Labor Productivity, Infrastructure Endowment, and Regional Spillovers in the European Union

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Abstract

This paper assesses whether disparities in regional public infrastructure endowments can explain regional disparities in labor productivity among European regions. Using a large sample of European regions, I distinguish the effects of overall infrastructure endowment from the effect of three categories of public infrastructure (transport network, energy provision and telecommunication network). When I control for a time trend and regional-specific effects, only the overall infrastructure endowment and telecommunication network boost regional labor productivity. I find evidence of spatial autocorrelation in labor productivity for contiguous regions and regions with identical levels of income per capita. When I control for spatial dependence, only the overall infrastructure index maintains its positive effect on regional productivity. The statistical results do not provide evidence of quantitatively important productivity spillovers.

- *Keywords*: infrastructure, European Union, regional disparities, regional policy, labor productivity
- *JEL Codes*: R10, O18, O11, O52

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1 Introduction

Since the 1990s, the effect of public infrastructure on output and productivity has received a lot of attention from policymakers and scholars. Research on the relationship between infrastructure and productivity was revived by several publications by David Aschauer. The estimates presented in Aschauer (1989b) indicate that output elasticity to public infrastructure is larger than the output elasticity to private capital. The validity of this estimation was soon questioned because of econometrical flaws. Because Aschauer's analysis indeed did not control for other determinants of output, nor for trend or fixed effects, the estimated coefficients could be due affected by spurious correlations. Most of the subsequent econometric investigations have been aimed at gaining consensus about the extent of the effect of public capital, but the question remains contentious. Romp and de Hann (2005), Musolesi (2002), de la Fuente (2000), and Gramlich (1994) provide complementary overviews of the literature on this topic.

Once fixed effects and time trend are accounted for, the estimated coefficient on infrastructure becomes much smaller, or loses its significance (Holtz-Eakin (1994), Garcia-Milà and McGuire (1992)). The sign and magnitude of this impact vary significantly with the estimation method used (estimating aggregate production functions where public infrastructure enters as an input, or by estimating cost function), and the disaggregation level of the data used. The effect of public infrastructure on output is usually larger in studies using data aggregated at a national level (Aschauer (1989b), Munnell (1992), Aschauer (1989a)) than at a more regional level (Picci (1999), Acconcia and Monte (1999), and Bronzini and Piselli (2006) for Italian regions, Cantos et al. (2002) and Boscá et al. (2002) for Spanish regions, Martin and Rogers (1995), Martin (1998) and Basile et al. (2001) for a panel of European regions, and Holtz-Eakin (1994) for US states).

Providing more evidence on the relationship between the stock of public infrastructure and regional labor productivity is of practical importance for the European Union (EU). Considering that more than a third of the funds allocated through EU regional policy finances infrastructure projects, the policy's overall success is contingent on the economic benefits of these infrastructure investments. The efficacy of the policy can therefore be assessed by checking whether infrastructure endowments have been key factors to explain regional disparities in labor productivities.

This paper further investigates the productivity elasticity to public infrastructure using a sample of European regions and panel data estimation techniques[1]. In addition to the overall impact of infrastructure on labor productivity, the availability of disaggregated endowment indices for transport network, energy supply and telecommunication networks allows to distinguish the effect of these core infrastructures, and therefore to test whether EU regional policy supports the infrastructure category(ies) that is (are) the most critical for labor productivity.

This paper also considers the existence of interregional spillovers and spatial dependence. Despite the vast interest for the impact of infrastructure on regional economies, the presence of spatial dependence and of productivity spillovers has been much less explored[2], even though their presence would bias output elasticity obtained with OLS estimations. I implement two spatial adaptations - adding a spatial lag in the theoretical model, and allowing for spatial autocorrelation in the error term.

To anticipate the outcome, regional overall infrastructure endowment positively affect regional productivity, which can be explained only partially by the effect of telecommunication network. Finally, despite strong productivity spatial dependence, I find only weak evidence on infrastructure-induced productivity spillovers.

The remainder of the paper is organized as follows. Section 2 briefly presents

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[1] While several papers have used Spanish regional data to carry out a panel data analysis (see de la Fuente (2000)), papers using larger samples of European regions usually carry out cross-section analysis (see Martin and Rogers (1995), Martin (1998) or Basile et al. (2001)).

[2] Holtz-Eakin and Schwartz (1995), Boarnet (1998), and Cohen and Paul (2004) examine the existence of spillovers in the US interstate highways system.

EU regional policy and the its focus on infrastructure projects. Section 3 describes the theoretical framework used in this paper. Section 4 presents the data used and some summary statistics that highlight substantial disparities in infrastructure endowments among European regions. Section 5 discusses the econometrics methods used to control for spatial dependence. Section 6 presents the estimation of the productivity elasticity to private inputs and public infrastructure, as well as estimation of interregional productivity spillovers. Section 7 provides some concluding remarks and policy implications.

2 Infrastructure and European Regional Policy

Since the endorsement of the Maastricht Treaty in 1992, one of the European Union's priorities has been to promote economic and social cohesion among and within its member states. In two reports on economic and social cohesion (European Commission (2001) and European Commission (2005)), the European Commission points out that adequate endowment in infrastructure constitutes a necessary but not sufficient condition to guarantee regional economic development and competitiveness. Because the provision of infrastructure networks is often subject to market failure, the European Union has made one of its priorities to develop European networks of transport, energy and telecommunication infrastructures, which led notably to the development of Trans-European Networks (Vickerman (1996)). The interest for infrastructure networks also coincided with the advancement of the Single Market project. Freedom of movement for goods, persons and services indeed required the various regional and national networks making up that market to be properly linked by modern and efficient infrastructure networks.

The European Union has consequently devoted a substantial fraction of its regional policy funding (known as the Structural Funds) to the financing of infrastructure projects, especially in the least prosperous member states, also known as the Cohesion countries[3]. Over the 1975-1989 period, infrastructure projects accounted for 75% of European Regional Development Fund expenditure, one of the programs of EU regional policy (Vickerman (1995)). During the 2000-2006 Structural Funds program, 34.3% of the funds were used for infrastructure investment projects in Objective 1 regions[4] (Table 1). Among the different infrastructure networks, transport infrastructures remain the principal investment target of the European regional policy. As indicated in Table 2, the EU has spent 50% of the Cohesion Funds on transport infrastructure projects. Moreover, among the different categories of transport infrastructures, 57% of the expenditure support road investment projects (Figure 1).

Given EU regional policy's focus on infrastructure projects, its success is contingent on the impact of infrastructures on regional economies.

Table 1: Structural Funds by Broad Area of Intervention in Objective 1 Regions as % of total Expenditure

	1989-1993	1994-1999	2000-2006
Infrastructure	35.2	29.8	34.3
Human Resources	29.6	24.5	23.9
Productive Environment	33.6	41.0	34.8
Other	1.6	4.7	7.0

Source: European Commission (2001)

Table 2: Cohesion Funds: Allocation by Type of Expenditure, 1994-1999

	Transport % of Total	Total Millions of €
Greece	51.2	2,998
Spain	49.7	9,251
Ireland	50.0	1,495
Portugal	48.1	3,005
Total	49.7	16,761

Source: European Commission (2001)

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[3] The Cohesion Funds are allocated to countries whose gross national product per capita is below 90% of the EU-average.

[4] Objective 1 regions have incomes per capita lower than 75% of the European average income per capita.

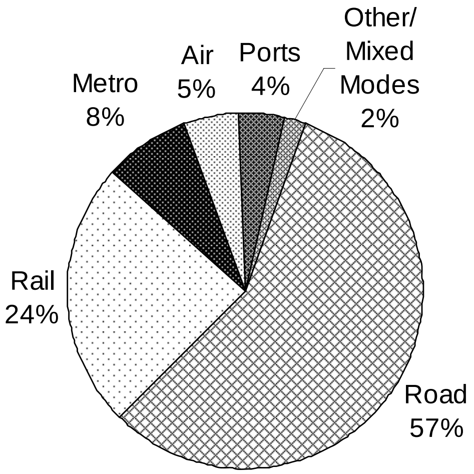

Figure 1: Breakdown of Expenditure on Transport Infrastructures, 1994-1999 (*Source: European Commission (2001)*)

3 Conceptual Framework

The model developed below sketches the effects of infrastructure endowments on labor productivity in a two-regions framework. Regions produce an identical good, using labor and capital stock as inputs. Their output is sold at price p. In this model, public infrastructure is assumed to be complementary to labor and private capital stock.

$$Y_{i,t} = A_{i,t} f(L_{i,t}, K_{i,t}) g(G_{i,t}) \tag{1}$$

where $A_{i,t}$ is the Hicks-neutral level of technology, $K_{i,t}$ is the private capital stock, $L_{i,t}$ the labor force. $G_{i,t}$ is the public capital stock, and can be taken as regional infrastructure endowment. The following conditions are met:

$$g'(G_{i,t}) > 0$$

$$f_K > 0,\ f_{KK} < 0$$

$$f_L > 0,\ f_{LL} < 0$$

If markets are perfectly competitive and factors of production are mobile across regions, the demand for each input is given by their respective marginal revenue products:

$$w_{i,t} = pA_{i,t} f_L(L_{i,t}, K_{i,t}) g(G_{i,t}) \tag{2}$$

$$r_{i,t} = pA_{i,t} f_K(L_{i,t}, K_{i,t}) g(G_{i,t}) \tag{3}$$

where w and r are respectively the price of labor and private capital stock.

To see how a change in regional infrastructure endowment affects both regions, let consider, as in Boarnet (1998), that region i experiences an increase in its infrastructure endowment. Initially, let assume that both regions have similar endowments in labor, private capital stock, and public infrastructure. From Equations 2 and 3, the prices of labor and private capital increase in region i as a result of the increase in G_i. Owing to free mobility of the factors of production, labor and capital will move from region j to region i. Consequently, output increases in the region with the larger infrastructure endowment, and decreases in the other (region j).

This scenario clearly suggests that, if factors of production are mobile across regions, one might observe negative interregional spillovers associated with regional infrastructure endowments. This is more likely to concern infrastructures the benefits of which are local (such as medical facilities and airports). These infrastructures are often referred to as “point infrastructures”. Yet, the benefits of some infrastructures (called “network infrastructures”) radiate beyond the borders of the financing region, which suggests the possibility of positive spillovers for this type of infrastructures. Positive spillovers occur when infrastructures are built in networks, and any component of one network is subordinate to the entire network (Moreno and López-Bazo (2003)).

Consequently, the analysis of the effects of public infrastructure on regional productivity should account for the possible existence of interregional spillovers. Munnell

(1992) indeed notes that, "as the geographic focus narrows, the estimated impact of public capital becomes smaller. The most obvious explanation is that, because of leakages, one cannot capture all of the payoff to an infrastructure investment by looking at a small geographic area." By using smaller administrative units data (such as NUTS2 or 3[5] regions in Europe), the researcher is likely to lose the potential backward and forward linkages among regions. In the analysis presented in Section 6, I check whether regional infrastructure stocks provide productivity benefits beyond a region's borders.

To account for these possible spillovers, the production function in Equation 1 is extended to include the infrastructure endowments of other regions:

$$Y_{i,t} = A_{i,t} f(L_{i,t}, K_{i,t}) g(G_{i,t}, G_{J,t}) \tag{4}$$

where $G_{J,t}$ is the infrastructure endowments of J other regions. Positive interregional spillovers would imply that $\frac{\partial G}{\partial G_J} > 0$, and negative spillovers would imply that $\frac{\partial G}{\partial G_J} < 0$.

4 Data

The data on Gross Value Added, Employment, and Investment Expenditure are obtained from Cambridge Econometrics. The data on capital stock are computed using investment expenditures (in constant 1995 euros) series provided by Cambridge Econometrics and the intertemporal method[6].

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[5] The Nomenclature of Territorial Units for Statistics (NUTS) was established by Eurostat in order to provide a uniform breakdown of territorial units for the production of regional statistics for the European Union.

[6]

$$K_{0,j} = \frac{I_{0,j}}{g_j + \delta_j} \tag{5}$$

where $K_{0,j}$ is the initial level of capital stock, $I_{0,j}$ is the initial level of investment for region j, δ_j is the depreciation rate and g_j the average growth rate of investment expenditure during the five first years. We assume that the growth rate of investment during these 5 years is representative of

Infrastructure data are collected from different sources, notably from two reports commanded by the European Commission (Commission (1982), ECOTER (1999)). Observations are available for an overall index for the following four years: 1970, 1978, 1985, and 1995. Data for infrastructure subcategories - transport, telecommunication, and energy- are not available for 1985.

Data are available for regions from 8 European countries: Belgium, France, Germany, Greece, Italy, Portugal, Spain and the UK. The data set is missing some observations for regions from Belgium, Greece, Portugal and Spain. This issue is later addressed in the robustness checks presented in Section 6. The level of regional disaggregation is chosen for each country depends on data availability and also on the level at which regions benefit from a certain administrative autonomy. The panel analysis is carried out on NUTS1 regions from Belgium, the UK and Germany and on NUTS2 regions from the 5 other countries.

Infrastructures are measured in physical terms, rather than in monetary terms. Each region's endowment is then normalized relative to the corresponding maximum value. As noted in Biehl (1991), monetary figures do not provide unequivocal information of the infrastructure capacity of a region, because the construction costs might vary with regions' landscapes. Romp and de Hann (2005) note several other reasons why many recent studies employ physical measures of infrastructure rather than monetary measures. First, the level of infrastructure expenditure may say little about the efficiency in implementing the projects (see Golden and Picci (2005) for Italian regions.) Second, the use of the perpetual inventory method to compute the public infrastructure stock might not be appropriate when the infrastructures are built in networks. Yet, when one uses physical measures of infrastructures, it is

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the growth rate of investment prior to the beginning of the series. The depreciation rates are based upon Hulten (1981). Following Young (1995), I derive the overall depreciation rate of each country as the weighted average of the depreciation rates of two broad categories of assets (equipment and structures). The weights are obtained according to the share of both categories in the country's total real capital stock. These data are obtained from OECD (1998).

important to keep in mind that they are not adjusted for quality.

Each infrastructure category is scaled by population if it is a “population-serving” infrastructure (such as telecommunication infrastructure) or by area if it is an “area-serving” infrastructure (like transport infrastructure). Thus, each variable captures regional relative capacity. For each year, a region’s infrastructure endowment is expressed relative to the infrastructure level of the most endowed region. More details on the data are available in Appendix A.

Table 3 provides some insights about the levels of disparities in labor productivity and infrastructure endowments. Variables are here all expressed relative to the maximum value in a given year before the average was taken. The maximum values displayed in the table do not always equal 100, because a single region has not enjoyed the best endowment in infrastructure in each year included in the sample. Infrastructure endowment disparities have been much larger for transport and energy infrastructure than for telecommunication networks. Regional disparities are also quite substantial in terms of capital stock per worker.

Table 3: Descriptive Statistics

	Mean	Standard Deviation	Minimum	Maximum
Levels: average value[7] for the period covered in the study				
labor productivity	57.30	18.75	19.55	97.92
capital stock per worker	7.88	14.32	0.10	100.00
Infrastructure index	33.65	14.90	10.73	82.99
Transport	21.58	15.64	2.24	86.93
Energy	21.01	17.65	0.00	88.27
Telecommunication	54.67	17.39	18.39	100.00

5 Econometric Issues

As noted in Section 3, labor productivity is likely to be spatially correlated across regions. This spatial dependence is part of the model developed above, but can also arise from a mismatch between the spatial units of the observations used in this paper (NUTS1 and NUTS2) and the spatial dimension of the economic variables presently studied (Anselin and Bera (1998)). This mismatch could result in spatial measurement errors and spatial autocorrelation between these errors among neighboring regions. Spatial autocorrelation in the error term would invalidate standard tests based on OLS estimations. The results would also suffer from an omitted variable bias. Spatial autocorrelation can also arise from common shocks and interregional spillovers of infrastructure networks. Consequently, the analysis of the effects of public infrastructure on regional productivity should account for the possible existence of interregional spillovers.

To study spatial dependence across regions, it is imperative to identify the factors of this dependence in the data. The selection of these factors remains quite arbitrary. The traditional approach relies on the notion of regional contiguity, designating as neighbors regions who share a common border. More formally, this gives rise to a binary symmetric matrix where the off-diagonal elements of the weight matrix $\mathbf{W}$, $w_{i,j} = 1$ when regions i and j have a common border, and $w_{i,j} = 0$ otherwise.

Other spatial weights specifications are possible. Weights can be based socio-economic characteristics, and measure the economic distance between regions (Case et al. (1993), Boarnet (1998)). The alternative definitions of $\mathbf{W}$ used in this paper are similar to those used in Boarnet (1998). These matrices measure how regions compete for mobile factors of production (as presented in Section 3). In this sense, neighboring regions are substitute locations for production, and do not need to share a border. The general formula used to construct these different matrices is:

$$w_{i,j} = \frac{1}{|X_i - X_j|} \tag{6}$$

These new matrices are also symmetric. Four regional characteristics are used in the above formula:

- $W_{popdensity}$: X_i = population density per squared meters in region i in 1987
- W_{income}: X_i = real per capita income in region i in 1987
- $W_{service}$: X_i = share of total employment in the service sector in region i in 1987
- $W_{manufacture}$: X_i = share of total employment in the manufacturing sector in region i in 1987

Spatial autocorrelation can be included in the empirical analysis in two ways: a functional relationship between the dependent variable y, or error term, ε, and its associated spatial lag, respectively Wy, and $W\epsilon$. The first strategy thus consists on controlling for spatial lag dependence, by including a weighted average of the values of the dependent variable in neighboring locations:

$$y = \rho W y + X\beta + \varepsilon \tag{7}$$

where W is an N by N matrix positive and symmetric matrix which expresses for each regions those regions that are defined as its neighbors. ρ is the spatial autoregressive parameter. This parameter measures the interregional spillovers described in Section 3. $(Wy)_i$ is always correlated not only with ε_i but also with the other error terms of other locations. OLS estimation is therefore inconsistent and biased.

A second way to control for spatial dependence is to specify a spatial disturbance process, by using a spatial autoregressive process in the error term:

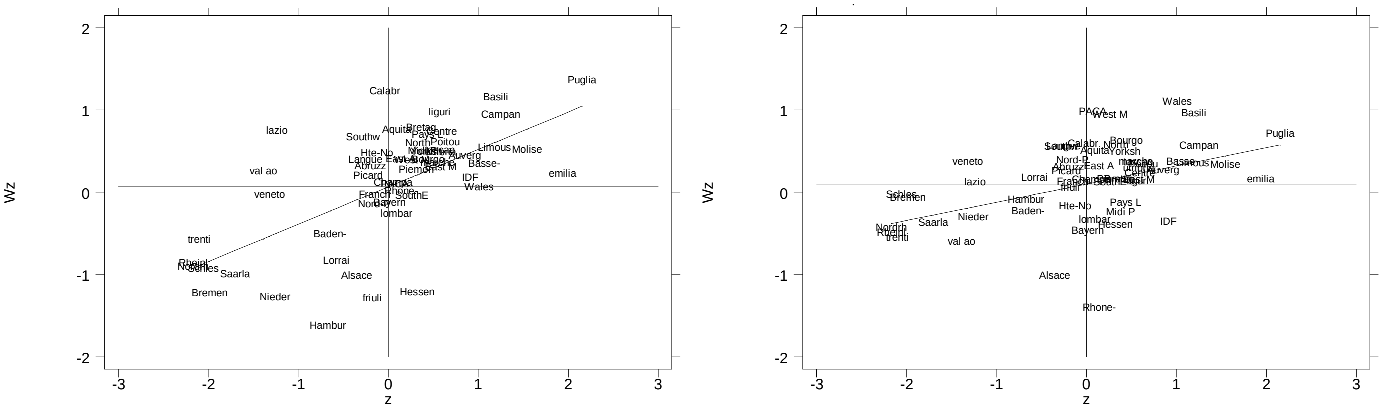
$$\varepsilon = \lambda W \varepsilon + \xi \tag{8}$$

where λ is the spatial autoregressive coefficient on $W\epsilon$, and ξ is an uncorrelated error term. The spatial autoregressive coefficient should be interpreted as a nuisance parameter (Anselin and Bera (1998)). Under this model, OLS estimate is unbiased and inefficient. The spatial dependence model will therefore be estimated using Maximum Likelihood Estimation (MLE).

The presence of spatial dependence can be tested by computing the Moran's I statistics which is given by

$$I = \frac{e'We}{e'e} \tag{9}$$

where $e = y - X\tilde{\beta}$ is a vector of OLS residuals, W is the spatial weight matrix. The null hypothesis tested here is that $\lambda = 0$ (the null hypothesis is that there is no spatial autocorrelation). Figure 5 presents the Moran's scatterplot for regional labor productivity, using the five weight matrices mentioned above. There is clear evidence of spatial dependence among regions that either share a border, or have more similar levels of income per capita.

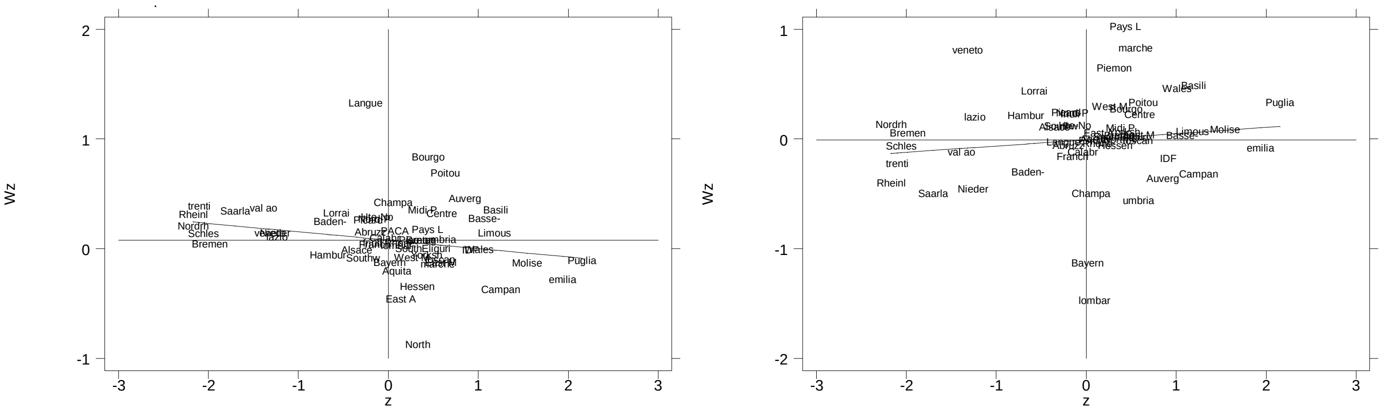


Moran’s I coefficient: 0.455, p-value: 0.000

Moran’s I coefficient: 0.221, p-value: 0.001

(a) Common Border

(b) Income per capita

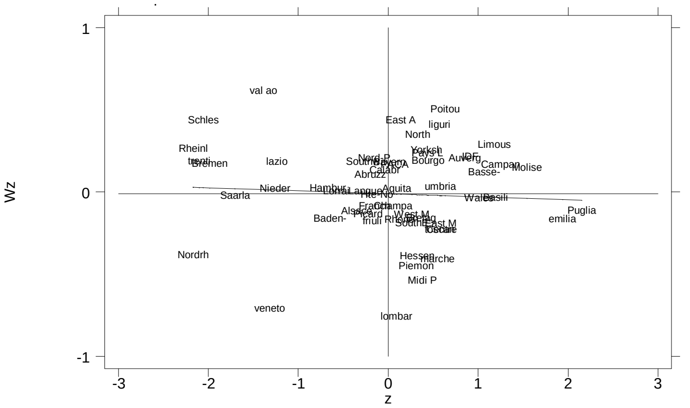


Moran’s I coefficient: -0.077, p-value: 0.222

Moran’s I coefficient: 0.057, p-value: 0.143

(c) Population density

(d) Share of Employment in the service sector



Moran’s I coefficient: -0.018, p-value: 0.497

(e) Share of Employment in the manufacturing sector

Figure 2: Moran’s I scatterplots of regional labor productivity, using different weight matrices

Table 4: Test for spatial autocorrelation of the variables included in the analysis

Border Weight Matrix		
Variables	Moran's I statistics	z-statistic
ln(y1999/y1975)	0.455***	4.737
ln(k1999/k1975)	0.253***	2.689
ln(infras1970/infras1995)	0.392***	4.104
ln(transport1970/transport1995)	0.216***	2.431
ln(Telecom1970/Telecomm1995)	0.450***	4.691
ln(Energy1970/Energy1995)	0.327***	3.448
ln(Agric1975/Agric1999)	0.250***	2.741
Income Weight Matrix		
Variables	Moran's I statistics	z-statistic
ln(y1999/y1975)	0.221***	3.152
ln(k1999/k1975)	0.044	0.81
ln(infras1970/infras1995)	0.054	0.941
ln(transport1970/transport1995)	0.081*	1.347
ln(Telecom1970/Telecomm1995)	0.166***	2.491
ln(Energy1970/Energy1995)	-0.007	0.137
ln(Agric1975/Agric1999)	0.135**	2.04

* significant at 10%; ** significant at 5%; *** significant at 1%

In addition to regional labor productivity, there is also sign of spatial dependence among contiguous regions in terms of their levels of capital stock per worker, infrastructure endowments, and the importance of agriculture in employment (Table 4). Evidence of spatial dependence among regions with similar levels of income per capita is weaker, as the Moran's coefficient is only significant for regional labor productivity, transport and telecommunication infrastructure, and the share of agriculture in total employment. Both weight matrices are used to estimate productivity elasticity to public infrastructure. The empirical tests and results are presented in the next section.

6 Empirical Test and Results

6.1 Empirical Test

Assuming a Cobb-Douglas aggregate production function, Equation 4 can be rewritten as

$$Y_{i,t} = A_{i,t} L_{i,t}^{\alpha_L} K_{i,t}^{\alpha_K} G_{i,t}^{\alpha_{G_i}} \prod_{j=1}^{J} X_{j,i,t}^{\alpha_{G_j}} \tag{10}$$

where X refers to other determinants of output, such as neighboring regions' infrastructure endowments.

I carry out the empirical analysis on the logged version of Equation 10, expressed in per worker terms:

$$y_{i,t} = A_{i,t} + \alpha_K k_{i,t} + \alpha_G g_{i,t} + \alpha_{G_J} \left(\sum_{j=1}^{J} w_{i,j} g_{j,t} \right) + t + \varepsilon_{i,t} \tag{11}$$

where lower-case variables refer to logged per-worker variables. t is a time trend, and is included to account for the increase in labor productivity and capital stock over time. J is the number of neighboring regions whose infrastructure endowments affect labor productivity in region i. The term $\sum_{j=1}^{J} w_{i,j} g_{j,t}$ denotes the weighted sum of infrastructure in neighboring regions, and controls for interregional infrastructure spillovers.

If we assume that the growth rate of technology, γ, is constant and common across regions, $\ln A_{i,t}$ can be rewritten as $\ln A_{i,t} = \ln A_{i,0} + \gamma$. $\ln A_{i,0}$ allows us to account for regional differences in technological efficiency, as well as for unobserved factors that could also affect regional output. Including these region fixed effects limits possible omitted variables bias on the productivity elasticities with respect to private capital, labor and public infrastructure.

Moreover, as noted in Holtz-Eakin and Schwartz (1994), high productivity allows a region to invest more in infrastructure, causing an upward bias when labor productivity is regressed on some infrastructure variables. To guard against this endogeneity bias and inconsistent coefficient estimates (as the error terms would be correlated with the infrastructure variables), it is important to include regional fixed effects in the specifications. The availability of data for several years permits estimation with panel data techniques.

To match the infrastructure data, I average the other data series over 4 periods: 1975-1980, 1981-1986, 1987-1992 and 1993-1999. These periods are then associated with the infrastructure data which are lagged relative to the 4 periods described above. This will limit the endogeneity problem.

As argued in Biehl (1991), a good theory of the impact of infrastructure on productivity should not only focus on infrastructure, but should also account for the other determinants of productivity so that it does not overestimate the importance of infrastructure. Consequently, the specification used below includes all of the regressors of Equation 11, as well as the share of agriculture in total employment (expressed in %) to control for the sectoral structure of regional economies.

Furthermore, if one uses disaggregated infrastructure data, it is important to include all of the infrastructure categories in order to avoid omitted variable bias, because endowments in these different categories are likely to be correlated. If I take the example of the three infrastructure categories indices (telecommunication, energy, and transportation network), the correlation between the transportation and telecommunication indices is 0.427, while the correlation between transportation networks and energy is 0.443.

6.2 Results

A a starting point, Equation 11 is estimated with pooled ordinary least squared without controlling for spatial dependence (Table 5, columns (1) and (2)). The elasticity of productivity with respect to private capital stock ranges between 0.217 and

0.240, which is smaller than the estimations obtained for the US states (Garcia-Milà and McGuire (1992), Garcia-Milà et al. (1996), Holtz-Eakin (1994)). When the infrastructure synthesis index is used as the measure for infrastructure endowment (column (1)), the productivity elasticity with respect to public infrastructure is equal to 0.045. These results are in line with the findings of papers using European data (Martin (1998), Musolesi (2002), Cantos et al. (2002), Acconcia and Monte (1999), Picci (1999), Bronzini and Piselli (2006)). When I use disaggregated infrastructure data to estimate the impact of transport, energy and telecommunication infrastructures on labor productivity (columns (2)), telecommunication network infrastructure is the only infrastructure category with a positive and significant impact on labor productivity. A 1% increase in regional telecommunication endowment is associated with a 0.05% increase in regional labor productivity. These results confirm that output elasticity of infrastructure is smaller than the elasticity of private capital stock.

Table 5: OLS Estimations of the labor productivity function

	(1)	(2)	(3)	(4)
	log specification		difference in log specification	
Capital per worker	0.278***	0.240***	0.174*	0.151
	(0.074)	(0.089)	(0.107)	(0.107)
Overall Infrastructure	0.045**		0.047	
	(0.019)		(0.043)	
Transport		0.011		0.046
		(0.023)		(0.043)
Energy		-0.014		-0.04**
		(0.015)		(0.02)
Telecommunication		0.05*		0.11**
		(0.027)		(0.046)
Share of Agriculture in Employment	0.03	0.039	-0.024	-0.022
	(0.055)	(0.055)	(0.752)	(0.077)
Regional Fixed Effects	yes	yes	no	no
Observations	221	207	57	57
Number of regions	89	85	57	57
R-squared	0.18	0.14	0.08	0.204
spatial error, Moran's I			5.920	3.988
(p-value)			(0.000)	(0.000)
spatial lag, LM			23.395	14.788
(p-value)			(0.000)	(0.000)

* significant at 10%; ** significant at 5%; *** significant at 1%

To control for spatial autocorrelation, the estimation needs to be run on cross-section data. Instead of using Equation 11, consider differencing the data by subtracting from Equation 11 the comparable equation for an earlier period. This log-difference allows to capture the long-run effect of infrastructure on labor productivity if the difference is taken between the first year and the last year of the sample:

$$y_{i,T}-y_{i,0}=\alpha_K(k_{i,T}-k_{i,0})+\alpha_G(g_{i,T}-g_{i,0})+\alpha_{G_J}\left(\sum_{j=1}^{J}w_{i,j}(g_{j,T}-g_{j,0})\right)+\varepsilon_{i,T}-\varepsilon_{i,0} \quad (12)$$

The inclusion of spatial lag or spatial error in the estimation requires the elimination of regions with missing observations. Island regions (such as Corsica, Sardegna, the Canarias) are excluded because they do not have contiguous neighboring regions. Regions with no infrastructure data in 1970 are also excluded. The sample is then reduced to 57 regions from France, Germany, Italy and the UK. To test for spatial dependence in the sample, Equation 12 is first estimated with OLS (columns 3 and 4 of Table 5). These results offer weaker evidence of the effect of infrastructure on labor productivity. The coefficient on the overall infrastructure endowment variable is no longer significant. This could be due to a more acute omitted variable bias or to the omission of the three Southern countries (Greece, Portugal, and Spain) where larger fractions of EU funding has supported infrastructure projects. Telecommunication infrastructure still has a positive productivity elasticity (0.11), while labor productivity now has a negative elasticity with respect to energy infrastructure (-0.04). In both columns, the significant Moran coefficient indicates strong spatial error patterns, while the LR statistics provides strong evidence of spatial lags. OLS estimates are therefore inefficient and biased.

Spatial filtering method is therefore applied, adding spatial lag or spatial error in the estimation. Equation 12 is estimated in STATA with the command spatreg, which does not allow to control for both spatial lags and spatial errors in the same estimation. Table 6 presents the results obtained when spatial dependence among contiguous regions is considered. When spatial errors are included in the estimation (columns (1) and (4)), the overall infrastructure endowment maintains its positive elasticity (0.071). This larger coefficient on the overall infrastructure variable confirms that accounting for spatial linkages increases the impact of infrastructure endowment on regional productivity (Cohen and Paul (2004)). Among the three infrastructure categories, only transport infrastructure are positively associated with labor productivity. Now a 1% increase in the growth rate of transport endowment between 1970 and 1995 is associated with a 0.06% increase in the growth rate of labor productivity. When the estimation controls for spatial lag (columns 2 and 5), there is evidence of spatial lag. Only the overall infrastructure endowment preserves its positive and significant coefficient.

Spatial lag controls only for interregional productivity spillovers, but does not provide a measure of interregional spillovers from infrastructure endowments. Using the same weights matrix based on contiguity and income, I construct variables measuring the weighted endowments of neighboring regions in infrastructure. These results are presented in columns 3 and 6 where spatial lag and spatial error are also controlled for. The presence of positive productivity spillovers across regions is confirmed, while these regressions suggest no empirical support for the existence of spillovers of public infrastructure on regional labor productivity.

When the specification is run with the income weight matrix, the overall infrastructure variable looses its significance. Telecommunication infrastructure is the only subcategory that promotes labor productivity, while energy infrastructure has a negative impact on regional labor productivity. The results also confirm that there exist negative productivity spillovers among regions with similar levels of income per capita. A 1% increase in one region's productivity is on average associated with a 0.006% decrease in a neighboring region's productivity. This result is in line with the predictions of the model when regions compete for mobile factors of production. As

Table 6: MLE Estimations of the labor productivity function

	(1)	(2)	(3)	(4)	(5)	(6)
	difference in log specification, dependent variable: $y_{i,T} - y_{i,0}$					
	border	border	border	border	border	border
Capital per worker	0.248***	0.193**	0.258***	0.223**	0.184**	0.229**
	(0.084)	(0.085)	(0.09)	(0.091)	(0.081)	(0.103)
Overall Infrastructure	0.071**	0.05*	0.078**			
	(0.03)	(0.03)	(0.034)			
Transport				0.033	0.05	0.059*
				(0.037)	(0.03)	(0.035)
Energy				-0.003	-0.023	-0.023
				(0.028)	(0.015)	(0.023)
Telecommunication				0.017	0.047	0.041
				(0.04)	(0.033)	(0.043)
Neighbor Labor productivity			0.031			0.044*
			(0.024)			(0.025)
Neighbor Overall Infrastructure			0.017			
			(0.041)			
Neighbor Transport						0.013
						(0.045)
Neighbor Energy						-0.03
						(0.03)
Neighbor Telecommunication						0.064
						(0.050)
Share of Agriculture in Employment	-0.100***	-0.051	-0.088*	-0.085	-0.052	-0.068
	(0.04)	(0.055)	(0.049)	(0.058)	(0.057)	(0.06)
Observations	57	57	57	57	57	57
Number of regions	57	57	57	57	57	57
Log-likelihood	62.63	59.44	63.81	61.075	60.47	63.733
spatial error, λ	0.692***		0.656***	0.677***		0.546***
(Z-statistic)	(9.59)		(7.52)	(6.92)		(3.51)
spatial lag, ρ		0.654***			0.610***	
(p-value)		(7.90)			(5.71)	

* significant at 10%; ** significant at 5%; *** significant at 1%

a region becomes more productive, its real wage and real rental price increase, which attracts more mobile labor and capital stock, at the expense of neighboring regions.

7 Conclusion

Using data on European regions which cover the years 1970 to 1999, I assess the productivity elasticity with respect to public infrastructure. When I use panel-data technique with region-fixed effects and a time trend, the productivity elasticity

Table 7: MLE Estimations of the labor productivity function

	(1)	(2)	(3)	(4)	(5)	(6)
	difference in log specification, dependent variable: $y_{i,T} - y_{i,0}$					
	income	income	income	income	income	income
Capital per worker	0.128	0.151	0.101	0.133	0.143	0.096
	(0.09)	(0.10)	(0.086)	(0.093)	(0.097)	(0.08)
Overall Infrastructure	0.016	0.033	0.024			
	(0.032)	(0.035)	(0.03)			
Transport				-0.01	0.026	0.013
				(0.047)	(0.037)	(0.037)
Energy				-0.027	-0.036**	-0.036*
				(0.021)	(0.181)	(0.02)
Telecommunication				0.054	0.074*	0.052
				(0.06)	(0.044	(0.037)
Neighbor Labor productivity			-0.005**			-0.006**
			(0.002)			(0.001)
Neighbor Overall Infrastructure			0.106**			
			(0.05)			
Neighbor Transport						0.031
						(0.07)
Neighbor Energy						0.153***
						(0.07)
Neighbor Telecommunication						-0.021
						(0.040)
Share of Agriculture in Employment	-0.08	-0.054	-0.054	-0.049	-0.041	-0.028
	(0.048)	(0.068)	(0.071)	(0.07)	(0.067)	(0.067)
Observations	57	57	57	57	57	57
Number of regions	57	57	57	57	57	57
Log-likelihood	51.01	51.01	53.53	53.64	54.16	58.74
spatial error, λ	0.597***		0.521**	0.549**		0.309
(Z-statistic)	(3.72)		(3.13)	(2.23)		(1.17)
spatial lag, ρ		0.543***			0.481***	
(p-value)		(3.56)			(2.76)	

* significant at 10%; ** significant at 5%; *** significant at 1%

to overall public infrastructure is much lower than the elasticity of private capital stock, and is equal to 0.05. Among the different core-infrastructure categories, only telecommunication networks are productivity-enhancing. The latter effect is however not very robust once the empirical model is estimated with a spatial error model.

Using several spatial diagnosis tests, I find strong evidence of spatial dependence, which causes OLS elasticity estimates to be inefficient and biased. Moran's I coefficients computed for regional labor productivity and regional infrastructure provide evidence of spatial autocorrelation among regions that share a border or that have similar levels of income per capita. Once spatial errors are included in the specification, the overall infrastructure index retains its positive effect on labor productivity. I also obtain weak evidence of productivity gains obtained from transport infrastructure. Interregional spillovers from labor productivity and infrastructure endowments only affect regions with similar levels of income per capita which are more likely to compete for mobile factors of production.

This paper's results clearly question the extent to which the current EU regional policy can boost regional labor productivity. Given that EU Structural Funds mostly co-finance infrastructure projects, and especially transport projects, this European regional policy is not likely to have a strong impact on regional labor productivity. This is in line with the conclusion reached by a large section of the literature on EU Structural Funds which finds no evidence that EU regional policy has enhanced regional convergence (Boldrin and Canova (2001), Dall'erba and Gallo (2003), and ?). The efficacy of EU regional policy would therefore be enhanced, were funds less directed towards transport projects. Since the positive effect of the infrastructure overall endowment cannot entirely be explained by the effects of transport, telecommunication or energy infrastructure, it can probably be explained by benefits derived from "non-core" infrastructure, which includes education. The smaller output elasticity of infrastructure could also indicate a saturation effect in some regions (Fernald (1999)). Overall, this paper's results suggest that, in EU15 countries, it is no longer justified to spend more EU funds on infrastructure projects.

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A Description of the Infrastructure Variables

A.1 Data from Commission (1982)

This report aimed at assessing the contribution of infrastructure to regional development. To carry out this analysis, they have compiled a large data set of twelve infrastructure categories, and constructed a synthesis index:

- Transportation: roads, highways, railway, waterway, airports, harbors, pipeline
- Communication: telephone, radio and television systems, computer and information centers
- Energy supply: electricity, gas, oil
- Water supply: water distribution, irrigation and draining, river regulation
- Environmental: purification plants, waste treatment, coastal and soil protection
- Education: schools, universities, training and research centers
- Health Infrastructure: hospitals, emergency services, rehabilitation centers
- Special Urban Infrastructure
- Sportive, touristic facilities
- Social Infrastructure

- Cultural facilities
- Natural endowment
- Total Infrastructure Indicator

Within each of these 12 categories, each subindicator (r) is normalized by dividing each indicator by the corresponding maximum value of an indicator series.

$$G_{i,r,t}^{scaled} = \frac{G_{i,r,t}}{MaxG_{r,t}} \tag{13}$$

The indicators of the 12 main infrastructure categories are then obtained by computing the algebraic mean of this category's subindicators. To get the total infrastructure indicator, these 12 categories are aggregated using a geometric mean.

Data were collected for 139 NUTS2 regions from Germany, France, Italy, the Netherlands, Belgium, Luxembourg, the United Kingdom, Ireland, Denmark, and Greece. The years covered are 1970 and 1978. Biehl notes that the report is based only on two cross-section datasets because it was hard to obtain yearly data for the 12 infrastructure categories.

A.2 Data from ECOTER (1999)

This study updates Commission (1982) data on the levels of infrastructure endowment in 132 NUTS 2 regions from 5 EU countries: France, Germany, Italy, United Kingdom, and Spain.

They collected data on 3 infrastructure categories:

- Transportation: roads, railways, airports, ports
- Communication: telephones
- Energy: electric power supply, oil, gas

Using these four categories, they also compute an overall infrastructure index. Data was collected for 1995. I also have the overall infrastructure indicator for 1985. The data are scaled with respect of EU5 average (=100). To make this dataset comparable to the data from Commission (1982), each region endowment is then normalized by the maximum regional endowment in each subcategory.