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Regional growth and convergence in the Spanish Provinces

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41st Congress of the European Regional Science Association. European Regional Development Issues in the New Millennium and Their Impact on Economic Policy

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title: Regional growth and convergence in the Spanish provinces

Abstract:

The aim of this paper is to quantify the effects of the spatial diffusion of growth, on the convergence process observed among the Spanish regions during the last 20 years.

A preliminary study on the β regional convergence processes, considering regions as geographically independent elements, is followed by the analysis of the spatial dimension of data: the possibility of spatial interactions among regions is tested using the spatial autocorrelation Moran's I index.

Finally, the spatial autocorrelation detected is included in the β -convergence model, in order to correct, on the one hand, the statistical inference problems originated in the spatial dependence of regions, and, on the other hand, to be able to quantify the regional spill-over effects of growth. Several spatial weights matrixes made of index numbers elaborated in analogy with Newton's gravitational law allow choosing the best-fit model.

The purpose of this paper is to quantify the spillover effects of growth on the convergence process experimented by the fifty Spanish provinces over the period 1980-1995. This requires the explicit introduction of spatial effects on the traditional β -convergence regression specifying the structure of the spatial dependence detected. This indirectly refers to the estimation of the matrix of spatial weights that best expresses the real spatial interactions that take place between regions and permit the geographical intergeneration and transmission of economic growth.

Section 1 discusses the scarce importance traditionally given to space effects on the β -convergence regressions. They rarely include explicitly the spatial heterogeneity or the spatial dependence, in spite of the strong geographical character of the elements described by neoclassical growth theory as being directly responsible for the convergence phenomena. We will correct that in section 2, following the previous analysis conducted by Rey and Montouri (1999) through the reformulation of a β -convergence model that takes into account the spatial autocorrelation detected by means of the Moran's I index. Finally, section 3 deals with the choice of the best spatial weights matrix through the introduction of three new variables underlying behind spatial interactions: distance, population and communication infrastructures.

1. Space matters

Most of the growth empirical literature considers the analyzed economic units independently of their geographical absolute or relative locations and links with other economic regions. The study of β -convergence has focused on investigating the existence of a long-term tendency towards the equalization of per capita income or product levels between nations or regions. The unique purpose was to contrast if poorer economies tend to grow faster than wealthier ones, without considering the spatial effects of the traditional mechanisms that are said to drive regional convergence, such as technological diffusion, factor mobility or transfers of payments.

The obtained results supported so far conditional convergence. As reflected in table 1, regions and nations seemed to be converging towards their national steady state at an annual rate of about 2 percent (Baumol, 1986; Dowrick and Nguyen, 1989; Barro, 1991 and Barro and Sala-i-Martin, 1991, 1992).

Table 1: Regional convergence

Countries	β (s.e.)	R^2 (s.e. regression)
USA (48 states) (1880-1990)	0,017 (0,002)	0,89 (0,0015)
Japan (47 prefectures) (1955-1990)	0,019 (0,004)	0,59 (0,0027)
Total Europe (90 regions) (1950-1990)	0,015 (0,002)	

Germany (11 regions)	0,014 (0,005)	0,55 (0,0027)
United Kingdom (11 regions)	0,030 (0,007)	0,61 (0,0021)
France (21 regiones)	0,016 (0,004)	0,55 (0,0022)
Italy (20 regions)	0,010 (0,003)	0,46 (0,0031)
Spain (17 regions) (1955-1987)	0,023 (0,007)	0,63 (0,004)
Canada (10 provinces)	0,024 (0,008)	0,29 (0,0025)

Recent literature, though, focuses on a regional scale. It allows a larger number of observations (Baumol, 1986; Abramovitz, 1986; Mankiw et al., 1992) and reflects in the late 90's a recognition of the importance of geography to regional income growth patterns. Regions are economically linked and constantly influenced by the economic performance of neighbor areas.

Lately, additional theoretical support has been given to the importance of location on growth processes. Following Krugman (1991) and Puga (1998), the location of manufacturing activities depends on the size of the market, which is, at the same time, determined by the initial spatial distribution of manufacturing. The accumulative process described can consolidate this way on a core-periphery pattern, far from the admitted conditional convergence at a 2% annual rate.

Finally, only in a few recent cases the introduction of spatial statistics and econometrics techniques in the empirical studies has permitted to correct the inference problems derived from the violation of the traditional assumptions of independence of observations and absence of correlation between variables and error terms (Armstrong, 1995; Fingleton, 1999; Rey and Montouri, 1999; López-Bazo et al., 1999).

Moreover, the use of spatial econometrics allows to explicitly introduce the spatial effects in the convergence model, and thus to quantify the spatial spillovers related to the endogenous variable (spatial lag model) or related to the omitted spatial variables in the original regression (spatial error model).

2. Spatial dependence on the Spanish provinces β -convergence model

Space matters in regional convergence processes, but the way that this occurs must be formulated. In the case of the Spanish provinces, data show apparently a

geographical pattern of distribution that can be referred to as positive spatial autocorrelation.

This means that high (low) values of per capita income can be found frequently close to other high (low) values. This spatial association of similar values seems to happen with a probability higher than what could be expected from a random distribution of the data among regions. The Moran's I index tests for the accuracy of this affirmation.

For a year t, the Moran's I equals
$$I_t = \frac{n}{\sum_{i=1}^n \sum_{j=1}^n W_{ij}} \cdot \frac{\sum_{i=1}^n \sum_{j=1}^n W_{ij} (x_{it} - \bar{x}_t)(x_{jt} - \bar{x}_t)}{\sum_{i=1}^n (x_{it} - \bar{x}_t)^2}$$
 where

W_{ij} is a binary contiguity matrix which elements $w_{ij}=1$ if provinces have a common frontier and $w_{ij}=0$ if they haven't; x_{it} is the natural logarithm of per capita income measured in province i at year t; \bar{x}_t is the mean, for year t and all the provinces, of the natural logarithms of per capita income and n is the number of regions.

A Moran's I coefficient larger than its expected value, $-1/(n-1)$, indicates positive spatial autocorrelation, and a Moran's I less than its expected value indicates negative spatial autocorrelation. In relation with the 50 Spanish provinces, the expected value of the Moran's I is $-1/49 = -0,020$, and the results are presented in table 2.

Table 2. Moran's I test for spatial autocorrelation

TEST FOR SPATIAL AUTOCORRELATIONSUMMARY OF WEIGHTS MATRICESWeights							
matrix		PR01R is row standardized					
MORAN'S I TEST FOR SPATIAL AUTOCORRELATION							
(normal approximation)DATA SET: LPPR VARIABLE WEIGHT I							
MEAN	ST.DEV.	Z-VALUE	PROB	L80	PR01R	0.6688126	-
0.020	0.091073	7.567811	0.000000				
L81	PR01R	0.6514633	-0.020	0.091073	7.377311	0.000000	
L82	PR01R	0.6619302	-0.020	0.091073	7.492241	0.000000	
L83	PR01R	0.6351293	-0.020	0.091073	7.197960	0.000000	
L84	PR01R	0.6697279	-0.020	0.091073	7.577860	0.000000	
L85	PR01R	0.6658639	-0.020	0.091073	7.535433	0.000000	
L86	PR01R	0.6575483	-0.020	0.091073	7.444126	0.000000	
L87	PR01R	0.6556362	-0.020	0.091073	7.423130	0.000000	
L88	PR01R	0.6597456	-0.020	0.091073	7.468253	0.000000	
L89	PR01R	0.6743780	-0.020	0.091073	7.628920	0.000000	
L90	PR01R	0.6772016	-0.020	0.091073	7.659924	0.000000	

L91	PR01R	0.6909001	-0.020	0.091073	7.810336	0.000000
L92	PR01R	0.6869542	-0.020	0.091073	7.767010	0.000000
L93	PR01R	0.7604317	-0.020	0.091073	8.573811	0.000000
L94	PR01R	0.7692360	-0.020	0.091073	8.670484	0.000000
L95	PR01R	0.7633210	-0.020	0.091073	8.605536	0.000000

The values found for the Moran's I vary from 0,63 to 0,77 and are highly significant during the period studied, thus indicating a strong positive spatial autocorrelation.

This proven spatial dependence has to be treated explicitly in the β -convergence model, for it implies the absence of the traditional assumption on independence of observations. This means that statistical inference will not be as efficient as for an independent equivalent sample. We will obtain larger variances for estimates, lower significance levels in tests of hypothesis and a poorer fit for models.

The mathematical formulation of β -convergence can be done through the following expression: $\frac{1}{T} \ln\left(\frac{y_{i,1995}}{y_{i,1980}}\right) = \alpha + \beta \ln(y_{i,1980}) + u_i$ where y_{it} is the per capita income of region i at year t , and T is the length of the period studied (15 years in this case). By means of this expression, we contrast the possibility of a negative relation between growth during the 1980-1995 period and the level of per capita income at the beginning of the period, in 1980. If the coefficient β is negative and significant, we can conclude in favor of a phenomenon of β -convergence.

The estimation of β allows to calculate the speed of convergence $\vartheta = -\ln(1+T\beta)/T$ and the length of the period needed for regions to cover half the distance that separates them from their steady state per capita income $\tau = -\ln(2)/\ln(1+\beta)$. The results of the initial estimation are presented in table 3.

Table 3: β -convergence model. OLS estimation.

ORDINARY LEAST SQUARES ESTIMATION							
DATA SET		CRECS					
DEPENDENT VARIABLE	CREC	OBS	50	VARS	2	DF	48
R2	0.0613	R2-adj	0.0418				
LIK	183.203	AIC	-362.406	SC	-358.582		
RSS	0.00192279	F-test	3.13647	Prob	0.0829086		
SIG-SQ	4.00581e-05	(0.00632915)	SIG-SQ(ML)	3.84558e-05	(0.00620127)		
VARIABLE	COEFF	S.D.	t-value	Prob			
CONSTANT	0.0682904	0.0273712	2.494976	0.016090			
L80	-0.00732949	0.0041386	-1.771009	0.082909			

The F test on the joint significance of slope coefficients takes on a value of 3,15, which for a F distribution of 48 degrees of freedom is not significant at a 95% level. It would only be significant at a 90% level. As a confirmation of that, we have to point out de same 90% low significance level for the coefficient estimated for the explanatory variable ($t = -1,78$).

Those results cannot permit to conclude in favor of a β -convergence process among Spanish provinces during the period of study. Furthermore, the regression diagnostics for spatial dependence (table 4) indicates the presence of spatial autocorrelation, as predicted by the Moran's I.

Table 4: β -convergence model. OLS estimation. Regression diagnostics

REGRESSION DIAGNOSTICS				
TEST ON NORMALITY OF ERRORS				
TEST	DF	VALUE	PROB	
Jarque-Bera	2	0.706091	0.702545	
DIAGNOSTICS FOR HETEROSKEDASTICITY				
RANDOM COEFFICIENTS				
TEST	DF	VALUE	PROB	
Breusch-Pagan test	1	0.121116	0.727827	
SPECIFICATION ROBUST TEST				
TEST	DF	VALUE	PROB	
White	2	1.157350	0.560641	
DIAGNOSTICS FOR SPATIAL DEPENDENCE				
FOR WEIGHTS MATRIX PR01R (row-standardized weights)				
TEST		MI/DF	VALUE	PROB
Moran's I (error)		0.248950	3.191069	0.001417
Lagrange Multiplier (error)		1	6.767605	0.009283
Robust LM (error)		1	14.779501	0.000121
Kelejian-Robinson (error)		2	11.039072	0.004008
Lagrange Multiplier (lag)		1	3.985580	0.045891
Robust LM (lag)		1	11.997475	0.000533
Lagrange Multiplier (SARMA)		2	18.765081	0.000084

The diagnosis for spatial dependence is conducted by means of a group of indicators, meaningful only in the case of normality of errors, exception made for the Kelejian-Robinson statistic that can be used in any case. The Jarque-Bera test presents a value of 0,71, which, for a distribution with 2 degrees of freedom, doesn't allow rejecting the null hypothesis of normality of errors. The whole group of spatial dependence test can then be taken into account.

The Moran's I adapted to the regression residuals by Cliff and Ord (1981) is the most extended test, but is unreliable. Following Anselin and Rey (1991), this statistic picks up a range of misspecification errors such as non-normality and heteroskedasticity, as well as spatial lag dependence. Moreover, it does not provide the information on the type of spatial dependence omitted. Anselin and Rey (1991) have proved that the joint use of the Lagrange Multipliers LM_{ERR} and LM_{LAG} statistics is the best way to choose the structure of the spatial dependence that provides the best fit for the data analyzed, the substantive or the error dependence.

Each test has the highest power of testing the case for which it was designed, even though it also detects the other alternative. Thus, when both test are significative, as in this case ($LM_{ERR} = 6,77$ and $LM_{LAG} = 3,99$), the one with the highest value represents the best alternative (LM_{ERR}). We can conclude, then, in favor of the presence of spatial dependence in regression residuals.

As all ignored elements in the specification of a regression are contained in the error term, if this one show a spatial pattern, it necessarily comes from the spatial interaction and spatial externalities present in those omitted variables.

When residuals follow a spatial autoregressive first order process, the model can be expressed as:

$$\frac{1}{T} Ln\left(\frac{y_{i,1995}}{y_{i,1980}}\right) = \alpha + \beta Ln(y_{i,1980}) + \varepsilon \quad \varepsilon = \lambda W\varepsilon + u \quad u \approx N(0, \sigma^2 I)$$

with λ being the scale parameter which represents the intensity of spatial autocorrelation between error terms. The lack of independence of error terms prevents against the use of Ordinary Least Squares estimation method in order to avoid the inefficiency of estimators. The estimation has to be done through the Maximum Likelihood Method.

Spatial autocorrelation of error terms implies that a shock in a specific region is transmitted to all the regions considered in the study. As $\varepsilon = \lambda W\varepsilon + u$, we can express it with $\varepsilon = (1 - \lambda W)^{-1}u$, and the whole model can be rewritten in the following terms:

$$\frac{1}{T} \text{Ln}\left(\frac{y_{i,1995}}{y_{i,1980}}\right) = \alpha + \beta \text{Ln}(y_{i,1980}) + (1 - \lambda W)^{-1}u.$$

$$\varepsilon = \frac{1}{T} \text{Ln}\left(\frac{y_{i,1995}}{y_{i,1980}}\right) - \alpha - \beta \text{Ln}(y_{i,1980})$$

multiplying by λW , we obtain:

$$\lambda W\varepsilon = \lambda W \left[\frac{1}{T} \text{Ln}\left(\frac{y_{i,1995}}{y_{i,1980}}\right) \right] - \lambda \alpha W - \lambda \beta W \text{Ln}(y_{i,1980})$$

As we have:

$$\varepsilon = \lambda W\varepsilon + u$$

then:

$$\frac{1}{T} \text{Ln}\left(\frac{y_{i,1995}}{y_{i,1980}}\right) = (\alpha - \lambda \alpha W) + \beta \text{Ln}(y_{i,1980}) + \lambda W \left[\frac{1}{T} \text{Ln}\left(\frac{y_{i,1995}}{y_{i,1980}}\right) \right] - \lambda \beta W \text{Ln}(y_{i,1980}) + u$$

or:

$$\frac{1}{T} \text{Ln}\left(\frac{y_{i,1995}}{y_{i,1980}}\right) = \text{constant} + \beta \text{Ln}(y_{i,1980}) + \rho W \left[\frac{1}{T} \text{Ln}\left(\frac{y_{i,1995}}{y_{i,1980}}\right) \right] + \gamma W \text{Ln}(y_{i,1980}) + u$$

with: $\rho = \lambda$, $\gamma = -\lambda \beta$ y $u \approx N(0, \sigma^2 I)$

This model presents two kinds of spillover or spatial diffusion effects. On the one hand, the growth rate of a province i is influenced by the growth rate of regions spatially connected to her through the endogenous variable spatially lagged, $W \left[\frac{1}{T} \text{Ln}\left(\frac{y_{i,1995}}{y_{i,1980}}\right) \right]$. On the other hand, growth rate of a province i is also related to the initial per capita income levels of contiguous provinces through the spatially lagged exogenous variable $W \text{Ln}(y_{i,1980})$.

The results of the estimated β -convergence for Spanish provinces through a spatial error model are presented in table 5.

Table 5: Spatial error model. Maximum likelihood estimation

SPATIAL ERROR MODEL - MAXIMUM LIKELIHOOD ESTIMATION						
DATA SET	CRECS	SPATIAL WEIGHTS MATRIX			PR01R	
DEPENDENT VARIABLE	CREC	OBS	50	VAR	2	DF 48
R2	0.4487	Sq. Corr.	0.0613	R2(Buse)	0.2112	
LIK	187.848	AIC	-371.695	SC	-367.871	
SIG-SQ	2.88572e-05	(0.00537189)		
VARIABLE	COEFF	S.D.	z-value	Prob		
CONSTANT	0.151261	0.0359212	4.210906	0.000025		
L80	-0.0198233	0.00541791	-3.658855	0.000253		
LAMBDA	0.61146	0.129001	4.739948	0.000002		

All coefficients are highly significant, including the spatial autoregressive parameter, lambda. Relative to the OLS estimates, the spatial error model achieves a higher likelihood (187,85 vs. 183,20 for OLS), which is to be expected, given the indications of the various diagnoses for spatial error dependence in the standard model and the high significance of λ .

The information criteria AIC (Akaike Information Criterion) and SC (Schwartz Criterion) also indicate a best fit for this model in relation with the OLS one (-371,70 and -367,87 vs. -362,41 and -358,58 for OLS), and there are no trace for heteroskedasticity in the model, as shown by the Breusch-Pagan and the Spatial B-P tests that show a value of 0,26.

The estimated spatial error model for Spanish provinces for the period 1980-1995 can be expressed this way

$$\frac{1}{T} \ln\left(\frac{y_{i,1995}}{y_{i,1980}}\right) = \text{constant} - 0,01982 \ln(y_{i,1980}) + 0,61146W \left[\frac{1}{T} \ln\left(\frac{y_{i,1995}}{y_{i,1980}}\right) \right] + 0,01212W \ln(y_{i,1980}) + u$$

The speed of convergence attains an annual rate of a 2,35% ($\vartheta = -\ln(1+T\beta)/T = 0,0235$) which settles the half life to 34,62 years, once the spatial effects are controlled for ($\tau = -\ln(2)/\ln(1+\beta) = 34,62$).

3. Spatial weights matrices: a gravity choice

All the spatial interactions considered for the estimation of the previous model have been done considering a simple binary contiguity matrix W_{ij} , which elements w_{ij}

are set to the value of 1 if provinces have a common frontier, and $w_{ij}=0$ if there's no contiguity between regions.

This supposes that the spatial economic relation of a province has the same intensity with all its contiguous regions, no matter the distance that separates their principal cities or the population of the neighbor provinces, or even the stock of communication infrastructure.

We'll try to correct this excessive simplification by the introduction of data accounting for these three fundamental elements for spatial economic interaction: distance, population and communication infrastructures. Different index numbers combining the mentioned elements are proposed as new possible elements for a spatial weights matrix. The selection criterion will be the best fit of the spatial error model built in section 2. Our purpose is the identification of the spatial weights matrix that best expresses the spatial interactions that do take place between regions and permit the geographical intergeneration and transmission of economic growth.

The data used are the total number of habitants of the province, the distance (in kilometers) by road that separates the principal cities of each province and, finally, the total number of kilometers of roads present in each province. The indexes proposed are inspired in the gravity model

The gravity model, based on an analogy with Newton's gravitational law (1686), has already been used to account for human behavior (Stewart, 1950; Anderson, 1979; Haynes, 1984; Isard, 1975 et 1998) related to spatial interaction, such as migration (Zipf, 1946; Sen, 1995) or shopping activities (Reilly, 1931).

Newton's law states that the attractive force between two bodies is directly related to their size and inversely related to the distance between them. Thus, the first index proposed as a measure of spatial economic interactions is:

$$I_{p \times d} = \frac{P_i * P_j}{d^2}$$

with :

P_i = population of province i

d_{ij} = distance (in kilometers) by road between principal cities of provinces i and j

Other index numbers of potential spatial economic interaction are built based on this first one. The suppositions behind the selection made are the existence of a direct relation between spatial economic interaction and variables expressing number of habitants or communication infrastructure, and, on the other hand, the existence of an inverse relation between potential links and distance.

Contiguity and distance

$I_{prdir_{ij}}$: Simple contiguity: estimated model

$$I_{prdir_{ij}} = \frac{w_{ij}}{d_{ij}}$$

$$I_{2prdir_{ij}} = \frac{w_{ij}}{d_{ij}^2}$$

with :

d_{ij} = distance (in kilometers) by road between principal cities of provinces i and j

w_{ij} = 1 if the provinces i and j present a common frontier, and 0 if they don't.

Population and distance

$$I_{pxp_{ij}} = P_i * P_j$$

$$I_{pxpd_{ij}} = \frac{P_i * P_j}{d_{ij}}$$

$$I_{pxpd2_{ij}} = \frac{P_i * P_j}{d_{ij}^2}$$

$$I_{pmp_{ij}} = P_i + P_j$$

$$I_{pmpd_{ij}} = \frac{P_i + P_j}{d_{ij}}$$

$$I_{pmpd2ij} = \frac{P_i + P_j}{d_{ij}^2}$$

with :

P_i = population of province i

d_{ij} = distance (in kilometers) by road between principal cities of provinces i and j

Communication and distance

$$I_{kxk_{ij}} = Km_i * Km_j$$

$$I_{kxkd_{ij}} = \frac{Km_i * Km_j}{d_{ij}}$$

$$I_{kxkd2_{ij}} = \frac{Km_i * Km_j}{d_{ij}^2}$$

$$I_{kmk_{ij}} = Km_i + Km_j$$

$$I_{kmkd_{ij}} = \frac{Km_i + Km_j}{d_{ij}}$$

$$I_{kmkd2_{ij}} = \frac{Km_i + Km_j}{d_{ij}^2}$$

with :

Km_i = total length (in kilometers) of roads built in province i

d_{ij} = distance (in kilometers) by road between principal cities of provinces i and j

Population, communication and distance

$$I_{kkpp_{ij}} = Km_i * Km_j * P_i * P_j$$

$$I_{kkppd_{ij}} = \frac{Km_i * Km_j * P_i * P_j}{d_{ij}}$$

$$I_{kkppd2ij} = \frac{K_{m_i} * K_{m_j} * P_i * P_j}{d_{ij}^2}$$

$$I_{kmpij} = (K_{m_i} + K_{m_j}) * (P_i + P_j)$$

$$I_{kmpdij} = \frac{(K_{m_i} + K_{m_j}) * (P_i + P_j)}{d_{ij}}$$

$$I_{kmpd2ij} = \frac{(K_{m_i} + K_{m_j}) * (P_i + P_j)}{d_{ij}^2}$$

$$I_{kxpij} = (K_{m_i} + K_{m_j}) * (P_i * P_j)$$

$$I_{kxpdij} = \frac{(K_{m_i} + K_{m_j}) * (P_i * P_j)}{d_{ij}}$$

$$I_{kxpd2ij} = \frac{(K_{m_i} + K_{m_j}) * (P_i * P_j)}{d_{ij}^2}$$

with :

P_i = population of province i

K_{m_i} = total length (in kilometers) of roads built in province i

d_{ij} = distance (in kilometers) by road between principal cities of provinces i and j

Table 5 summarizes the principal results.

Table 5: Spatial Weights Matrix selection. Summary of principal results

Spatial Weights index	LIK	AIC	SC	Constante (proba)	L80 (proba)	λ (proba)
$I_{pr01r_{ij}}$	187.848	-371.695	-367.695	0.1512 (0.000)	-0.0198 (0.000)	0.6115 (0.000)
$I_{prdir_{ij}}$	186.861	-369.721	-365.897	0.1343 (0.000)	-0.0173 (0.001)	0.5396 (0.000)

l2prdir_{ij}	185.669	-367.339	-363.515	0.1028 (0.002)	-0.0125 (0.014)	0.3824 (0.008)
lpxp_{ij}	188.579	-373.157	-369.333	0.1202 (0.000)	-0.0152 (0.002)	0.4766 (0.000)
lpxpd_{ij}	187.741	-371.483	-367.659	0.1077 (0.001)	-0.0133 (0.007)	0.4192 (0.002)
lpxpd2_{ij}	186.978	-369.957	-366.133	0.0944 (0.003)	-0.0113 (0.020)	0.3470 (0.010)

Spatial Weights index	LIK	AIC	SC	Constante (proba)	L80 (proba)	λ (proba)
lpmp_{ij}	189.163	-374.325	-370.501	0.1282 (0.000)	-0.0164 (0.001)	0.5179 (0.000)
lpmpd_{ij}	188.118	-372.235	-368.411	0.1130 (0.000)	-0.0141 (0.005)	0.4490 (0.001)
lpmpd2_{ij}	187.057	-370.114	-366.290	0.0957 (0.003)	-0.0115 (0.019)	0.3529 (0.011)
lkxk_{ij}	191.077	-378.155	-374.331	0.1614 (0.000)	-0.0213 (0.000)	0.6451 (0.000)
lkxkd_{ij}	189.303	-374.606	-370.782	0.1407 (0.000)	-0.0182 (0.000)	0.5609 (0.000)
lkxkd2_{ij}	187.271	-370.542	-366.718	0.1064 (0.001)	-0.0130 (0.011)	0.3960 (0.005)
lkmk_{ij}	190.896	-377.791	-373.967	0.1581 (0.000)	-0.0208 (0.000)	0.6344 (0.000)
lkmkd_{ij}	189.268	-374.537	-370.713	0.1387 (0.000)	-0.0179 (0.000)	0.5547 (0.000)
lkmkd2_{ij}	186.377	-368.754	-364.930	0.0891 (0.005)	-0.0105 (0.032)	0.2917 (0.034)
lkkpp_{ij}	188.885	-373.769	-369.945	0.1268 (0.000)	-0.0162 (0.001)	0.5017 (0.000)
lkkppd_{ij}	187.890	-371.780	-367.956	0.1114 (0.000)	-0.0139 (0.005)	0.4344 (0.001)
lkkppd2_{ij}	187.080	-370.160	-366.336	0.0969 (0.002)	-0.0117 (0.017)	0.3585 (0.008)
lkmp_{ij}	189.489	-374.979	-371.155	0.1333 (0.000)	-0.0172 (0.000)	0.5379 (0.000)
lkmpd_{ij}	188.272	-372.543	-368.719	0.1159 (0.000)	-0.0146 (0.004)	0.4609 (0.000)
lkmpd2_{ij}	187.146	-370.292	-366.468	0.0975 (0.002)	-0.0118 (0.017)	0.3613 (0.009)
lkmxp_{ij}	188.791	-373.582	-369.758	0.1243 (0.000)	-0.0158 (0.001)	0.4928 (0.000)
lkmxpd_{ij}	187.857	-371.714	-367.890	0.1099 (0.000)	-0.0137 (0.005)	0.4294 (0.001)
lkmxpd2_{ij}	187.055	-370.111	-366.287	0.0959	-0.0115	0.3545

				(0.002)	(0.018)	(0.009)
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We can extract the following conclusions from the comparison of the obtained results. Related to the paper of distance in spatial economic interaction, the presence of its inverse (or the squared inverse) in the index numbers elaborated doesn't bring any additional quality to the model. This one, reestimated several times with new index numbers incorporating the distance parameter, turns to show a lower capacity to explain the data. In a context of middle distances among cities, thus, the distance itself cannot be used to establish predictions on the intensity of spatial economic relation among provinces.

Indicators of communication infrastructures and regional population compose the best index numbers, those behind the best fit of the spatial error model. The best model corresponds to the index $I_{kxk_{ij}} = Km_i * Km_j$ which is examined in detail in table 6.

Table 6 : Estimation of chosen model

SPATIAL ERROR MODEL - MAXIMUM LIKELIHOOD ESTIMATION						
DATA SET	CRECS	SPATIAL WEIGHTS MATRIX			KXK	
DEPENDENT VARIABLE	CREC	OBS	50	VAR	2	DF
R2	0.5197	Sq. Corr.	0.0613	R2(Buse)	0.2385	
LIK	191.077	AIC	-378.155	SC	-374.331	
SIG-SQ	2.81410e-05 (0.00530481)					
VARIABLE	COEFF	S.D.	z-value	Prob		
CONSTANT	0.161431	0.0358934	4.497509	0.000007		
L80	-0.0213342	0.00539079	-3.957537	0.000076		
LAMBDA	0.645098	0.121494	5.309693	0.000000		
REGRESSION DIAGNOSTICS						
DIAGNOSTICS FOR HETEROSKEDASTICITY						
RANDOM COEFFICIENTS						
TEST	DF	VALUE	PROB			
Breusch-Pagan test	1	0.436245	0.508940			
Spatial B-P test	1	0.436512	0.508811			
DIAGNOSTICS FOR SPATIAL DEPENDENCE						
SPATIAL ERROR DEPENDENCE FOR WEIGHTS MATRIX				KXK (row-standardized weights)		
TEST	DF	VALUE	PROB			
Likelihood Ratio Test	1	15.748522	0.000072			
TEST ON COMMON FACTOR HYPOTHESIS						
TEST	DF	VALUE	PROB			
Likelihood Ratio Test	1	2.988400	0.083863			
Wald Test	1	8.909687	0.002837			
LAGRANGE MULTIPLIER TEST ON SPATIAL LAG DEPENDENCE						
WEIGHT	STAND	ZERO	DF	VALUE	PROB	

KXK	yes	no	1	4.062784	0.043838
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All coefficients are highly significant, including the spatial autoregressive parameter, lambda. Relative to the precedent model, the use of the new spatial weights matrix achieves a higher likelihood (LIK=191,077 vs. 187,85).

Moreover, the information criteria AIC (Akaike Information Criterion) and SC (Schwartz Criterion) also indicate a best fit for this model in relation with the precedent one (-378,155 and -374,331 vs. -371,70 and -367,87). There is no trace for heteroskedasticity in the model (test de Breusch-Pagan = 0,44) and the likelihood test of common factors isn't significant at a 95%, which confirms the functional form of a spatial error model.

The estimated spatial error β convergence model for Spanish provinces for the period 1980-1995 can be expressed this way:

$$\frac{1}{T} \ln\left(\frac{y_{i,1995}}{y_{i,1980}}\right) = \text{constante} - 0,02133 \ln(y_{i,1980}) + 0,64509 W \left[\frac{1}{T} \ln\left(\frac{y_{i,1995}}{y_{i,1980}}\right) \right] + 0,01376 W \ln(y_{i,1980}) + u$$

The speed of convergence attains an annual rate of a 2,57% ($\vartheta = -\ln(1+T\beta)/T = 0,0257$) which settles the half life to 32,15 years, once the spatial effects are controlled for ($\tau = -\ln(2)/\ln(1+\beta) = 32,15$).

Once internal coherence of the model assured, the conclusion we can extract is that the measure of spatial economic interrelations depends mainly on communications infrastructure and, secondarily (3rd best model), on the volume of regional population. The distance that exists among principal cities loses importance when communications reveal to be sufficient. The estimated speed of convergence is higher when the spatial effects are computed in function of communication infrastructure.

4. Conclusions

The conventional OLS estimation of β convergence applied to the 50 Spanish provinces during period 1980-1995 doesn't allow concluding in favor of the existence of a higher growth of poorer provinces. However, the detected presence of spatial autocorrelation in the error terms of the regression indicates the inefficiency of the OLS obtained estimators.

The correction of this lack of error terms independence is realized through the explicit introduction of an autoregressive functional form for residuals and the Maximum Likelihood estimation of the model. This permits to eliminate the inference problems and to establish a first quantification of spatial interaction effects among provinces, apart from concluding in favor of a β convergence process with a speed of convergence attaining an annual rate of 2,35%. The information criteria AIC (Akaike Information Criterion) and SC (Schwartz Criterion) also indicate a best fit for this model in relation with the OLS one.

Once the spatial error model established, new spatial weights matrixes based on an analogy with Newton's gravitational law are designed to express the spatial interactions that do take place among regions. The combination of three fundamental elements for spatial economic interaction: distance, population and communication infrastructures in different index numbers, allow us to conclude in favor of the principal importance of these communications infrastructures in the explanation for spatial economic interactions.

The estimations made for the best-fit model show a significant process of β convergence among Spanish provinces for the period 1980-1995, with a higher speed of an annual rate of 2,57%. Higher spatial effects, thus, allow for a higher speed of convergence in the sample and period studied.

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