XII

Volume XII, Number 1, May 2009

Journal of Applied Economics

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UNIVERSIDAD DEL CEMA
MCMLXXVIII
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Edited by the Universidad del CEMA

Print ISSN 1514-0326
Online ISSN 1667-6726

Journal of Applied Economics. Vol XII, No. 1 (May 2009), 11-32

A SPATIAL AND ECONOMIC ANALYSIS FOR TELECOMMUNICATIONS: EVIDENCE FROM THE EUROPEAN UNION

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Submitted January 2007; accepted June 2008

This paper evaluates the role of a number of determinants of telecommunication services in the European Union. We use a logistic model with spatial covariates to estimate the demand function for telecommunications in the Union. Our results show that different types of interconnections generate diverse estimates for country specific demand. The impact on telecommunications from countries with spatial, economic or social similarities differs based on those characteristics. Omitted variable bias from not modeling spatial interdependence is limited in models under spatial connectivity criteria. This satisfies the statistical inference drawn by previous empirical studies regarding determinants of telecommunications.

JEL classification codes: C21, C22, C23, L96
Key words: decay effect, telephone traffic demand, spatial econometrics

I. Introduction

Over the last few years, the telecommunications sector has received increasing attention in the economic literature and a large volume of theoretical and empirical work has been published in this area. The telecommunications market has changed to a more deregulated environment (Armstrong 1998) following the rules established by regulatory authorities and the demand for telecommunications services has increased tremendously as a result of the expansion of the economic activities of

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many multinational organizations. This paper focuses on explaining the demand for international telecommunications at a European country level.

There are a number of papers in the existing literature that are related to our work. Gatto et al. (1988) model residential demand by developing systems of five interdependent equations, corresponding to alternative ways of placing a call for each state. However, they do not apply a *spatial* econometric framework and thus their results may suffer significant bias. Interestingly, Christaller (1966) uses the number of telephone stations per person to develop a hierarchy of centers among Southern Germany's cities in 1963 and illustrate his central place theory (CPT). Green (1955) employs telephone call data to define the common boundary of the hinterlands of New York City and Boston. Various inter-city flows (e.g., migration, commuting, and tourism) have been used to analyze regional settlement structures, uncover central place hierarchies, delineate functional and nodal sub-regions, and identify regional disparities (e.g., core and periphery). The latter regional structure motivates the *social* correlation of telecommunications. Finally, De Fontenay and Lee (1983) analyze residential calls between British Columbia and Alberta. They find that call duration has an inverse relationship with price (*economic* factors). All the above results justify the empirical formulation of our model. However, the contribution most closely related to ours is that of Gruber and Verboven (2001) who studied the technological determinants of mobile telecommunication services in the European Union and their analysis provided us with considerable insights of the workings of telecommunications market in Europe. In contrast to Gruber and Verboven (2001) and considering the results of the existing empirical literature, we analyze the determinants of demand for telecommunications and evaluate them using a multidimensional method (spatial econometrics).[1] Thus, the contribution of the paper is three-fold: (i) decompose the impact of alternative factors that stimulate the demand for telecommunications, (ii) illustrate the effect of geographic proximity, trade and tourism flows on the demand for telecommunication services per country and, (iii) modify and extend the model of Gruber and Verboven (2001) to correct for multifactor bias of the estimates.

We take a more general look (Blonigen et al. 2006) at empirically modeling spatial interactions in demand for telecommunications and ask three fundamental

[1] Several empirical studies, such as Agiakloglou and Yiannelis (2005), Bewley and Fiebig (1988), Acton and Vogelsand (1992), Madden and Savage (2000), Sandbach (1996), Garin Munoz and Perez Amaral (1998), and Wright (1999) have tried to estimate price elasticities for international telecommunications demand for different countries based on time series data.

questions not yet addressed by the previous literature.[2] First, to what extent does omission of spatial interactions bias affect coefficients on the traditional regressor matrix in empirical telecommunications studies? Significant bias would call into question much of the existing empirical work and inference. Second, how are spatial relationships estimated using alternative specifications of *connectivity effects* (social and economic)? Given the existing literature, an obvious issue to examine is the differences across those criteria and whether their presence affects the results. Finally, we examine the evidence of country specific effects. The described approximation may be viewed as an alternative extension of the framework of technological determinants described in Gruber and Verboven (2001) for the telecommunications services.

The remainder of the paper proceeds as follows. Section II discusses the empirical strategy of estimation along with the data. Section III shows the empirical results and illustrates the country-specific effects, whereas Section IV presents some concluding remarks.

II. Empirical strategy

Connectivity effects cannot be ignored from any analysis as long as the data supports such evidence (Zucker et al. 1998). Several factors, such as labor mobility, trade between regions, knowledge diffusion and more generally regional spillovers, may lead to various interconnections among European countries. Thus, the objective of this study is to determine demand elasticities for telecommunications taking into consideration various connectivity effects. Having identified the objective, we turn the discussion in choosing the proper model specification.

A. Model specification

The demand for international telecommunications of a country i is defined as the amount of calling time used during some period of time, where the calling time is distributed over different distances. Let $m(d, g, t)$ denote the calling time in distance

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[2] The performance of the telecommunications market has been examined by several research papers, such as the one by Kiss and Lefebvre (1987) in which they applied a variety of telecommunications cost models to American firms or those by Laffont and Tirole (1993 and 2000) where they focused their research on regulatory framework models and on how to make regulation more efficient. In fact, they concluded that a good regulatory framework requires cost and demand information. Gasmi et al. (1999) indicate that despite efficiency gains from regulatory schemes, consumers might experience significant losses.

zone d, with g denoting the local economic characteristics, such as, for example, per capital income and population density, and t is the time period. The demand for international telecommunications $[m(d, g, t)]$ is a function of a vector x of explanatory variables. Following the Park et al. (1983) approach and assuming that the demand elasticity for calling time is proportional to price and that there are no cross price effects, we use specification 1 to estimate the demand equation:[3]

$$m_{i,t} = x_{i,t}\beta + k\sum_{\substack{j=1 \\ i\neq j}}^{n} w_{ij}m_{j,t} + \varepsilon_{i,t}, \tag{1}$$

where w_{ij} is the vector of the connectivity (spatial[4]) weights for n countries (with $w_{ii} = 0$; Anselin 1988) and k is the connectivity parameter[5] also known as spatial autocorrelated parameter. If k is zero there will be no neighboring effect. Without the term $k\sum_{j=1,i\neq j}^{n} w_{ij}m_{j,t}$ equation (1) can be easily estimated provided that the error process shows no temporal correlations, so that the lagged m is independent of the error process. Recent work on this model can be found in Kelejian and Prucha (2005).

In this model, the dependent variable is affected by the values of the dependent variable in nearby units, with "nearby" suitably defined. However, in many cases there may be several possible networks or forms of dependence that can be included in the model.[6] For example, it is possible to generalize the spatial autoregressive

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[3] Under the condition that equation (1) converges to a balanced growth path in which the rate of telecommunications services is equal across European countries.

[4] In spatial econometrics the structure of dependence between observations is assumed to be known by the researcher and not to be estimated. Indeed, this structure is given by what is known as the "connectivity matrix", which specifies the degree of connectivity (weights) between any two observations. Let the connectivity matrix denoted by W, where a typical element w_{ij} has a value greater than 0, if the observations i and j are connected. By convention, units are not considered to be connected to themselves, so any diagonal entry $w_{ii} = 0$. The connectivity matrix is standardized so that each row vector w_i sums to unity. As a consequence, it is not critical to worry about the units to measure connectivity, since W is invariant to affine transformations.

[5] The term spatial autocorrelation refers to the coincidence of attribute similarity and locational similarity as discussed by Anselin (1988, 2002).

[6] The model is analogous to the temporal autoregressive model that is used to test, for example, habit-persistence theory. Because the full vector of left hand side variables also appears on the right hand side, this model would be particularly similar to a hypothetical temporal autoregressive model, where the present is influenced by both the past and the future. In contrast to the time domain, spatial lag operators imply a shift over space, but are restricted by some complications that arise when one tries to make analogies between the time and space domains (Cressie 1993).

model (1) by using two distinct vectors w_{ij1} and w_{ij2} of spatial weights in which case the model adopts specification 2:

$$m_{i,t} = x_{i,t}\beta + k_1 \sum_{\substack{j=1 \\ i\neq j}}^{n} w_{ij1} m_{j,t} + k_2 \sum_{\substack{j=1 \\ i\neq j}}^{n} w_{ij2} m_{j,t} + \varepsilon_{i,t}, \tag{2}$$

where k_1 and k_2 are the relative connectivity parameters that need to be estimated. The expanded autoregressive model (2) is estimated as the standard spatial autoregressive model, provided that the two matrices are sufficiently different and do not contain entirely overlapping information.[7] Lacombe (2004) uses a similar model to estimate parameters distinguishing within-state unit and between-state unit effects of welfare programs on female labor force participation.

Moreover, equation (2) can be further expanded, as suggested by Zucker et al. (1998), by using the two distinct vectors of connectivity effects w_{ij1} and w_{ij2} with exogenous variables as follows, in specification 3:

$$m_{i,t} = x_{i,t}\beta + k_1 \sum_{\substack{j=1 \\ i\neq j}}^{n} w_{ij1} m_{j,t} + k_2 \sum_{\substack{j=1 \\ i\neq j}}^{n} w_{i2} m_{j,t} + \rho_1 \sum_{\substack{j=1 \\ i\neq j}}^{n} w_{ij1} w_{ij2} x^{s}_{j,t} + \rho_2 \sum_{\substack{j=1 \\ i\neq j}}^{n} w_{ij1} w_{ij2} x^{v}_{j,t} + \varepsilon_{i,t}, \tag{3}$$

where the full vector of exogenous variables is defined as (x_i, x_j^s, x_j^v), meaning that in this case the explanatory variables are divided into three groups with x_i denoting the exogenous variables of general interest (i.e., prices), x_j^s the exogenous variables related to neighboring infrastructure (i.e., number of lines per country) and x_j^v the exogenous variables related to neighboring economic prosperity (i.e., GDP).

Consequently, we estimate all specifications by using the instrumental variable (IV) method (Brueckner 2003) and employing three different distance weight matrices defined as: a) a binary distance measure of contiguity, b) an inverse distance measure of contiguity and c) a k-neighbors measure of contiguity for $k = 6$. Beside the distance matrix, we consider an economic weight matrix, using as index the volume of trade, and a social weight matrix, using as index the flow of tourists.

In a geographic context, the elements of the connectivity matrix are determined purely by physical distance.[8] However, in a non-geographic context, the notion of "distance" is determined by the trade volume and by the number of tourists. We

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[7] For further details see Brueckner (2003).

[8] We may use any notion of nearness that makes theoretical sense, as long as it does not violate any of the assumptions about the connectivity matrix stated above. For alternative specifications of weight matrices see Anselin , (2002).

consider as neighbors, countries with similar volume of trade flows. The trade connectivity matrix differs from the previous distance matrix in two notable ways. First, the trade matrix consists of weights where the importance of another state j to state i is given by the volume of the dyadic trade flow between i and j as a proportion of country i's total trade, whereas the distance matrix assigns equal weights to any geographical neighbor. Second, the trade connectivity matrix weights large trading partners much more heavily than smaller trading partners, whereas in the distance matrix, any neighbor of i must always have j as a non-trivial neighbor. Therefore, the elements of trade connectivity matrix are defined as:

$$S_{ji} = 1 - [\sum_i \sum_j \left| trade_j - trade_i \right| / K_{ji}], \tag{4}$$

and, by construction, this index ranges from 0 to 1, with K denoting the total amount of trade among countries i and j. In particular, if the proportion of trade in all activities is the same between the two regions, then $S_{ji} = 1$. The elements of trade connectivity matrix take the value of 0 if all the volume of trade of country j is in sectors for which country i has no volume of trade. Notice that this definition of similarity is symmetric in that $S_{ji} = S_{ij}$.

One interesting feature of the trade matrix is that more open countries have the bulk of their trade with large, wealthy, countries, which tends to demonstrate significant demand for outgoing calls. As a result, these countries that have greater openness and trade will tend to have a higher "connectivity lag" on average demand for telecommunications among their trading partners. Moreover, the volume of tourists per country may generate an alternative contiguity matrix (with similar definition as in (4)), which captures the significant human flows among different countries that affect the demand for telecommunications. Thus, trade and number of tourists may identify a very different set of pull factors than geographical proximity.

B. Data

Model specifications 1, 2 and 3 for telecommunications flows, presented above, are structurally similar to the regional spatial interaction models (Martínez and Araya 2000). However, the selected explanatory variables are significantly different involving trade, tourism and financial commonalities. The demand for international telecommunications is strongly affected by a large number of factors. These factors are presented as explanatory variables, and the annual data for them is obtained from 2005 *Eurostat statistics*, European Commission, for the period 1999 to 2002, for the 25 member countries of the Union.[9]

Outgoing minutes of conversations, *m*, is the dependent variable of our analysis, measured in thousands of minutes. The *price* variable is the real average price (in Euros) per minute (including taxes) faced by customers, whereas the *gdp* variable denotes the real per capita GDP of each country measured in millions of Euros. Deflation of the nominal prices and per capita GDP is based on the consumer price index (CPI) for the corresponding years of our analysis. The variable *trade* shows the volume of trade (measured in millions of Euros) as an aggregate amount between European countries. It captures any economic transactions among different countries and represents significant economic activities.[10] The variable *tourists* refers to the number (measured in thousands) of tourists (European citizens) that visited the European countries, whereas the variable *rd* stands for research and development grants (measured in millions of Euros) for telecommunications, which are the funds for investments used in telecommunication sector per country. Lastly, the variable *line*, which is the actual number of major telecommunications lines per country, provides an insight about country *i*'s infrastructure. Table 1 provides a descriptive analysis of all the variables of our model:

Table 1. Descriptive statistics

Variable	Mean	Minimum	Maximum	Standard deviation
m	1,676	25	9,474	2,306
price	1.05	0.16	2.79	0.56
trade	945	6,754	489,896	45,789
tourists	8,870	12	552	121.57
rd	1.43	0.22	4.27	0.95
gdp	53,852	3,065	26,008	5,776
line	48.3	25	76	12.61

[9] The member countries are Austria, Belgium, Czech Republic, Denmark, Germany, Estonia, France, Finland, Greece, Great Britain, Spain, Sweden, Ireland, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Poland, Portugal, Slovenia, and Slovakia. Period 1999 to 2002 is a significant period for the expansion process of the European Union including a substantial number from the above countries.

[10] Although spatial concentration of economic activities in European countries has been documented by Bottazzi and Peri (2003), few studies take into account spatial interdependence between them.

Beside the information from Table 1, we provide in the Appendix Tables A1 and A2. The first table presents the overall demand for telecommunications across countries in each year and a measure of the decay effects across countries over time. The second table presents all the spatial weights per country relative to all the others. Such information is particularly useful should we examine the degree of spatial similarity among any two European countries.

III. Estimation results

The presentation of results is based on the categorization of spatial effects. Subsection A covers a binary distance criterion, Subsection B illustrates an inverse distance criterion and Subsection C employs a *k*-neighbor criterion. Finally, a country specific effects analysis is incorporated in the last subsection.

A. A binary distance measure of contiguity

Telecommunication flows between countries may be likely to occur between nearby countries in a geographical sense. Hence, the first connectivity criterion is based on the geographical distance between European countries (Table 2). We use the minimum distance data to define countries as connected if they are within 500 km of one another.[11] This yields a binary connectivity matrix where each entry w_{ij} is 1, if states i and j are within 500 km distance from each other and 0 otherwise. Each neighboring country is given equal weight in the row for country i.

Table 2 reports the estimation results obtained by using specifications 1, 2 and 3. In particular, specification 1 has a spatial lag of dependent variable with a distance weight scheme (k), whereas specification 2 has both a distance weight scheme (k_1) and a trade (or tourism) weight scheme (k_2). Finally, specification 3 uses, in addition to the spatial lags of specification 2, both alternative weight schemes (trade and tourism) in respect to specific independent variables. Hence, an interaction weight component (w_{ij1} w_{ij2}) is created to estimate the impact of differentiated vectors of weight transformations. The interaction weight components capture the effects from countries with similar distance and trade (or tourism) characteristics, simultaneously.[12]

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[11] As suggested by the software of SpaceStat ®.

[12] Spatial dependence is multidimensional, as suggested by Anselin (1988) and Brueckner (2003) . In our case, neighbors influence the behavior of their neighbors *and vice versa*. The multidimensional nature of spatial dependence leads to multiple implications. Interaction components aim to capture that

Table 2. Estimation results under predefined distance proximity

Variables	Spatial and trade weights			Spatial and tourism weights		
	Specification 1	Specification 2	Specification 3	Specification 1	Specification 2	Specification 3
price	-0.82***	-0.63***	-0.58***	-0.96***	-0.71**	-0.39***
	(22.1)	(16.2)	(12.1)	(10.91)	(2.37)	(3.71)
trade	0.14***	0.09*	0.12**	0.11***	0.08*	0.06***
	(16.75)	(1.89)	(3.11)	(7.72)	(1.89)	(4.18)
tourists	0.05***	0.07**	0.06**	0.03***	0.02*	0.09**
	(4.11)	(2.96)	(3.15)	(3.88)	(1.83)	(2.23)
rd	0.55	0.49	0.39	1.34	0.22*	0.41*
	(1.01)	(1.15)	(0.97)	(0.42)	(2.11)	(2.89)
gdp	0.09**	0.12*		0.11***	0.19*	
	(2.71)	(2.51)		(8.93)	(2.11)	
line	0.91	0.43		0.16*	0.21*	
	(0.88)	(1.51)		(2.01)	(2.34)	
Spatial component						
k	0.12***			0.05***		
	(7.72)			(3.23)		
k_1		0.15***	0.09***		0.06**	0.04**
		(8.91)	(7.82)		(3.01)	(2.97)
Trade/tourism component						
k_2		0.12*	0.07**		0.02	0.02*
		(1.96)	(2.29)		(0.67)	(1.98)
Interaction component						
ρ_1			0.01			0.02
			(0.44)			(0.79)
ρ_2			0.05			0.01
			(0.31)			(0.05)
Country dummies	No	Yes	Yes	No	Yes	Yes
R^2 adjusted	0.68	0.71	0.72	0.62	0.68	0.69
F test	9.17	9.64	10.01	9.36	9.75	10.85
Chi square test	64.27	65.16	68.11	65.52	68.79	66.75

Note: Numbers in parentheses are t statistics, where *, **, *** are significance at 10%, 5% and 1% respectively.

An F-test shows that the spatial lags per country are statistically significant in most estimated equations (Mátyás 1998).[13]

Connectivity weights have important impact on the demand for telecommunications. The impact of those weights is denoted by the estimated elasticities of all the specifications of the model. Estimates of the spatial components (i.e., estimates of coefficients k and k_1) are significant and noticeable. In fact, their values vary from 0.04 (tourism criterion) to 0.15 (trade criterion), indicating that the presence of spatial effects on both criteria captures significant patterns of intercommunications among European countries. For instance, if we increase neighboring outgoing demand for telecommunications by 1%, the domestic demand will change by 0.12% (Table 2, 1st column, k).[14] The magnitude of that elasticity is relatively lower than the estimate of Guldmann (2000), which is 0.6%. However, the suggested spatial methodology used by Guldmann (2000) differs from the Anselin's (1988) methodology used in this paper. Additionally, the impact (Table 2) of trade or tourism weigh schemes (k_2) varies from 0.02 to 0.12 where Guldman's (2000) results range between 0.09 to 0.52. Those estimates capture the omitted telecommunication bias in the models without any connectivity effects.[15] Given their significance, the previous literature fails to account for their impact on the elasticity measures. Thus, their inclusion corrects the estimates of telecommunication elasticities. On the other hand, the estimates of the interaction components (i.e., the estimates of coefficients ρ_1 and ρ_2) are all insignificant, no matter the criterion. Therefore, specification 3 does not provide any further insight and hence the simultaneous use of all weight specifications does not identify any significant

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multidimensionality but in terms of alternative forms of dependence. They provide additional insight as far as that dependence and do not capture the effects from spatial components. Their significance varies along with the definition of spatial weights and alternative types of weight. The paper shows that those components do affect the magnitude of the elasticities but their impact should be evaluated as part of the aggregate impact of all types of weights.

[13] For this purpose specifications (1, 2 and 3) are estimated and the LM-ERR and LM-LAG test statistics (Anselin and Bera 1998) are computed. Since the values of the LM-LAG test statistic are higher (lower p-value) than the LM-ERR test statistic, we conclude that the spatial lag formation is the proper formulation for our analysis.

[14] Here, neighboring refers to a group of countries based on the weight criterion.

[15] We computed all the standard models (specifications 1 and 3) without any connectivity effects (or interaction effects). However, space limitations restrict us from including OLS estimation of results. The differences between those results and the one presented are the result of the bias discussed in the paper.

pattern among the outgoing calls. A potential justification of the insignificance of interaction components is that spatial and economic components capture most of the omitted bias of the standard models.[16]

The level of outgoing calls is affected significantly by the price and by the volume of trade among the countries of our data set regardless of the model specification.[17] Under any type of weight schemes, geographic, economic or social, the coefficients of price and trade have a negative and positive impact on the number of calls, respectively.[18] The latter conclusion follows the line of results of Garin-Munoz and Pérez-Amaral (1998) who find that the price elasticity and the volume of trade elasticity are 0.8 and 0.3, respectively. It is interesting to note that the absolute value of the coefficient of price is less than one, indicating that demand for international calls is inelastic.

The estimates of the coefficients of the remaining explanatory variables –*tourists*, *rd*, *gdp*, and *line*– exhibit the expected sign (positive), but diverse impacts on the amount of outgoing calls. Their level of significance varies according to the chosen specification and the connectivity criterion. The inclusion of GDP and number of lines in a spatially lagged formulation (i.e., specification 3) considers the impact of "neighboring" countries not only from an infrastructure perspective (*line*, through the coefficient of ρ_1) but also from an economic perspective (*gdp*, through the coefficient of ρ_2); although the estimates of the coefficients were not significant. In contrast to our results, Acton and Vogelsang (1992), analyzing the annual telephone traffic between the United States and 17 West European countries over the period 1979-1986, indicate that neighboring GDP variables range from 0.11 and 0.27.

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[16] It should be emphasized that including interaction components does not alter significantly the estimated results with connectivity effects.

[17] Actually, we take into account the endogeneity of both prices and other countries' demand by using the instrumental variable (IV) method (Brueckner 2003). In spatial econometrics it is generally accepted to use as instruments neighboring (spatial lags) explanatory variables (see Brueckner 2003 for the theory, and Brett and Pinkse 2000 for a recent application).

[18] Demand in neighboring countries is deemed to be positively correlated with demand in the primary country, so to get the apparent negative bias on price that we see, it must be that demand in neighboring countries is negatively correlated with own price. Perhaps prices are correlated across countries, so an increase in the own price is related to an increase in a neighboring country's price, resulting in less demand in the neighboring country. We are grateful to the referee for this thoughtful comment.

B. Inverse distance measure of contiguity

Our second specification of weight matrices uses the inverse distance criterion to account for the geographical distance between European countries. The inverse distance-based approach places less importance to all countries *j* that are far away from country *i*. In particular, the elements w_{ij} of the inverse distance-based weight matrix are computed as: $w_{ij} = \left(d_{ij}\right)^{-2}$, where d denotes distance between countries *i* and *j*, and are defined as a decaying function in space. The current specification of weights provides significant insight about the role of distance in telecommunications.

Table 3 presents similar results to those obtained by the previous weight specifications. First, spatial effects can be detected only using specifications 1 and 2 since the estimates of the interaction components are not significant. Only the estimate of the interaction component (coefficient of GDP, ρ_2) is significant. The latter result verifies the existence of regional economic clusters, since neighboring GDP for any two countries affect the demand for calls. In contrast, no evidence is found for the relationship among outgoing calls of country i and neighboring infrastructure from countries *j* (coefficient ρ_1). The latter result is robust to any type of weight criteria and in line with Cameron and White (1990). They use a sample of 26,672 long-distance calls originating from British Columbia, and they find that call duration decreases with distance (a result similar to Pacey 1983).

The remaining estimates follow a similar pattern with the results of Table 2. Their magnitude and their significance do not present any serious alterations, indicating that the robustness of these results is not affected either by the definition of economic or social weight specifications or by the nature of geographic weights. In fact, even the absolute magnitude of the elasticities of demand does not change.

C. *K*-neighbors measure of contiguity (*k* = 6)

The *k*-neighbors criterion is based on a predetermined number (*k*) of countries that are geographically close to country *i*. The choice of the exact number *k* is based on the number of geographical observations and their locational characteristics. Although we use $k = 6$ (Table 4), specifications 1, 2 and 3 have also been estimated under alternative definitions of *k*, i.e., $k = 4$ and 8, but the results did not present any significant changes.

The alternative clustering procedure is implemented by Fischer et al. (1994) with Austrian regional telephone flows. They conclude that the strength of the interaction among groups of regions is an important determinant for the demand

Table 3. Estimation results under inverse distance proximity

Variables	Spatial and trade weights			Spatial and tourism weights		
	Specification 1	Specification 2	Specification 3	Specification 1	Specification 2	Specification 3
price	-0.71***	-0.58**	-0.48***	-0.96***	-0.68**	-0.34***
	(19.23)	(3.01)	(10.09)	(10.91)	(2.67)	(3.23)
trade	0.12***	0.10**	0.09***	0.11***	0.07*	0.05***
	(14.57)	(2.39)	(7.55)	(7.72)	(1.95)	(3.64)
tourists	0.04***	0.06*	0.05***	0.02***	0.02	0.08
	(3.58)	(1.94)	(3.68)	(3.14)	(0.97)	(1.05)
rd	0.48	0.39	0.27	1.17	0.19	0.36**
	(0.88)	(0.67)	(1.64)	(0.37)	(0.84)	(2.51)
gdp	0.08**	0.11*		0.1***	0.16**	
	(6.71)	(1.95)		(7.77)	(2.33)	
line	0.79	0.55		0.14*	0.19*	
	(0.77)	(0.39)		(1.75)	(2.01)	
Spatial component						
k	0.10***			0.04**		
	(10.2)			(2.81)		
k_1		0.12***	0.08***		0.05**	0.03**
		(6.01)	(6.94)		(2.18)	(3.29)
Trade/tourism component						
k_2		0.07*	0.06**		0.02	0.02*
		(1.88)	(2.55)		(0.91)	(2.06)
Interaction component						
ρ_1			0.01			0.02**
			-0.31			(2.65)
ρ_2			0.04			0.01
			-0.17			(0.11)
Country dummies	No	Yes	Yes	No	Yes	Yes
R^2 adjusted	0.58	0.63	0.65	0.55	0.59	0.63
F test	8.11	8.92	9.11	8.74	8.36	9.77
Chi square test	75.08	73.72	70.92	71.11	70.96	73.41

Note: Numbers in parentheses are t statistics, where *, **, *** are significance at 10%, 5% and 1% respectively.

for telecommunication. Their result is in accordance with the results using a predetermined number of countries to examine telephone flows. However, the innovation of our results relative to the results of Fischer et al. (1994) is that they do not account for multidimensional omitted bias but only for bias originated from social interactions.

The most interesting result is that the predetermined number of neighbors affects the significance of cross-connectivity effects. The latter criterion allows one to examine the elasticity of telecommunication industry at a 'neighborhood' level, offering significant insight for potential clusters at telecommunication flows. As shown in Table 4, specification 3 now has significant estimates of the interaction components under both trade and tourism criteria, with values ranging from 0.03 (tourism criterion) to 0.07 (trade criterion). The magnitudes of those elasticities should not be evaluated individually but in relation to the spatial and economic (trade/tourism) components.[19] An example refers to southern Mediterranean countries where the volume of outgoing calls is affected by the group of countries located in the area. The geographic cluster coincides with the economic and social cluster and indeed this result verifies that countries with significant amount of tourists do affect the demand for outgoing calls. The latter results are innovative in the existing literature and provide an additional perspective.

Table 4 presents estimates which are very similar to those estimates previously obtained. The main difference refers to the magnitude of the elasticity of demand for international telecommunications which has slightly changed and is elastic, though only for specification 1, whereas for all other specifications it remains inelastic. The estimates of the coefficients of the remaining explanatory variables –*tourists*, *rd*, *gdp*, and *line*– have all the expected sign and their magnitude does not differ significantly from the previously obtained results. Karikari and Gyimah-Brempong (1999), using traffic data between the United States and 45 African countries over the 1992-1996 period, implement a simultaneous equations approach and regress the number of calls in one direction on the lagged traffic in this direction, the return traffic, the price of an outgoing call, the GDP per capita, the volume of trade, the differential in outgoing and incoming prices, and the product of the number of households. The latter results are in line with our estimates.

In general, the results in Table 4 are more difficult to interpret. The positive and highly significant coefficients of the interaction terms point out to the complex and synergistic effect of financial or infrastructure commonalities. Estimated results

[19] Please refer to footnote 15.

Table 4. Estimation results under *k*-neighbors proximity

Variables	Spatial and trade weights			Spatial and tourism weights		
	Specification 1	Specification 2	Specification 3	Specification 1	Specification 2	Specification 3
price	-1.07***	-0.84***	-0.79***	-1.26***	-0.85***	-0.63**
	(28.95)	(15.19)	(11.03)	(14.29)	(6.83)	(2.54)
trade	0.18***	0.14**	0.17**	0.14***	0.11**	0.09*
	(21.94)	(2.58)	(2.44)	(10.11)	(2.45)	(1.99)
tourists	0.07***	0.11**	0.09*	0.03***	0.05	0.11
	(5.34)	(2.52)	(2.04)	(4.11)	(1.05)	(1.1)
rd	0.72	0.63*	0.48*	1.53	0.24*	0.31*
	(1.32)	(2.01)	(2.11)	(0.48)	(2.039	(2.15)
gdp	0.12***	0.19**		0.14***	0.23**	
	(10.1)	(2.53)		(10.18)	(2.33)	
line	1.19	0.72*		0.18**	0.14*	
	(1.15)	(2.03)		(2.29)	(1.91)	
Spatial component						
k	0.13***			0.16***		
	(13.36)			(15.35)		
k_1		0.16**	0.14**		0.07**	0.04*
		(2.67)	(2.93)		(2.61)	(1.84)
Trade/tourism component						
k_2		0.11***	0.09***		0.03	0.03*
		(8.01)	(6.84)		(0.54)	(1.93)
Interaction component						
ρ_1			0.04**			0.05**
			(2.61)			(3.02)
ρ_2			0.07*			0.03*
			(2.07)			(1.99)
Country dummies	No	Yes	Yes	No	Yes	Yes
R^2 adjusted	0.57	0.58	0.59	0.61	0.68	0.71
F test	8.86	9.17	9.89	8.42	9.59	9.22
Chi square test	88.62	93.64	94.77	86.23	90.12	93.68

Note: Numbers in parentheses are t statistics, where *, **, *** are significance at 10%, 5% and 1% respectively.

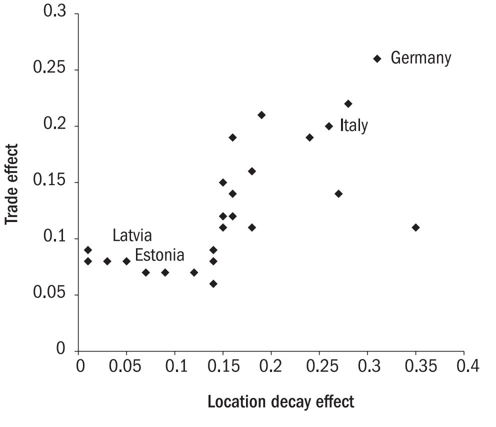
suggest that clusters of countries with similar financial and social standards encourage the demand for telecommunications. Consequently, there are connectivity structure effects in international telecommunications, of both competitive and agglomerative nature.

D. Country-specific effects

We further investigate the spatial effects in telecommunications by examining the relationship between country-specific effects and location decay effects. For this purpose, we use equation (3) to examine country specific decay effect through the use of dummy variables. Actually, we evaluate it for each country separately and we plot the bundle of trade (Figure 1) –or tourism (Figure 2)– weights along with the spatial (decay) weights. Hence, we plot the coefficient of spatial, trade, and tourism components per country, resulting in 25 points of observation (number of European countries), to get the individual country specific effects. The results are shown in Figures 1 and 2 with respect to trade and tourism effects.

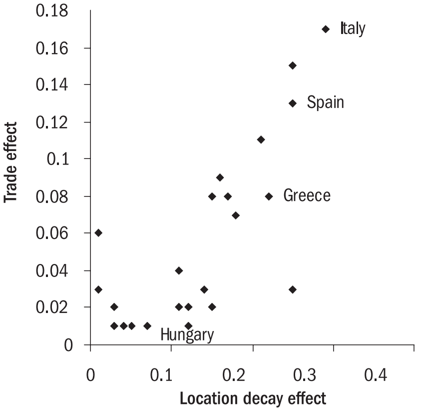
Figure 1 reveals a strong relationship between the existence of geographical interconnections (location decay effect) and the importance of trade flows (country-specific trade effects) which indicates that geographical clusters play an important role in trade activities. This may be attributed to three factors: First, countries with several trade partners and important volume of trade (i.e., Germany and Italy) are more likely to present high trade effects and high degree of clustering, a result which

Figure 1. Estimated country-specific trade effects and location decay effect



Note: European countries are represented by dots.

Figure 2. Estimated country-specific tourism effects and location decay effect



Note: European countries are represented by dots.

is in line with Krugman (1991). Second, locational concentrations may result from cultural commonalities which encourage extended financial activities. Thus, countries which present low trade activities (e.g., Estonia and Latvia) normally exhibit insignificant locational decay effect.

Figure 2 illustrates the relationship between the existence of geographical interconnections (location decay effect) and tourism flows (country-specific tourism effects) across the European Union. For instance, Greece and Italy are characteristic cases of tourism and geographical externalities, since significant flows of visitors are partially facilitated by the geographical proximity of those countries. These countries present similar values of country-specific tourism effects and similar values of locational decay effect. In contrast, Hungary and Spain exhibit significantly different values of both country-specific tourism effects and locational decay effect.

IV. Concluding remarks

In this study, we examine demand models for telecommunications for European countries in the context of spatial econometrics. In fact, because of the geographic heritage of these models, their primary application is to incorporate physical notions of space (distance) into the estimation procedure and to argue that geographically nearby units are linked together. Telecommunications in any country depend on the telecommunications in proximate countries or on similar countries in terms of economic or social characteristics. Such types of interdependences have been largely ignored by the empirical telecommunication literature with only a couple of recent papers accounting for such issues in their estimation. This paper manages to incorporate them in its approximation using data from the European Union. Actually, geographic proximity (spatial effects) has a significant role since it allows for the study of agglomeration spillovers, trade interdependencies (economic effects) emphasize the existence of strong financial relationships across European countries and considerable tourism flows (social effects) show a pattern of human migration across Europe. The latter effects are essential for the analysis of telecommunication models.

The most important aspect in spatial econometrics is the definition of the connectivity matrix. We defined the distance weight matrices in three different ways: i.e., a) a binary distance measure of contiguity, b) an inverse distance measure of contiguity and c) a k-neighbors measure of contiguity for $k = 6$, and we also considered two alternative weight matrices: an economic weight matrix using the volume of trade and a social weight matrix using the flow of tourist to incorporate the economic and social effects. This study finds evidence of important connectivity effects and the results are robust across the different specifications of connectivity matrices. Moreover, they indicate the importance of trade and tourism for telecommunications services in any country.

Geographic and other spatial characteristics may have a different impact on internet networks than on mobile or wire line communications networks. The rise of these alternative and competing networks presents a potential problem for our approach. For instance, in the United States there has been a significant decline in measured or metered telecom service –which is being replaced first by flat rates for local and toll calls, and later by bundled service packages– masking the per unit call price. Thus, the emergence and the rapid growth of these alternative networks and payment plans should be evaluated on a parallel basis since the nature of this sector of telecommunications is different from the one studied in this paper.

The results we present are innovative for the existing literature of telecommunications. Omitted variable bias is limited in telecommunications models with spatial, economic and social connectivity effects. On the other hand, it is worth noting that we find significant omitted telecommunications variable bias under economic or social criteria. This point is particularly applicable to the few previous studies of spatial effects in empirical telecommunications models.

Appendix

Table A1. Aggregate demand for telecommunications and decay rates

Country	Aggregate demand				Decay rates			
	1999	2000	2001	2002	1999	2000	2001	2002
Austria	2517.8	2648.4	2356.4	2377.5	0.15	0.14	0.14	0.15
Belgium	1249.8	1543.1	1767.5	1865.4	0.18	0.17	0.19	0.21
Czech Rep.	454.5	359.9	321.7	315.6	0.35	0.39	0.41	0.38
Cyprus	163.0	195.6	220.2	255.8	0.15	0.17	0.17	0.18
Denmark	655.8	700.5	740.0	656.4	0.01	0.02	0.02	0.02
Germany	7900.0	9223.0	8386.0	9474.0	0.16	0.18	0.17	0.19
Estonia	73.4	75.5	48.2	78.2	0.31	0.32	0.36	0.34
France	3200.0	3487.6	3675.4	3781.9	0.05	0.06	0.06	0.05
Finland	588.9	700.0	456.7	567.9	0.28	0.32	0.33	0.32
Great Britain	7077.5	7751.2	7935.1	8356.4	0.16	0.17	0.18	0.19
Greece	728.7	724.6	718.5	1123.1	0.19	0.21	0.22	0.21
Hungary	131.1	134.1	132.7	139.2	0.16	0.20	0.21	0.20
Spain	1956.0	2547.0	3178.6	3297.8	0.12	0.13	0.14	0.15
Sweden	1516.0	1642.0	1360.0	1363.0	0.27	0.30	0.31	0.31
Ireland	1015.0	1639.0	1543.7	1774.2	0.16	0.18	0.18	0.19
Italy	3523.0	3849.0	5021.4	5788.3	0.09	0.10	0.11	0.10
Latvia	56.3	63.2	61.1	63.0	0.26	0.29	0.30	0.28
Lithuania	59.9	64.9	67.1	81.3	0.03	0.03	0.03	0.04
Luxembourg	319.1	366.3	394.6	366.0	0.01	0.01	0.01	0.02
Malta	39.0	25.2	28.7	29.5	0.15	0.17	0.17	0.16
Netherlands	2150.0	2500.0	2600.0	2877.6	0.07	0.08	0.08	0.07
Poland	624.2	663.7	706.7	752.9	0.24	0.26	0.28	0.29
Portugal	540.0	511.0	550.4	541.0	0.18	0.20	0.21	0.22
Slovenia	181.7	220.7	249.2	106.7	0.15	0.17	0.17	0.18
Slovakia	162.7	162.2	172.5	214.9	0.14	0.15	0.16	0.15

Note: Aggregate demand shows the total minutes of demand for international outgoing calls where decay rates are estimated based on equation (5) and by using data from each country as suggested in Section II.

Table A2. Spatial weights

Country	Austria	Belgium	Czech Rep.	Cyprus	Denmark	Germany	Estonia	France	Finland	Great Britain	Greece	Hungary	Spain	Sweden	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Netherlands	Poland	Portugal	Slovenia	Slovakia
Austria	0																								
Belgium	0.4	0																							
Czech Rep.	0.9	0.7	0																						
Cyprus	0.2	0.1	0.2	0																					
Denmark	0.3	0.7	0.4	0.1	0																				
Germany	0.9	0.9	0.9	0.1	0.9	0																			
Estonia	0.6	0.5	0.6	0.1	0.8	0.8	0																		
France	0.8	0.9	0.8	0.1	0.6	0.9	0.2	0																	
Finland	0.3	0.5	0.4	0.1	0.8	0.8	0.9	0.4	0																
Great Britain	0.3	0.9	0.6	0.1	0.8	0.7	0.6	0.8	0.7	0															
Greece	0.5	0.3	0.6	0.9	0.2	0.4	0.1	0.6	0.1	0.1	0														
Hungary	0.9	0.7	0.8	0.1	0.6	0.8	0.6	0.6	0.4	0.3	0.6	0													
Spain	0.8	0.8	0.6	0.1	0.6	0.7	0.1	0.9	0.1	0.7	0.3	0.5	0												
Sweden	0.3	0.5	0.4	0.1	0.8	0.8	0.9	0.4	0.9	0.7	0.2	0.4	0.3	0											
Ireland	0.3	0.8	0.6	0.1	0.8	0.7	0.6	0.8	0.7	0.9	0.1	0.2	0.6	0.4	0										
Italy	0.8	0.7	0.7	0.2	0.5	0.8	0.3	0.9	0.4	0.6	0.9	0.6	0.8	0.4	0.2	0									
Latvia	0.3	0.5	0.4	0.1	0.8	0.8	0.9	0.3	0.8	0.6	0.2	0.3	0.2	0.7	0.4	0.2	0								
Lithuania	0.3	0.5	0.4	0.1	0.8	0.8	0.9	0.3	0.8	0.6	0.2	0.3	0.2	0.7	0.4	0.2	0.9	0							
Luxembourg	0.8	0.9	0.8	0.1	0.6	0.9	0.2	0.9	0.6	0.6	0.2	0.6	0..6	0.7	0.6	0.6	0.7	0.6	0						
Malta	0.8	0.7	0.7	0.2	0.5	0.8	0.3	0.9	0.4	0.6	0.9	0.6	0.8	0.4	0.2	0.9	0.4	0.1	0.3	0					
Netherlands	0.8	0.9	0.8	0.1	0.6	0.9	0.2	0.9	0.6	0.6	0.2	0.6	0..6	0.7	0.6	0.6	0.7	0.6	0.9	0.2	0				
Poland	0.3	0.5	0.4	0.1	0.8	0.8	0.7	0.3	0.8	0.6	0.2	0.3	0.2	0.7	0.4	0.2	0.8	0.9	0.8	0.4	0.7	0			
Portugal	0.7	0.7	0.5	0.1	0.5	0.5	0.1	0.8	0.1	0.6	0.2	0.2	0.9	0.2	0.1	0.4	0.1	0.1	0.4	0.3	0.5	0.3	0		
Slovenia	0.9	0.7	0.7	0.1	0.5	0.8	0.3	0.9	0.4	0.6	0.9	0.9	0.8	0.4	0.2	0.9	0.5	0.5	0.6	0.7	0.7	0.8	0.4	0	
Slovakia	0.9	0.7	0.9	0.1	0.5	0.8	0.3	0.9	0.4	0.6	0.9	0.9	0.8	0.4	0.2	0.9	0.5	0.5	0.6	0.7	0.9	0.8	0.4	0.8	0

Note: Estimation of the non-standardized weights is done with the SpaceStat software.

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