 per cent.[10]

In terms of the additional variables in the model, the coefficient on high-skilled education is positive, though not significant, while that on low-skilled education is negative and significant in the case of the total economy at least. The lack of significance of this variable is consistent with findings in the growth literature where human capital and growth have found to be only weakly, or even negatively, related (see for example Benhabib and Spiegel, 1994; Pritchett, 2001). Finally, we consider the coefficients on the spillover variables. For the common border variable we find a coefficient of 0.02 for the total economy, which is significant, and 0.01 for the total market economy. These coefficients are smaller than those found by Ciccone (2002) who finds a coefficient of 3.3 per cent. This may reflect the Modifiable Areal Unit Problem with the distances in this paper being much larger than those in Ciccone (2002), which may lower the importance of spillovers. Considering the spillover variable for different values of ϕ, we tend to find that the coefficient is positive, significant and relatively large for high values of ϕ becoming smaller (and sometimes negative in the case of the market economy) and insignificant for smaller values of ϕ. These results are consistent with existing results indicating that spillovers decline rapidly with distance.[11]

[10] In particular, the modifiable areal unit problem suggests that the choice of spatial scale is likely to affect the results. Moreover, we may expect larger spillovers at the NUTS-3 level due to the average distance between regions at the NUTS-3 level being much larger. As discussed above, existing literature suggests that spillovers decline rapidly with distance.

[11] As mentioned above, in some specifications we also include internal distances in the spillover variable to account for the fact that internal distances at the NUTS-2 level can be quite large. When doing this the results for density tend to be consistent with those reported above, while the coefficients on the spillover variables tend to increase, reinforcing the short-distance nature of spillovers. Results are available on request.

4.2 Sectoral Results

Table 2 reports results for density and spillover effects in the different sectors.[12] The coefficients on density, the share of high- and low-skilled workers and, where relevant, cross-regional spillovers are estimated separately for each sector, thus allowing the coefficients on the dummies to vary across sectors. The coefficients on the density variable in Table 2 (Column 1) indicate that there

Variable		Intra Spillovers	Common Border	$\theta = 10.00$	$\theta = 5.00$	$\theta = 2.50$	$\theta = 1.00$	$\theta = 0.25$
Density	Agriculture	-0.032***	-0.036***	-0.040***	-0.048***	-0.055***	-0.053***	-0.031***
		(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
	Manufacturing	0.042***	0.042***	0.040***	0.040***	0.040***	0.039***	0.044***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Construction	0.057***	0.057***	0.056***	0.057***	0.060***	0.060***	0.056***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Trade	0.057***	0.056***	0.056***	0.056***	0.057***	0.056***	0.059***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Business services	0.057***	0.057***	0.056***	0.056***	0.057***	0.057***	0.058***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Public services	0.055***	0.054***	0.053***	0.053***	0.054***	0.054***	0.057***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Spillover	Agriculture		0.073***	0.120***	0.174***	0.296***	0.927***	3.010***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Manufacturing		0.006	0.056***	0.049**	0.045	0.245**	1.591***
			(0.487)	(0.000)	(0.020)	(0.223)	(0.034)	(0.001)
	Construction		0.008	0.036**	-0.001	-0.069*	-0.292***	-1.093**
			(0.442)	(0.022)	(0.955)	(0.054)	(0.009)	(0.026)
	Trade		0.018**	0.049***	0.031	0.009	0.103	1.115**
			(0.035)	(0.001)	(0.184)	(0.826)	(0.435)	(0.037)
	Business services		0.010	0.056***	0.035	0.005	0.037	0.512
			(0.140)	(0.000)	(0.111)	(0.896)	(0.736)	(0.253)
	Public services		0.037***	0.093***	0.058**	0.029	0.113	1.041**
			(0.001)	(0.000)	(0.018)	(0.464)	(0.338)	(0.036)

All regressions include time, country and NUTS1 dummies; p-values in brackets are based on heteroscedasticity consistent standard errors; ***,**, * denote significance at the 1, 5, and 10 % level.

Table 2: Agglomeration and spillover effects at the sectoral level

are significant agglomeration effects in five of the six sectors. Only in the case of agriculture do we find a significantly negative coefficient. For this industry therefore we find evidence of a congestion effect, which may reflect the smaller average land holdings of farmers in denser regions that may limit the ability to exploit economies of scale. Where positive the size of the coefficients are also in line with those reported at the aggregate level both in this paper and in previous studies, suggesting that a doubling of employment density in a particular sector is associated with an increase in labour productivity of around 5.5 per cent. The size of the coefficient also tends to be fairly similar across industries, though somewhat lower for manufacturing.

Introducing spillover effects (Columns 2-7) has no discernible impact on the size, sign and sig-

[12] The full set of results is available upon request.

nificance of the coefficients on density. The coefficients on the spillover variables themselves tend to differ across sectors. While we find positive and significant spillover effects for all specifications in agriculture, this is not the case for other industries. The results do suggest, however, that the spillover variable is positive and significant for all sectors for high values of θ, again suggesting that spillovers are important, but that their importance declines quickly with distance.

5 Instrumental Variable Results

Ciccone (2002) argues that there are two competing explanations for the agglomeration effects he finds. The first of these suggests that productivity is high because of agglomeration effects, while the second would argue that agglomeration is an outcome of high productivity and not a cause. In the absence of information on all variables causing productivity, Ciccone proceeds to employ an instrumental variables approach to deal with this problem using land area as an instrument for employment density. Ciccone (2002) shows that land area and employment density are negatively correlated after controlling for country fixed effects, a correlation which, Ciccone argues, relates to history. In particular, he argues that the size of regions was determined largely for administrative reasons, with the equalization of the population a natural criterion. Given the historical nature of the correlation between area and employment density, area can be used as an instrument for employment density as long as the original cause of cross-region differences in area affects productivity today largely through agglomeration. Ciccone (2002) finds that using area as an instrumental variable for employment density slightly lowers the estimate of agglomeration effects, but the coefficient is still found to be positive and highly significant. We follow the approach of Ciccone (2002) and use area as an instrument for employment density.[13] We thus proceed to re-estimate the above models using area as an instrument for employment density.

5.1 Total economy

Table 3 presents the results for the total economy and the total market economy. Consistent with the results of Ciccone (2002) we find in Table 3 in most cases a lower coefficient on the density variable when using the instrumental variables approach as compared with the OLS

[13]Regressing employment density on area, country and time dummies at both the aggregate and sectoral levels results in a significant negative association between density and area. These results are available upon request.

results reported in Table 1. The coefficients tend to remain significant for the total economy, but are often insignificant when the total market economy is considered. The coefficients on the education variables are also generally consistent with those from the OLS estimation, with negative coefficients found for the share of low-educated workers and positive, though usually insignificant coefficients found for the share of high-educated workers. Finally, in terms of the spillover variable, we find results again consistent with those in Table 1 with a positive and significant coefficient found for the common border weighting as well as for high values of θ, but insignificant coefficients found for lower values of θ.[14]

Variable	Intra Spillovers	Common Border	$\theta = 10.00$	$\theta = 5.00$	$\theta = 2.50$	$\theta = 1.00$	$\theta = 0.25$
				Total economy			
Density	0.041 ***	0.027 *	0.009	0.015	0.030	0.033 *	0.045 ***
	(0.002)	(0.085)	(0.607)	(0.510)	(0.199)	(0.058)	(0.001)
High skill	0.577	0.703 *	0.914 **	0.838 *	0.685	0.651	0.559
	(0.135)	(0.066)	(0.031)	(0.064)	(0.129)	(0.123)	(0.141)
Low skill	-0.936 ***	-0.943 ***	-0.972 ***	-0.955 ***	-0.941 ***	-0.938 ***	-0.933 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Spillovers		0.025 **	0.076 ***	0.064 **	0.047	0.163	0.797
		(0.016)	(0.000)	(0.015)	(0.353)	(0.211)	(0.186)
F	429.256	389.603	411.794	419.541	423.243	425.428	429.621
R^2	0.933	0.932	0.931	0.931	0.932	0.932	0.933
Obs.	1530	1506	1530	1530	1530	1530	1530
				Total market economy			
Density	0.015	0.003	-0.004	0.001	0.014	0.013	0.015
	(0.310)	(0.858)	(0.846)	(0.954)	(0.566)	(0.497)	(0.313)
High skill	0.721	0.831	0.901	0.844	0.734	0.740	0.723
	(0.227)	(0.163)	(0.154)	(0.192)	(0.248)	(0.233)	(0.217)
Low skill	-0.286	-0.264	-0.306	-0.293	-0.287	-0.289	-0.284
	(0.260)	(0.313)	(0.244)	(0.259)	(0.259)	(0.255)	(0.253)
Spillovers		0.021 *	0.046 ***	0.034	0.007	0.053	-0.089
		(0.062)	(0.005)	(0.213)	(0.899)	(0.692)	(0.890)
F	436.620	427.187	414.179	418.425	430.549	430.591	431.426
R^2	0.910	0.908	0.907	0.908	0.910	0.910	0.910
Obs.	1530	1506	1530	1530	1530	1530	1530

All regressions include time, country and NUTS1 dummies; p-values in brackets are based on heteroscedasticity consistent standard errors; ***,**, * denote significance at the 1, 5, and 10 % level.

Table 3: Density and spillovers at the aggregate level - IV results

5.2 Sectoral dimension

Table 4 presents the results from the IV estimation for the individual sectors. The results, when excluding spillovers (Column 1), tend to be consistent with the aggregate results and

[14]For reasons of brevity we choose not to report the results when including internal distances in the spillover specification. These results are, however, available upon request.

Variable		Intra Spillovers	Common Border	$\theta = 10.00$	$\theta = 5.00$	$\theta = 2.50$	$\theta = 1.00$	$\theta = 0.25$
Density	Agriculture	0.060***	0.025	0.032	0.019	0.011	0.017	0.065***
		(0.008)	(0.263)	(0.201)	(0.590)	(0.824)	(0.588)	(0.007)
	Manufacturing	0.045***	0.042**	0.013	0.014	0.028	0.030	0.055***
		(0.003)	(0.020)	(0.541)	(0.593)	(0.347)	(0.158)	(0.001)
	Construction	0.039***	0.032**	0.021	0.034*	0.053***	0.051***	0.034***
		(0.002)	(0.033)	(0.206)	(0.077)	(0.008)	(0.001)	(0.007)
	Trade	0.039***	0.025*	0.017	0.019	0.028	0.030*	0.043***
		(0.002)	(0.089)	(0.306)	(0.344)	(0.198)	(0.067)	(0.001)
	Business services	0.039***	0.031**	0.014	0.018	0.032	0.035**	0.041***
		(0.002)	(0.027)	(0.408)	(0.369)	(0.122)	(0.028)	(0.002)
	Public services	0.041***	0.018	0.002	0.012	0.028	0.033**	0.046***
		(0.002)	(0.251)	(0.931)	(0.590)	(0.186)	(0.044)	(0.001)
Spillover	Agriculture		0.064***	0.082***	0.099**	0.160	0.567***	3.140***
			(0.000)	(0.006)	(0.044)	(0.140)	(0.003)	(0.000)
	Manufacturing		0.006	0.067***	0.067**	0.064	0.281*	1.692***
			(0.587)	(0.000)	(0.027)	(0.319)	(0.058)	(0.002)
	Construction		0.015	0.048***	0.013	-0.061	-0.260**	-1.213**
			(0.256)	(0.007)	(0.625)	(0.202)	(0.036)	(0.019)
	Trade		0.026***	0.056***	0.049*	0.046	0.191	0.896
			(0.010)	(0.000)	(0.055)	(0.373)	(0.160)	(0.159)
	Business services		0.014*	0.060***	0.050**	0.032	0.097	0.324
			(0.055)	(0.000)	(0.034)	(0.480)	(0.399)	(0.550)
	Public services		0.041***	0.100***	0.076***	0.055	0.166	0.908
			(0.001)	(0.000)	(0.005)	(0.236)	(0.174)	(0.125)

All regressions include time, country and NUTS1 dummies; p-values in brackets are based on heteroscedasticity consistent standard errors; ***,**, * denote significance at the 1, 5, and 10 % level.

Table 4: Agglomeration and spillover effects at the sectoral level - IV results

existing literature in that the coefficient on the density variable is smaller in most cases, though the coefficients remain positive and significant. The main difference between the OLS and IV results at the sectoral level is that the coefficient on agriculture, which in the OLS case was negative and significant, becomes positive and significant in the IV case. This suggests that the endogeneity problem is rather strong for the agricultural sector. When controlling for the potential endogeneity that higher productivity regions (generally urban areas with a low share of agriculture and relatively low productivity in agriculture as economies of scale cannot be exploited) attract more workers (i.e. a migration from agricultural regions to metropolitan areas) we also find significant density effects for the agricultural sector. As large units of land are necessary to exploit the economies of scale in agriculture, and land area is fixed, migration allows the exploitation of these economies of scale.

Turning to the results when spillovers are allowed we again find that the coefficients on the density variables are generally smaller in size than the corresponding OLS coefficients. Moreover, while the coefficients are always significant when spillovers are excluded and for a value of θ equal to 0.25, for other specifications of the spillover variable the density coefficient is often insignificant, though always positive. The coefficients on the spillover variables themselves are largely consistent with the OLS results. In particular, we tend to find positive and significant coefficients across sectors for the common border weighting and for high values of θ, but largely insignificant coefficients for low values of θ.

6 Results for Country Subsamples

A relevant question, given the above results and given our comparison with the existing studies of Ciccone and Hall (1996) and Ciccone (2002), is whether agglomeration effects are similar across countries or groups of countries and, in particular, whether agglomeration effects found in advanced countries are also present in the new EU member states.[15] To test for such differences we estimated the model above on two sub-samples: 'old Europe' (EU-15) and 'new Europe' (EU-12).[16] Though it may not be clear why one should expect differences in the density effects between old and new member states, there are reasons for density to have larger impacts on productivity levels in the new member states. For example, economic activity seems to be more concentrated in the regions bordering Western European countries and to be relatively more concentrated in urban areas, particularly capital cities (when compared with Western European regions). The bordering regions and the capital cities have profited from trade integration and foreign direct investment flows to a much much larger extent than other regions in this phase of transition. Similarly, productivity levels in these particular regions relative to overall productivity levels appear to be relatively high when compared with the ratios in old member states. This may be due to some regions in the new member states still having large shares of agriculture or a less favourable industrial structure. Also, productivity increases are caused by large inflows of foreign capital with positive effects on productivity through technology transfer and a larger capital stock. Foreign direct investment can lead to significant clustering activities (e.g. the automobile cluster in the Slovak Republic) and thus lead to significant spillover effects (see for example Campos and Kinoshita, 2003; Kim et al., 2003; Pelegrín and Bolancé, 2008). Finally, note that employment rates in these particular regions are in most cases higher than in agricultural

[15]The group of new member states (i.e. countries that became EU members in 2004 or thereafter) consists of Bulgaria, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic and Slovenia.

[16]It should be noted that we still allow for spillovers across regions from the total sample.

regions for example, again strengthening the effect of employment density on productivity. There is, however, scarce empirical literature examining whether density effects differ across different types of regions, though Anastassova (2006) reports differences in density effects for metropolitan versus non-metropolitan regions with the effects being about two times larger for metropolitan (urban) regions. These leads us to expect density effects to be larger in the regions of the new member states.[17]

6.1 Total economy

Table 5 reports for both groups of countries the results for the total economy and total market economy respectively. For brevity we only report the IV results.[18] The results from the two country sub-samples suggest large differences in the extent of agglomeration. For old Europe we tend to find coefficients on the density variable that are either small, positive and insignificant or small, negative and significant. For new Europe, however, we find coefficients that are large, positive and significant. The size of the coefficients for new Europe tends to be around three times as large as those reported in Table 1. The results at the aggregate level therefore suggest that, while agglomeration effects in old Europe tend to be small at best, in new Europe they are strong and significant. The results on the new member states thus support our expectations though the strength of the effect is surprisingly high.[19]

6.2 Sectoral dimension

The sectoral results for density and spillover effects when splitting the sample into the different country groupings are reported in Table 6. We again choose to report the IV results only. The results at the sectoral level are largely consistent with those from the aggregate level. In particular, the coefficients on density are generally small and insignificant for old Europe, but large and positive for new Europe. Once again the size of the coefficients in new Europe tends to be around three times the size of the coefficients reported in Table 2 and by Ciccone (2002). For

[17] In this respect, most countries among the new member states are rather small and in some cases the country as a whole (i.e. including the capital city) is counted as the NUTS 2 region.

[18] The OLS results are available upon request. The coefficients from the OLS regressions are generally larger in size and more often significant for both groups of countries.

[19] These results also suggest that it may be interesting to distinguish the regions according to various typologies to test for differences in density effects by type of regions. We leave this possibility to future research.

Variable	Intra Spillovers	Common Border	$\theta = 10.00$	$\theta = 5.00$	$\theta = 2.50$	$\theta = 1.00$	$\theta = 0.25$
			Total economy: Old Member States				
Density	0.009	-0.004	-0.011	-0.004	0.003	0.006	0.006
	(0.372)	(0.767)	(0.470)	(0.813)	(0.886)	(0.671)	(0.581)
High skill	0.846 ***	0.959 ***	1.075 ***	0.982 ***	0.907 ***	0.879 ***	0.855 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Low skill	-0.553 ***	-0.543 ***	-0.546 ***	-0.547 ***	-0.550 ***	-0.552 ***	-0.551 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Spillovers		0.021 **	0.043 ***	0.027	0.022	0.061	-0.407
		(0.029)	(0.003)	(0.166)	(0.557)	(0.512)	(0.279)
F	660.759	526.658	703.777	677.465	663.438	661.861	645.485
R^2	0.807	0.782	0.795	0.799	0.804	0.806	0.806
Obs.	1206	1188	1206	1206	1206	1206	1206
			Total economy: New Member States				
Density	0.202 ***	0.190 ***	0.191 ***	0.204 ***	0.204 ***	0.200 ***	0.204 ***
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
High skill	-0.659	-0.501	-0.517	-0.650	-0.670	-0.645	-0.664
	(0.496)	(0.614)	(0.594)	(0.504)	(0.494)	(0.514)	(0.500)
Low skill	-1.323 ***	-1.326 ***	-1.446 ***	-1.336 ***	-1.291 ***	-1.295 ***	-1.309 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Spillovers		0.036	0.207 ***	0.217 ***	0.256 **	0.554 **	1.909
		(0.328)	(0.000)	(0.001)	(0.013)	(0.039)	(0.113)
F	95.520	96.096	106.478	100.196	96.390	95.480	93.924
R^2	0.876	0.874	0.884	0.882	0.880	0.879	0.878
Obs.	324	318	324	324	324	324	324
			Total market economy: Old Member States				
Density	-0.021 *	-0.030 *	-0.032 **	-0.022	-0.013	-0.016	-0.030 *
	(0.078)	(0.066)	(0.043)	(0.206)	(0.493)	(0.248)	(0.051)
High skill	1.224 ***	1.318 ***	1.342 ***	1.235 ***	1.149 ***	1.183 ***	1.270 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Low skill	-0.168 *	-0.134	-0.168 *	-0.167 *	-0.169 *	-0.165 *	-0.140
	(0.081)	(0.167)	(0.087)	(0.082)	(0.075)	(0.084)	(0.164)
Spillovers		0.012	0.023	0.002	-0.029	-0.084	-1.380 ***
		(0.220)	(0.120)	(0.911)	(0.460)	(0.384)	(0.002)
F	320.578	252.593	292.941	314.472	329.894	324.525	311.290
R^2	0.794	0.777	0.783	0.793	0.801	0.798	0.787
Obs.	1206	1188	1206	1206	1206	1206	1206
			Total market economy: New Member States				
Density	0.201 ***	0.193 ***	0.201 ***	0.205 ***	0.201 ***	0.198 ***	0.202 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
High skill	-0.903	-0.803	-0.833	-0.891	-0.902	-0.893	-0.910
	(0.322)	(0.400)	(0.362)	(0.326)	(0.325)	(0.335)	(0.324)
Low skill	-0.741 *	-0.749 *	-0.796 *	-0.643	-0.612	-0.669	-0.700
	(0.090)	(0.082)	(0.059)	(0.118)	(0.137)	(0.111)	(0.101)
Spillovers		0.043	0.192 ***	0.237 ***	0.300 ***	0.654 **	2.319 **
		(0.252)	(0.001)	(0.000)	(0.003)	(0.012)	(0.047)
F	62.683	57.098	67.840	64.975	62.164	61.483	60.896
R^2	0.810	0.804	0.818	0.819	0.816	0.815	0.812
Obs.	324	318	324	324	324	324	324

All regressions include time, country and NUTS1 dummies; p-values in brackets are based on heteroscedasticity consistent standard errors; ***,**, * denote significance at the 1, 5, and 10 % level.

Table 5: Agglomeration and spillover by country groups in the total economy (IV results)

Variable	Industry	Intra Spillovers	Common Border	$\theta = 10.00$	$\theta = 5.00$	$\theta = 2.50$	$\theta = 1.00$	$\theta = 0.25$
				Old Member States				
Density	Agriculture	0.011	0.002	0.009	0.005	-0.009	-0.012	0.017
		(0.388)	(0.916)	(0.613)	(0.841)	(0.829)	(0.590)	(0.162)
	Manufacturing	0.010	0.012	-0.004	0.009	0.013	0.008	0.007
		(0.369)	(0.404)	(0.831)	(0.647)	(0.622)	(0.645)	(0.545)
	Construction	0.008	-0.002	-0.007	0.005	0.014	0.013	0.005
		(0.372)	(0.875)	(0.636)	(0.754)	(0.394)	(0.295)	(0.658)
	Trade	0.008	-0.008	-0.011	-0.008	-0.002	0.004	0.007
		(0.370)	(0.583)	(0.440)	(0.654)	(0.915)	(0.783)	(0.518)
	Business services	0.008	-0.004	-0.007	-0.003	0.003	0.006	0.004
		(0.363)	(0.770)	(0.596)	(0.857)	(0.863)	(0.608)	(0.693)
	Public services	0.009	-0.010	-0.016	-0.007	0.002	0.005	0.008
		(0.374)	(0.499)	(0.318)	(0.674)	(0.919)	(0.671)	(0.486)
Spillover	Agriculture		0.017	0.007	0.015	0.066	0.334**	1.794***
			(0.140)	(0.718)	(0.687)	(0.473)	(0.046)	(0.000)
	Manufacturing		-0.004	0.024*	0.000	-0.012	0.032	-0.380
			(0.640)	(0.089)	(0.987)	(0.848)	(0.805)	(0.307)
	Construction		0.019	0.036**	0.008	-0.020	-0.089	-0.729**
			(0.103)	(0.021)	(0.688)	(0.568)	(0.324)	(0.040)
	Trade		0.027***	0.043***	0.035*	0.039	0.098	-0.274
			(0.004)	(0.002)	(0.079)	(0.336)	(0.328)	(0.487)
	Business services		0.019**	0.033***	0.023	0.020	0.046	-0.577*
			(0.014)	(0.008)	(0.171)	(0.546)	(0.574)	(0.086)
	Public services		0.030***	0.054***	0.036*	0.027	0.069	-0.169
			(0.005)	(0.000)	(0.070)	(0.440)	(0.430)	(0.658)
				New Member States				
Density	Agriculture	1.097*	1.025	1.153	1.290	1.587	1.904	1.543
		(0.065)	(0.101)	(0.119)	(0.146)	(0.203)	(0.241)	(0.134)
	Manufacturing	0.213***	0.222***	0.193***	0.209***	0.214***	0.211***	0.216***
		(0.002)	(0.004)	(0.006)	(0.003)	(0.003)	(0.003)	(0.003)
	Construction	0.181***	0.173***	0.175***	0.184***	0.183***	0.179***	0.182***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Trade	0.177***	0.174***	0.178***	0.185***	0.180***	0.175***	0.178***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Business services	0.177***	0.170***	0.175***	0.180***	0.179***	0.176***	0.179***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Public services	0.178***	0.162***	0.180***	0.185***	0.181***	0.177***	0.181***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Spillover	Agriculture		0.103	-0.180	-0.841	-2.747	-8.494	-17.097
			(0.638)	(0.727)	(0.439)	(0.316)	(0.280)	(0.184)
	Manufacturing		-0.030	0.161**	0.225***	0.268**	0.612**	2.522*
			(0.513)	(0.019)	(0.003)	(0.015)	(0.032)	(0.050)
	Construction		0.036	0.158***	0.209***	0.288***	0.623**	2.021*
			(0.210)	(0.000)	(0.000)	(0.003)	(0.015)	(0.069)
	Trade		0.008	0.166***	0.228***	0.280**	0.580**	1.714
			(0.787)	(0.006)	(0.003)	(0.012)	(0.038)	(0.167)
	Business services		0.028	0.132***	0.148***	0.193**	0.445**	1.660*
			(0.302)	(0.000)	(0.002)	(0.015)	(0.037)	(0.081)
	Public services		0.103***	0.229***	0.207***	0.267***	0.648***	2.426**
			(0.005)	(0.000)	(0.000)	(0.003)	(0.008)	(0.028)

All regressions include time, country, sector and NUTS1 dummies; p-values in brackets are based on heteroscedasticity consistent standard errors; ***, **, * denote significance at the 1, 5, and 10 % level.

Table 6: Density and spillover effects at the sectoral level in the Old and New Member States - IV results

agriculture, however, we obtain a coefficient that is infeasibly large. The results on the spillover variables for old Europe tend to mirror earlier ones, with the spillover variable tending to be positive and significant for the common border measure and for high values of θ, but insignificant for smaller values of θ. For new Europe the spillover variable tends to be positive and significant for all values of θ, though hardly ever significant when the common border weighting is used.

7 Conclusions

In this paper we extend the model proposed in Ciccone and Hall (1996) and Ciccone (2002) to the industry or sectoral level. We then test the model on an extended sample of countries, which includes data on all EU member countries (with the exception of Malta) at the NUTS 2-digit level over the period 1998-2004. Our dataset allows us to consider agglomeration effects for six sectors (agriculture, manufacturing, construction, distribution services, business and public services). As an additional extension over the Ciccone paper we examine differences in the extent of agglomeration among new and old EU members.

At the aggregate level our results broadly confirm the findings of Ciccone (2002) for our extended sample of EU countries, in terms of both the significance and size of the agglomeration effect. The results are weaker once we account for endogeneity, but are still largely in line with the results of Ciccone (2002). The results at the sectoral level indicate significant agglomeration effects for five out of the six sectors, with the coefficients being similar in size to those for the total economy. For the final sector, agriculture, we often find a significant negative coefficient. Where positive the coefficients on the density variable tend to be similar in size across sectors. As with the aggregate results, the sectoral results when accounting for endogeneity tend to be weaker, though significant agglomeration effects are usually found.

While the results for the full sample are to an extent in line with existing literature, we find important differences when we split the sample into new and old Europe. In particular, we find that the effect of density on productivity in old Europe is limited, both at the aggregate and sectoral levels. For new Europe, however, we find large coefficient estimates for the effect of density on productivity, suggesting large agglomeration effects in new Europe over the period considered. As with the results for the full sample, there are few differences in the extent of agglomeration effects across the individual sectors. These large effects could be caused by clustering effects driven by foreign capital inflows in particular into bordering regions and capital cities and concentration of economic activities in these regions. One potential implication of this result is that dense regions, such as capital cities, will have better prospects for productivity growth, while peripheral regions may not achieve catch-up. This suggests that there may be a divergence in development patterns across European regions, which the results particularly show for the regions in the new member states. However, other counteracting effects such as spillover effects across regions and a more balanced pattern of FDI inflows and investment structures may offset such an effect in the longer run.

It appears that additional analysis is needed, when looking for agglomeration effects at the sectoral or industry level, extending the Ciccone model to account for both localization and urbanization economies.

A Mathematical appendix

Average labour productivity is given by

$$\frac{Q_{isc}}{N_{isc}} = \Omega_{isc}^{\gamma_i} \left(H_{isc}^{\beta_i} (\tfrac{K_{isc}}{N_{isc}})^{1-\beta_i} \right)^{\alpha_i\gamma_i} (\tfrac{N_{isc}}{A_{sc}})^{\alpha_i\gamma_i - 1}$$

and demand for capital under the above mentioned assumptions is

$$K_{isc} = \tfrac{\alpha_i(1-\beta_i)}{r_{ic}} Q_{isc}.$$

Inserting yields

$$\begin{aligned}
\frac{Q_{isc}}{N_{isc}} &= \Omega_{isc}^{\gamma_i} \left(H_{isc}^{\beta_i} K_{isc}^{1-\beta_i} N_{isc}^{\beta_i - 1} \right)^{\alpha_i\gamma_i} (\tfrac{N_{isc}}{A_{sc}})^{\alpha_i\gamma_i - 1} \\
&= \Omega_{isc}^{\gamma_i} \left(H_{isc}^{\beta_i} (\tfrac{\alpha_i(1-\beta_i)}{r_{ic}} Q_{isc})^{1-\beta_i} N_{isc}^{\beta_i - 1} \right)^{\alpha_i\gamma_i} (\tfrac{N_{isc}}{A_{sc}})^{\alpha_i\gamma_i - 1} \\
&= \Omega_{isc}^{\gamma_i} \left(H_{isc}^{\beta_i} (\tfrac{\alpha_i(1-\beta_i)}{r_{ic}})^{1-\beta_i} \right)^{\alpha_i\gamma_i} (\tfrac{Q_{isc}}{N_{isc}})^{(1-\beta_i)\alpha_i\gamma_i} (\tfrac{N_{isc}}{A_{sc}})^{\alpha_i\gamma_i - 1} \\
\left(\frac{Q_{isc}}{N_{isc}} \right)^{1-(1-\beta_i)\alpha_i\gamma_i} &= \Omega_{isc}^{\gamma_i} \left(H_{isc}^{\beta_i} (\tfrac{\alpha_i(1-\beta_i)}{r_{ic}})^{1-\beta_i} \right)^{\alpha_i\gamma_i} (\tfrac{N_{isc}}{A_{sc}})^{\alpha_i\gamma_i - 1}
\end{aligned}$$

and thus

$$\frac{Q_{isc}}{N_{isc}} = \Omega_{isc}^{\gamma_i \frac{1}{1-(1-\beta_i)\alpha_i\gamma_i}} \left(H_{isc}^{\beta_i} (\tfrac{\alpha_i(1-\beta_i)}{r_{ic}})^{1-\beta_i} \right)^{\alpha_i\gamma_i \frac{1}{1-(1-\beta_i)\alpha_i\gamma_i}} (\tfrac{N_{isc}}{A_{sc}})^{(\alpha_i\gamma_i - 1)\frac{1}{1-(1-\beta_i)\alpha_i\gamma_i}}.$$

Rearranging and using the above definitions yields

$$\begin{aligned}
\frac{Q_{isc}}{N_{isc}} &= \Omega_{isc}^{\frac{\gamma_i}{1-(1-\beta_i)\alpha_i\gamma_i}} \left(\tfrac{\alpha_i(1-\beta_i)}{r_{ic}}\right)^{\frac{(1-\beta_i)\alpha_i\gamma_i}{1-(1-\beta_i)\alpha_i\gamma_i}} (H_{isc})^{\frac{\alpha_i\beta_i\gamma_i}{1-(1-\beta_i)\alpha_i\gamma_i}} \left(\tfrac{N_{isc}}{A_{sc}}\right)^{\frac{\alpha_i\gamma_i - 1}{1-(1-\beta_i)\alpha_i\gamma_i}} \\
&= \Omega_{isc}^{\omega_i} \Gamma_{ic} (H_{isc})^{\theta_i + 1} (\tfrac{N_{isc}}{A_{sc}})^{\theta_i}.
\end{aligned}$$

B Classifications

Industry code	NACE 1-digit	Description
Agriculture	A	Agriculture, hunting and forestry
	B	Fishing
Manufacturing	C	Mining
	D	Manufacturing
	E	Electricity, gas and water supply
Construction	F	Construction
Hotels	G	Wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods
	H	Hotels and restaurants
	I	Transport, storage and communication
Business services	J	Financial intermediation
	K	Real estate, renting and business activities
Public services	L	Public administration and defence; compulsory social security
	M	Education
	N	Health and social work
	O	Other community, social and personal service activities
	P	Activities of households
	Q	Extra-territorial organisations and bodies

Table 7: Sectoral aggregates

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