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Agglomeration effects in Europe

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Abstract

The paper estimates agglomeration effects for France, Germany, Italy, Spain, and the UK. Estimation takes into account endogeneity of the spatial distribution of employment and spatial fixed effects. Empirical results suggest that agglomeration effects in these European countries are only slightly smaller than agglomeration effects in the US: the estimated elasticity of (average) labor productivity with respect to employment density is 4.5 percent compared to 5 percent in the US. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Two of the main explanations for spatial differences in average labor productivity within countries are spatial externalities and increasing returns at the firm level combined with non-tradabilities or transportation costs. Both explanations have been examined in detail for the US.[1] There has not been much empirical work for European countries however. This is quite surprising as spatial differences in average labor productivity within European countries are large; for example, average labor productivity in the manufacturing sector and

[1] For a review of the literature see Henderson (1988) and Fujita (1989). See also Sveikauskas (1975), Segal (1976), Henderson (1986), and Ciccone and Hall (1996).

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service sector in the five most productive German *Kreise* in 1986 was 140 percent higher than in the five least productive *Kreise*. Another reason why the lack of empirical work for European countries is surprising is that many of them collect data at a fine level of geographic detail; for example, regional data on value added for France, Germany, Italy, Spain, and the UK can be found at a level of geographic detail that corresponds roughly to the county level in the US. This allows for a more flexible empirical approach to agglomeration effects with European data than with US data.

This paper combines spatial data on value added for Germany, Italy, France, Spain, and the UK (all other European Community countries lack some of the relevant data) with data on employment and education in order to estimate agglomeration effects. The sample consists of 628 so-called *Nuts 3*-regions, which correspond to *Départements* in France, to *Kreise* in Germany, to *Provincie* in Italy, to *Provincias* in Spain, and to *Counties* in the UK.[2] Estimation is based on two simple models of spatial agglomeration – one based on spatial externalities and the other on non-tradable inputs produced with increasing-returns – which lead to the same reduced-form relationship between employment density and productivity at the local geographic level (Ciccone and Hall, 1996).[3]

The main problem with the estimation of agglomeration effects is that it is difficult to distinguish between two competing explanations for the positive correlation between agglomeration and productivity. First, productivity is high because of agglomeration effects. Second, agglomeration is a consequence – not a cause – of high productivity. Telling these explanations apart is complicated when the econometrician does not observe all the variables that determine total factor productivity. This paper proposes two ways to deal with this problem. First, to include variables that may explain spatial differences in total factor productivity in the empirical analysis. In particular, the relatively large number of observations on value added at the *Nuts 3*-level allows for the inclusion of detailed regional fixed effects in the estimation. The second approach also includes regional fixed effects but additionally uses an instrument for regional employment density at the *Nuts 3*-level. The instrument used is the total land area of *Nuts 3*-regions. It turns out that – controlling for fixed effects at the country level – employment density and total land area are significantly negatively correlated across *Nuts 3*-regions. This is somewhat surprising because the *Nuts 3*-subdivision is historically predetermined – going back to the 19th century at least. The likely explanation for the correlation is that the subdivision was

[2] *Nuts* stands for 'Nomenclature of Territorial Units for Statistics' in French. Section 3 discusses the geographic subdivision of European Community countries in some detail.

[3] The main theoretical difference between models based on spatial externalities and models based on increasing returns at the firm level and non-tradabilities or transportation costs is that models with externalities postulate interdependent production possibility sets.

usually done for administrative purposes. This made equalization of population size a natural criterion. Equalization of population size across *Nuts 3*-regions in turn induced a negative correlation between total land area and employment density, which persisted into modern days. These historical considerations suggest that total land area of *Nuts 3*-regions can be used as an instrument for employment density if the original sources of population agglomeration (being close to a navigable river or a river-crossing for example) affect modern productivity mainly through the legacy of agglomeration.

The empirical results of the paper are easily summarized. There are substantial agglomeration effects in the five European countries in the sample and agglomeration effects do not appear to differ significantly between countries. Least-squares estimates suggest that a doubling of the employment density increases average labor productivity by approximately 5 percent (the standard error of this estimate is 0.45 percent). This estimate is very similar to the value obtained with data on value added across US states (Ciccone and Hall, 1996). Using total land area as an instrument for employment density yields a somewhat lower estimate of 4.5 percent (with a standard error of 0.55 percent). This estimate remains unchanged when spatial externalities across neighbouring *Nuts 3*-regions are taken into account, but falls to 3.4 percent (with a standard error of 0.9 percent) when the share of value added generated in the agricultural sector is included in the empirical analysis.

The remainder of the paper is structured in the following way. Section 2 outlines the model. Sections 3 and 4 describe the data and the estimation procedure. Section 5 summarizes the results and discusses some of the main problems of the approach used in the paper. Section 6 concludes.

2. The basic model

To see how agglomeration effects can be estimated with regional data, it is useful to consider a model with spatial externalitites due to the density of economic activity. It can be demonstrated however that models with non-tradable differentiated inputs produced with increasing returns result in the same estimating equation (Ciccone and Hall, 1996). Denote the production function on an acre of land in region s contained in a country or larger region (defined below) c by

$$q = \Omega_{sc} f(nH, k; Q_{sc}, A_{sc}); \tag{1}$$

q denotes output produced on the acre of land, n the number of workers employed on the acre, H the average level of human capital of workers on the acre, and k the amount of physical capital used on the acre; Ω_{sc} denotes an index of total factor productivity in the region; and Q_{sc} and A_{sc} denote total production and total acreage of the region and will be used to capture spatial externalities. The empirical work assumes that spatial externalities are driven by the density of production in the region Q_{sc}/A_{sc}. This is because density of production – rather than volume – is key when externalities are associated with physical proximity (Ciccone and Hall, 1996). The empirical approach also assumes that the elasticity of output-per-acre with respect to the regional density of production is constant. The specification used is

$$q = \Omega_{sc} f(nH, k; Q_{sc}, A_{sc}) = \Omega_{sc}((nH)^{\beta} k^{1-\beta})^{\alpha} \left(\frac{Q_{sc}}{A_{sc}}\right)^{(\lambda-1)/\lambda}, \tag{2}$$

where $0 \le \alpha \le 1$ captures returns to capital and labor on the acre and $0 \le \beta \le 1$ is a distribution parameter.[4] There are positive spatial externalities in this formulation if and only if $\lambda > 1$.

To go from (2) to an estimating equation at the regional level, it is necessary to assume that labor and capital are distributed equally among the acres in each region. This assumption yields that aggregate production Q_{sc} in each region is implicitly defined by $Q_{sc} = A_{sc} q = A_{sc}\Omega_{sc}((N_{sc}H_{sc}/A_{sc})^{\beta}(K_{sc}/A_{sc})^{1-\beta})^{\alpha}(Q_{sc}/A_{sc})^{(\lambda-1)/\lambda}$ where N_{sc} is total employment in the region, H_{sc} the average level of human capital of workers in the region, and K_{sc} the total amount of physical capital used in the region. Solving for average labor productivity yields

$$\frac{Q_{sc}}{N_{sc}} = \Omega_{sc}^{\lambda}\left(H_{sc}^{\beta}\left(\frac{K_{sc}}{N_{sc}}\right)^{1-\beta}\right)^{\alpha\lambda}\left(\frac{N_{sc}}{A_{sc}}\right)^{\alpha\lambda-1}. \tag{3}$$

To work with an empirically meaningful measure of the density of production, it is necessary to estimate spatial externalities at a fine level of geographic detail. In Europe, this means working at the level of so-called *Nuts 3*-regions (details on the geographic subdivision of European Community countries will be given in the next section). The main disadvantage of working at this level of geographic detail is that there is no data on the quantity of physical capital. This disadvantage can however be dealt with by assuming that the rental price of capital is the same everywhere within a country or larger region (a larger region is simply defined as a region containing several *Nuts 3*-regions). To see this, denote the rental price of capital in country or larger region c with r_c. The capital-demand function in *Nuts 3*-regions in this country or larger region can be derived using (2) as

$$K_{sc} = \frac{\alpha(1-\beta)}{r_c} Q_{sc}. \tag{4}$$

[4] The production function displays either constant ($\alpha = 1$) or decreasing ($\alpha < 1$) returns to capital and labor. The easiest way to see this is to notice that nH stands for $\sum_{z \in E} zn(z)$ where $n(z)$ is the number of workers with human capital z employed and E is the set of levels of human capital available in the labor market.

This capital-demand function can be used to substitute for the amount of capital in (3). Solving for average labor productivity yields[5]

$$\frac{Q_{sc}}{N_{sc}} = \Lambda_c \Omega_{sc}^{\omega} H_{sc} \left(\frac{N_{sc} H_{sc}}{A_{sc}} \right)^{\theta}, \tag{5}$$

where Λ_c depends on the rental price of capital in the country or larger region, ω is some unimportant constant, and

$$\theta = \frac{\alpha\lambda - 1}{1 - \alpha\lambda(1-\beta)}; \tag{6}$$

θ measures the effect of the regional density of employment and human capital on regional productivity. The equation for average labor productivity in (5) can be used to estimate θ without data on physical capital or the rental price of capital. This is because differences in Λ_c across countries or larger regions can be taken into account by allowing for spatial fixed effects at the level of countries or larger regions; θ can therefore be estimated with data on human capital and employment at the regional level only.

To understand the determinants of θ, it is useful to consider some special cases. Suppose first that $\lambda = 1$ and hence that there are no externalities from the density of production in the region. Suppose also that $\alpha = 1$ and therefore that there are constant returns to capital and labor on each acre in the region. In this case (6) yields that $\theta = 0$ and (5) that the density of employment and human capital is irrelevant for productivity across *Nuts 3*-regions. This remains true as long as decreasing returns to capital and labor on each acre $\alpha < 1$ (which can be seen as capturing congestion effects) and positive externalities in the region $\lambda > 1$ balance in the sense that $\alpha\lambda = 1$. Density of employment and human capital will have a positive effect on regional average labor productivity only if positive externalities at the regional level more than offset congestion effects in the sense that $\alpha\lambda > 1$. The expression for θ in (6) also implies that if $\alpha\lambda > 1$, then the greater $1 - \beta$ the greater θ. To understand this implication notice that the assumptions made so far imply that physical capital moves to more productive regions. The effect of an increase in total factor productivity – driven by an increase in the density of employment or human capital – on regional average labor productivity will therefore be reinforced by an inflow of physical capital. This effect will become stronger as $1 - \beta$ becomes greater. When congestion

[5] The fact that average labor productivity (and wages) will be higher in denser regions when $\theta > 0$ raises the question of why some workers would stay in less-dense regions. The simplest answer is that some workers prefer to live in areas that are less-dense (because there may be less congestion, pollution, crime, etc.). Another answer is that the low price of housing compensates workers in low-wage regions, see Fujita (1989) or Ciccone and Hall (1996).

effects dominate positive externalities in the sense that $\alpha\lambda < 1$, then a higher regional density is associated with lower average labor productivity. In the remainder of the paper, θ will be referred to as the *agglomeration effect*.[6]

Taking logarithms of (5) implies

$$\log Q_{sc} - \log N_{sc} \\ = \log \Lambda_c + \theta(\log N_{sc} - \log A_{sc}) + (\theta + 1)\log H_{sc} + \omega \log \Omega_{sc}. \quad (7)$$

This yields the equation that will be estimated,

$$\log Q_{sc} - \log N_{sc} = \text{Country/Regional Dummies} \\ + \theta(\log N_{sc} - \log A_{sc}) + \sum_{e=1}^{E_c} \delta_{ec} F_{esc} + u_{sc}, \quad (8)$$

where u_{sc} captures differences between exogenous total factor productivity in region sc and the country or larger region that contains region sc; F_{esc} denotes the fraction of workers with level of education e in region s in country c; E_c denotes the number of education levels for which there is data in country c; and δ_{ec} the effect of education level e on productivity in country c. Country/Regional Dummies denotes dummies that will be included to control for differences in exogenous total factor productivity and rental prices of capital between different countries as well as different regions in the same country. The main difference between the estimating equation in (8) and the estimating equation in Ciccone and Hall (1996) is that the estimating equation used here is more flexible in two respects. First, it allows for dummies at the country and regional level. Second, it allows for different education levels to enter in different ways. This more flexible approach is possible because European data on value added is available at a much finer level of geographic detail than US data.

Notice that the estimating equation in (8) cannot be used to estimate the strength of spatial externalities. To get an idea of the magnitude of $(\lambda - 1)/\lambda$, it is possible to use the following approach. Under the assumption of perfect competition, $1 - \alpha$ is equal to the income share of land used in the manufacturing sector and service sector, while $\alpha(1 - \beta)$ is the income share of physical capital. With data on these income shares and θ, it is therefore possible to calculate $(\lambda - 1)/\lambda$ as

$$\frac{\lambda - 1}{\lambda} = 1 - \frac{\alpha + \alpha(1 - \beta)\theta}{1 + \theta}. \quad (9)$$

[6] A better but longer name would be *net agglomeration effect*. This terminology would make explicit that the effect of agglomeration on productivity depends on congestion effects on the one hand and (positive) externalities on the other.

2.1. Externalities across neighboring regions

So far, the model captures spatial externalities within *Nuts 3*-regions only. There is no reason to believe however that spatial externalities do not extend beyond these regions. This is why it is desirable to allow for spatial externalities in each *Nuts 3*-region to be partly driven by the density of production in neighboring *Nuts 3*-regions. To see how this can be done in a simple way, assume that total factor productivity Ω_{sc} in region *sc* depends on the density of production in neighboring regions,

$$\Omega_{sc} = \Phi_{sc}\left(\frac{Q_{scn}}{A_{scn}}\right)^{\mu}; \tag{10}$$

Φ_{sc} denotes exogenous total factor productivity in region *sc*, and Q_{scn} and A_{scn} denote total production and total acreage in neighboring *Nuts 3*-regions. Combining (10) with (7) and (8) yields the augmented estimating-equation

$$\begin{aligned}\log Q_{sc} - \log N_{sc} = {} & \text{Country/Regional Dummies} \\ & + \omega\mu(\log Q_{scn} - \log A_{scn}) + \theta(\log N_{sc} - \log A_{sc}) \\ & + \sum_{e=1}^{E_c} \delta_{ec} F_{esc} + u_{sc}. \end{aligned} \tag{11}$$

This estimating equation allows for estimation of spatial externalities within *Nuts 3*-regions and across neighboring *Nuts 3*-regions.

3. Data

It has already been said that estimation of the model requires data on value added, as well as data on employment and education, at a detailed regional level. Data on value added at factor costs and salaried employment at the regional level for Germany, Italy, France, Spain, and the UK is available from the *Regio*-database assembled by *Eurostat* (1992). *Eurostat* divides each European Community country into *Nuts 1*-regions, each *Nuts 1*-region into *Nuts 2*-regions, and each *Nuts 2*-region into *Nuts 3*-regions. *Nuts 1*-regions correspond to *Zeat* in France, to *Länder* in Germany, to *Gruppi di Regioni* in Italy, to *Agrupaciones de Communidades Autonomas* in Spain, and to *Standard Regions* in the UK. *Nuts 2*-regions correspond to *Régions* in France, to *Regierungsbezirke* in Germany, to *Regioni* in Italy, to *Communidades Autonomas* in Spain, and to *Groups of Counties* in the UK. Finally, *Nuts 3*-regions correspond to *Départements* in France, to *Kreise* in Germany, to *Provincie* in Italy, to *Provincias* in Spain, and to *Counties* in the UK.[7] The model requires data on non-agricultural, private value added as neither the role of government nor the role of agriculture are dealt with. *Regio* contains data on employment and value added in manufacturing and services at the *Nuts 3*-level for France, Germany, and Spain. For Italy and the UK, there is data on employment in manufacturing and services at the *Nuts 3*-level. But value added in manufacturing and services is only available at the less geographically detailed *Nuts 2*-level; at the *Nuts 3*-level, there is data on *total* value-added (the sum of value added in manufacturing, services, and agriculture). Value added in manufacturing and services at the *Nuts 3*-level in Italy and the UK had to be constructed using the following procedure. First, agricultural average labor productivity at the *Nuts 2*-level was calculated by dividing agricultural value added at the *Nuts 2*-level by agricultural employment. Second, value added in manufacturing and services at the *Nuts 3*-level was calculated by subtracting agricultural employment at the *Nuts 3*-level multiplied by agricultural average labor productivity at the corresponding *Nuts 2*-level from total value added at the *Nuts 3*-level. The data on valued added and employment is only available for a few years in the late 1980s for each country, and years available differ by country. Estimation therefore uses data on different years for different countries.[8] The data on education of the labor force comes from census sources and also varies by level of geographic detail. For most countries, there is data on the fraction of the population with one of six to eight education levels at the *Nuts 3*-level. The UK has the worst data on education as there is data on five education levels at the *Nuts 1*-level only.[9]

The data on regional value added shows that regional differences in average labor productivity within European countries are large. For example, average labor productivity in the five most productive German *Kreise* is 140 percent higher than in the five least productive *Kreise*; average labor productivity in the five most productive French *Départements*, Italian *Provincie*, and Spanish *Provincias* is approximately two-thirds higher than in the five least productive *Départements*, *Provincie*, and *Provincias*; and average labor productivity in the five most productive *Counties* is approximately one-third higher than average labor productivity in the five least productive *Counties*.[10]

[7] The median size of *Nuts 3*-regions in these countries is 1511 km^2. This is somewhat smaller than the median size of US counties.

[8] The data used for France is from 1988, the data used for Germany and Spain from 1986, and the data for Italy and the UK from 1987.

[9] For the French education data see Pissarides and Wassmer (1997), for the German data see *Volkszählung* (1987) and Seitz (1995), for the Italian data see *Censimento Generale della Popolazione Generale* (1991), for the Spanish data see Pérez (1996), and for the data for the UK see the *Labor Force Survey* (1996).

[10] Descriptive statistics for *Nuts 3*-regions are given in the appendix.

4. Estimation

Estimation of (8) will always control for fixed effects at the country level. Furthermore, regional fixed effects at the *Nuts 1*-level and *Nuts 2*-level will also be taken into account (there are on average five *Nuts 3*-regions per *Nuts 2*-region). These fixed-effects will pick up differences in productivity associated with a particular country, *Nuts 1*-region, or *Nuts 2*-region. They will also pick up differences in the physical capital intensity due to differences in the rental price of capital. The elasticity of average labor productivity with respect to employment density and all other parameters in (8) will be estimated conditional on whatever regional fixed effects are included in the empirical analysis.

The paper takes two approaches to estimate agglomeration effects. The first consists of least-squares (LS) estimation. This approach yields inconsistent estimates if regional fixed effects do not capture exogenous differences in total factor productivity across *Nuts 3*-regions and if *Nuts 3*-regions with higher exogenous total factor productivity attract more workers. To obtain consistent estimates under these circumstances, the paper also estimates agglomeration effects using an instrumental-variables approach. This requires identifying a characteristic of *Nuts 3*-regions that is unrelated to modern exogenous total factor productivity but correlated with employment density. The characteristic used here is total land area of *Nuts 3*-regions. Total land area is a historically predetermined variable and therefore not affected by modern differences in exogenous total factor productivity: the French *Départements* go back to 1789; the German *Kreise* to 1872–1884: the Italian *Provincie* to 1861; the Spanish *Provincias* to 1833; and the *Counties* in the UK to 1835–1888.[11] Despite being historically predetermined, total land area of *Nuts 3*-regions is negatively correlated with modern differences in employment density. It has already been said that this is probably because the *Nuts 3*-subdivision served administrative purposes – making the equalization of population size a natural criterion. Hence, total land-area of *Nuts 3*-regions can be used as an instrument for employment density if the original sources of population agglomeration do not affect modern exogenous total factor productivity.

To get a sense of the quality of total land area as an instrument for employment density in the late 1980s, it is useful to regress employment density at the *Nuts 3*-level on dummies for *Nuts 2*-regions and total land area at the *Nuts 3*-level. The R^2 of this regression is 80 percent, and the coefficient on land area is significantly negative at the 0.1-percent level. Dropping land area at the *Nuts 3*-level as an explanatory variable lowers the R^2 of this regression to 52 percent.

[11] See *La Grande Encyclopédie Larousse* (1973) for France, the *Brockhaus Enzyklopädie* (1990) for Germany, the *Encyclopedia Italiana* (1935) for Italy, Guaita (1975) for Spain, and the *Encyclopaedia Britannica* (1973) for the UK. There have, however, been several changes in the administrative and political role played by these *Nuts 3*-regions.

5. Results

Tables 1–3 summarize the estimates of agglomeration effects obtained by implementing the estimating equation in (8) at the *Nuts 3*-level for France, Germany, Italy, Spain, and the UK. Table 1 contains the LS and two-stage least-squares (2SLS) estimates of θ with education controls and country dummies but without regional fixed effects. The LS-estimate of θ is 5.1 percent with a White-adjusted standard error of 0.42 percent. This estimate is very close to the 5.2 percent estimated for the US using the same approach at the state level (Ciccone and Hall, 1996). Agglomeration effects, education, and country dummies explain 64 percent of the variation in productivity across European

Table 1
Results for France, Germany, Italy, Spain, and the UK with education controls and country dummies

	LS	2SLS
Estimate of θ	5.058%	4.55%
Standard error	(0.417%)	(0.507%)
	$R^2 = 63.6\%$	—

Note: Estimating equation in (8). All standard errors are White adjusted.

Table 2
Results for France, Germany, Italy, Spain, and the UK with education controls and *Nuts 1*-region dummies

	LS	2SLS
Estimate of θ	5.07%	4.445%
Standard error	(0.452%)	(0.55%)
	$R^2 = 66.93\%$	—

Note: Estimating equation in (8). All standard errors are White adjusted.

Table 3
Results for France, Germany, Italy, Spain, and the UK with education controls and *Nuts 2*-region dummies

	LS	2SLS
Estimate of θ	4.97%	4.444%
Standard error	(0.492%)	(0.592%)
	$R^2 = 72.5\%$	—

Note: Estimating equation in (8). All standard errors are White adjusted.

regions. The 2SLS-estimate of θ is 4.6 percent with a White-adjusted standard-error of 0.51 percent. The fact that the 2SLS-estimate is somewhat lower than the LS-estimate suggests that there may be a (minor) endogeneity problem when Eq. (8) is estimated using LS.

Differences in agglomeration effects across countries can be tested for by allowing θ in the estimating equation in (8) to vary by country. The 2SLS estimate of θ for Germany – which will be the benchmark – is 4.8 percent with a standard error of 0.63 percent. Point estimates of the difference in agglomeration effects between France and Germany on the one hand and Spain and Germany on the other are 0.06 percent and 0.3 percent respectively, with standard errors of 1.4 percent and 2.5 percent. The point estimate of the difference in agglomeration effects between Germany and the UK is 3.2 percent with a standard error of 1.8 percent; the point estimate of the difference between Germany and Italy is -2.5 percent with a standard error of 2.5 percent. Hence, there is no evidence that agglomeration effects differ significantly between countries. LS estimates yield a similar pattern.

Table 2 contains the LS estimate and 2SLS estimate of θ with education controls and regional fixed effects at the *Nuts 1*-level. The table indicates that the LS estimate of θ remains basically unchanged when dummies for *Nuts 1*-regions are included in the estimation. The adjusted R^2 goes from 62.3 percent with country dummies only to 63.8 percent with dummies for *Nuts 1*-regions. The hypothesis that the dummies for *Nuts 1*-regions do not enter the estimating equation in (8) can be rejected at the 5-percent significance level.

Differences in agglomeration effects across countries conditional on fixed effects at the *Nuts 1*-level can be tested for by allowing θ to vary by country and – at the same time – including dummies for *Nuts 1*-regions in (8). The results are basically identical to the case with country dummies only.

Table 3 contains the LS estimate and the 2SLS estimate of θ with education controls and regional fixed effects at the *Nuts 2*-level. The table indicates that the inclusion of *Nuts 2*-region dummies does not affect estimates of θ in a significant way. The adjusted R^2 of the LS-regression is 65.4 percent; the hypothesis that the dummies for *Nuts 2*-regions do not enter the estimating equation in (8) can be rejected at the 5-percent significance-level.

The test for differences in agglomeration effects across countries yields similar results to the case with country-dummies only, indicating that there are no significant differences in agglomeration effects across countries.

Finally, estimates of agglomeration effects can be combined with estimates of the income share of physical capital and land used in the manufacturing sector and service sector to obtain an estimate of $(\lambda - 1)/\lambda$ in (9). The value of the capital-income share is taken to be 30 percent as usual. Estimating the income share of land is more difficult. The lack of data for Europe makes it necessary to use the value of 1.5 percent that Ciccone (1997) argues is reasonable for the US.

These values combined with a 4.5 percent estimate of θ yield an estimate of $(\lambda-1)/\lambda$ of 4.4 percent. This estimate varies between 4 and 5 percent for reasonable variations in the income share of physical capital and land.

5.1. Agricultural land use and agglomeration

One of the problems of the analysis so far is that it is assumed that the density of production is the same throughout each *Nuts 3*-regions. There is little that can be done about this because there is no data on the distribution of production within *Nuts 3*-regions. The assumption is especially unrealistic because *Nuts 3*-regions differ in the extent in which land is used for agricultural production. One way to resolve this problem would be to use non-agricultural employment per non-agricultural acre in *Nuts 3*-regions in the estimating equation in (8). Unfortunately, there is no data on land used for agricultural purposes at the *Nuts 3*-level. An alternative approach that seems useful given the lack of such data is to include the share of total value added generated in the agricultural sector at the *Nuts 3*-level as an additional explanatory variable in the estimating equation in (8).[12] The problem with this approach is that the share of agriculture is most likely related to unobserved determinants of exogenous productivity and that there is no instrument available. Including the share of agriculture in total value added – together with dummies for *Nuts 2*-regions – as an explanatory variable in the estimating equation in (8) yields that the 2SLS estimate of θ falls to 3.4 percent with a standard error of 0.9 percent. Estimation also yields that a 1-percent increase in the share of agriculture in total value added reduces average labor productivity in manufacturing and services by 0.9 percent with a standard error of 0.3 percent.

5.2. Externalities across neighboring regions

Externalities across neighboring *Nuts 3*-regions can be estimated by empirically implementing (11). Implementation must take into account that the density of production of neighbors in (11) is an endogenous variable. It is therefore necessary to use an instrumental-variables approach. The instrument used for the density of production in neighboring *Nuts 3*-regions is the arithmetic average of the land area of neighboring *Nuts 3*-regions. Estimation of (11) with 2SLS using dummies for *Nuts 2*-regions yields the following results: θ equal to 4.4 percent with a standard error of 1 percent and $\omega\mu$ equal to 3.3 percent with a standard error of 1.3 percent. Hence, the estimate of agglomeration effects within *Nuts 3*-regions remains basically unaffected by the inclusion of the density

[12] I thank the referees for raising this issue and suggesting this solution.

of production of neighbors. Production in neighboring regions does however have a significant effect on regional productivity.

6. Summary and conclusions

The paper has estimated regional agglomeration effects for France, Germany, Italy, Spain, and the UK. The empirical results suggest that agglomeration effects in these European countries are only slightly lower than in the US and do not vary significantly across countries.

One of the questions requiring further research is the effect of agglomeration on industry structure. It seems reasonable to suspect that productivity gains in dense regions are partly realized through a change in industry structure. One of the reasons for this change in industry structure is probably that externalities are stronger in some industries that in others (Henderson, 1974). Furthermore, increasing returns and transportation costs also differ across industries. Addressing this question requires detailed and comparable data on the industry structure of regions in different European countries. Such data is not yet available. It would also be interesting to use the estimates of agglomeration effects to assess the consequences of European economic integration for aggregate productivity. It has been argued that European economic integration may increase the degree of spatial specialization in Europe, bringing it closer to the pattern in US (Krugman, 1993). This reasoning may also apply to the degree of spatial agglomeration. The estimates of agglomeration effects in this paper suggest that this would increase aggregate productivity. Whether this effect is economically significant is an open question.

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Appendix

The median size of the *Nuts 3*-regions in the sample is 1511 km^2 (for comparison, the median size of US counties in 1623 km^2). The average size of the *Nuts 3*-regions in the sample is 3099 km^2 and the standard deviation is 3585.

Tables 4–8 give descriptive statistics country by country.

Table 4
Nuts 3-level descriptive statistics for France

	Median	Mean	Standard deviation
Productivity (1988)	33.6	34.5	3.6
Employment (1988)	151	190	150
Area	5999	5875	1680

Note: 'Productivity' stands for average labor productivity in the manufacturing sector and service sector and is measured in millions of 1988-ECUs. 'Employment' stands for employment in the manufacturing sector and service sector and is measured in thousands of workers. 'Area' stands for the total land area and is measured in square kilometers.

Table 5
Nuts 3-level descriptive statistics for Germany

	Median	Mean	Standard deviation
Productivity (1986)	31.4	32.5	5.7
Employment (1986)	54	81	93
Area	736	745	491

Note: See Note of Table 4.

Table 6
Nuts 3-level descriptive statistics for Italy

	Median	Mean	Standard deviation
Productivity (1987)	30.4	30.3	3.7
Employment (1987)	148	216	256
Area	2756	3132	1678

Note: See Note of Table 4.

Table 7
Nuts 3-level descriptive statistics for Spain

	Median	Mean	Standard deviation
Productivity (1986)	22.2	22.4	3.2
Employment (1986)	118	193	273
Area	10287	10478	4683

Note: See Note of Table 4.

Table 8
Nuts 3-level descriptive statistics for the UK

	Median	Mean	Standard deviation
Productivity (1987)	23.3	23.7	1.6
Employment (1987)	259	381	513
Area	2631	3561	3767

Note: See Note of Table 4.

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