The Impact of Spatial Externalities on the Economic Convergence in the Euro Mediterranean Countries: Empirical Analysis with Spatial Econometrics

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Abstract:

Recent models of economic growth have underlined the importance of external effects on the accumulation of factors of production (ROMER 1986, 1990; LUCAS 1988). The technology knowledge rises with stock of factors of production (human capital, physical capital, R&D, etc.) to witch all the producers contribute with identical manner. The idea is that the knowledge is considered as a free good and spread in entire economy. However, this new approach brings more explanation of economic growth; but it doesn't integrate the spatial dimension of these externalities.

To make better this new theory, we add for fundamental hypothesis of this approach, the hypotheses that these external effects have a geographic dimension affecting the economic convergence.

Adopting this new hypothesis, we derive an equation of convergence with external effects issue from the Mankiw, Romer & Weil (1992) model, and we propose to estimate it with the recent methods of spatial econometrics to test the presence of these externalities and to estimate their effects on the economic convergence.

For the empirical validation, relying on the application for the Euro Mediterranean countries during the period 1995-2004, and using the matrix of distance and the matrix of contiguity to measure the interactions between these countries, we estimate the equation of convergence with spatial externalities derived from the model of Mankiw, Romer & Weil (1992).

The results of estimation based on the integration of spatial dimension of externalities permit to appreciate better than the a-spatial growth theory, the effects of these externalities on the economic convergence in the case of economic integration in space. They allow to quantify a double effect of geographic spillovers and to valid the hypothesis that taking account of spatial externalities doesn't necessarily reduce the divergence between the North and the South Mediterranean countries. The reason of the persistence of this divergence is related to the absence of efficient interactions and coordination between these countries.

Key words: External effects, economic convergence, spatial econometrics, economic integration.

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INTRODUCTION

The recent models of endogenous growth have considered the importance of external effects on the accumulation of factor of production. A first approach (Romer, 1986; Lucas, 1988) tries to endogenous the technology by the **“Marshallien externalities”** on the stock of knowledge. The introduction of apprenticeship effects **“learning by doing”** permit to do of the knowledge a factor of production supplementary and to consider it as a joint output. The external effect proceeds from accrue of knowledge due to the increase of total stock of capital. Considered as a free good, meaning not perfectly appropriated by the producer, the knowledge is accessible freely and profit theoretically for all with the same manner.

A second approach (Romer, 1990; Aghion and Howitt, 1990) models explicitly the sector of research and its effects on the deepening of the technology innovation. The progress of technology proceeds then from a “production of technology” realised with a specialised activity of “R&D” which is distinct from the production

- **A first externality** proceeds from the sector of « R&D »: each researcher has potentially to accede to the stock of accumulated knowledge in this sector for his own research.

- **A second externality** proceeds from the sector of production: with baying the intermediate goods, agents profit not only from this capital, but also from the increase of the technology incorporated in these goods of production.

These two explanations of technology progress, based on endogenous accumulation of knowledge, beget theoretically increasing returns to scale in the global level which can engender endogenous growth.

However, although this contribution, the theory of endogenous growth remains limited. Especially, because it doesn’t takes into account of spatial dimension of these externalities and their role in explaining issues such as growth and economic convergence.

In this sense, the conjoint development of New Geographic Economy models (Krugman, 1991; Krugman and Venables, 1995) and the endogenous growth models in the 1990 years have permit for economists to propose more appropriate approaches of problematic “innovation-localisation-growth”(Foray, 2000).

Essentially, the theoretical models of “New Geographic Economy-Endogenous Growth” (C.Baumont, 1995) support on the hypothesis of geographic dimension of externalities of knowledge for explaining the specificity of phenomenon of spatial concentration of innovation and dynamics of differentiated growth that proceeds.

Until the beginning of 1990 years, this hypothesis hasn’t any empirical validation. Thus, only lately those empirical studies had proposed to integrate the effects of spatial externalities on the regional growth (Amstrong, 1995; Rey and Montouri, 1999; López-Bazo et al, 1999). Their suggestions are consistent with predictions of endogenous growth models and new geographic economy that insist on the role of **interactions between agents** which are considered as the sources of agglomerations of activities of innovation in some regions and not in others (Fujita et al, 1999).

On this base, in our present work we consider that **the external effects on the accumulation of factors of production (human capital and physical capital) are geographically burned and they influence the economic convergence.**

For verifying it empirically, we privilege the methods of **spatial econometrics** which constitute a powerful tool to test the presence of spatial externalities and to estimate their impacts on the regional convergence.

Starting with this new approach, we adopt for our work the following structure:

- The first section will be reserved for developing the model of Mankiew, Romer and Weil (1992) which introduces in the function of production the external effects on the accumulation of production factors (human and physical capital stocks). We suggest that the equation of convergence derived from this model possess similarities with the specifications of spatial models used in spatial econometrics.

- On this base, in the second section, we will chow why these spatial models permit to test better the presence of spatial externalities and to estimate their effects on the economic convergence.

- In the third section, we will expose results of the empirical validation applied to a sample composed of fifteen counties of the European Union and the eleven Mediterranean south counties on the period 1995-2004.

- Finally, in the conclusion, we will resume the interpretations of results.

I. MODEL OF MANKIW, ROMER AND WEIL (1992)

In this section, we present the model growth with technological externalities of Mankiw, Romer and Weil (1992).

Formally, the model of M.R.W (1992) incorporates the human capital and physical capital in the function of production:

$$y_{it} = \mathrm{A}_{\mathrm{it}} \ \mathrm{k}_{\mathrm{it}}^{\theta_{\mathrm{k}}} \ h_{it}^{\theta_{\mathrm{h}}} \qquad [1]$$

Where, y_{it} is the level of income in region i and period t, k_{it} and $h_{it,}$ the levels of physical capital and human capital and θ_ℓ (ℓ=k,h) measures the average internal returns.

The level of technology A_{it} in a region i reflect both an externality within the region i to investments in k and the technological interdependence across neighbouring regional economies. We have then,

$$\mathrm{A}_{it} = \Delta k_{it}^{\delta_k} h_{it}^{\delta_h} \left(k_{\rho it}^{\theta_k} h_{\rho it}^{\theta_h}\right)^{\gamma} \qquad [2]$$

Where, Δ is the level of exogenous technology, $\delta_l \quad (l = k, h)$ is the measure of external returns within the region to physical and human capital (caused by the effects of the accumulation of these factors in each region) and γ measures the effect of spatial externalities between economies, that is assumed to be positive.

From this expression, we can observe that the M.R.W model considers, with a latent manner that the level of technology in a region depends of the accumulation of human capital and physical capital within a region i, but also to the accumulation of these factors in the neighbouring regions by the effect of spatial externalities. This, chow that this model already predicts, but without demonstrates, that the external effects on the accumulation of factor of production are geographically burned.

Substituting [2] in [1], we obtain:

$$y_{it} = \Delta k_{it}^{(\theta_k + \delta_k)} h_{it}^{(\theta_h + \delta_h)} A_{\rho it}^{\gamma} \qquad [3]$$

From this expression, we deduce a convergence equation, such as the dynamics in the proximity of the steady state is characterised bye the following expression ([1]):

$$g_y = \xi - \left(1 - e^{-\beta T}\right) \ln y_0 + \frac{\left(1 - e^{-\beta T}\right)\gamma}{1 - (\tau_k + \tau_h)} \ln y_{0\rho} + \gamma g_{y\rho} + \frac{\left(1 - e^{-\beta T}\right)}{1 - (\tau_k + \tau_h)} [\tau_k (\ln s_k - \ln(n + g + d)) + \tau_h (\ln s_h - \ln(n + g + d)))] \qquad [4]$$

Where, $\beta = (1 - \tau_k - \tau_h)(n + g + d)$ is the spread of convergence, $\tau_k = \theta_k + \delta_k$, $\tau_h = \theta_h + \delta_h$ et

$$\xi = (1 + \gamma) g - \left(1 - e^{-\beta T}\right) \left(1 - \frac{\gamma}{1 - (\tau_k + \tau_h)}\right) (\ln \Delta_0 + gT)$$

§ ([1]) details of this transformation of convergence equation are given in the paper of López-Bazo E, Vayá E and Artís M (2004); Regional externalities and growth: evidence from European regions, *Journal of Regional Science* 44: 43-73.

Equation [4] expresses that the growth in each region depends of the level of initial income in this region, as well as of the initial level and the growth of income in the neighbouring regions.

II. ECONOMETRIC SPECIFICATION

The equation of growth with spatial externalities possesses common points with specification used in presence of spatial dependence in the spatial models defined in spatial econometrics. With these transformations, the empirical counterpart of this expression is the following:

$$\boxed{g_y = \alpha - \left(1 - e^{-\beta}\right)\ln y_0 + \lambda\left(1 - e^{-\beta T}\right)W \ln y_0 + \lambda W g_y + \varepsilon} \qquad [5]$$

Where, $\lambda\left(1 - e^{-\beta}\right)W \ln y_0$ is the spatial lag of the initial level of income; $\lambda W g_y$ is spatial lag of growth rate of income and W is the weight matrix (the definition of this matrix will be presented in the next paragraph).

This expression clearly indicates that technological externalities are associated to substantive phenomenon which implies that the growth in a region depends on the initial level of income and the initial and growth of income in neighbouring countries. Moreover, this expression explains why the empirical evidence based on the traditional spatial model selection procedure has shown preference for the spatial error specification. It is because the similarity between the expression in (5) and the spatial model of Durbin which derived from the spatial model with autocorrelation in error term.

In the following paragraph we present how the spatial model of Durbin can be derived from the equation of convergence with spatial autocorrelation in error term. Our aim is to determinate the common points of this model with our empirical specification (equation 5).

III. 1. Spatial model of Durbin

To present the spatial model of Durbin, we must at first expose the absolute convergence equation [2] with spatial autocorrelation in terms of error.

In this case, the spatial autocorrelation is defined by the fact that the errors process is such as the covariance between the different terms of error, associated for different regions is not null. When the errors follow the autoregressive process, the equation of convergence become:

$$g_y = \alpha - \left(1 - e^{-\beta T}\right) \ln y_0 + \varepsilon \qquad [6]$$
$$\varepsilon = \lambda W \varepsilon + \mu$$

Where, λ is the parameter that expresses the intensity of spatial correlation between the residues of regression and W is the weight matrix that models interactions between unities of analysis.

The use of OLS[3] method in presence of non spherical errors produces inefficient estimators. The inference based on OLS is not efficient since the estimate of variances-covariances matrix is biased.

However, since $\varepsilon = \lambda W \varepsilon + \mu$, we deduce that $\varepsilon = (I - \lambda W)^{-1} \mu$ and the model can be rewritten as:

$$g_y = \alpha - \left(1 - e^{-\beta}\right) \ln y_0 + (I - \lambda W)^{-1} \mu \qquad [7]$$

Pre-multiplying this expression by $(I - \lambda W)$, we obtain

$$g_y (I - \lambda W) = \alpha (I - \lambda W) - \left(1 - e^{-\beta T}\right) \ln y_0 (I - \lambda W) + \mu \qquad [8]$$

Thus, the expression of the spatial model of Durbin is:

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[2] Equation of convergence without spatial externalities

[3] Ordinary Least Square

$$g_y = (I - \lambda W)\alpha - (1 - e^{-\beta})\ln y_0 + \lambda W g_y + \lambda(1 - e^{-\beta})W \ln y_0 + \mu \quad [9]$$

We note that this model can correspond to a minimal model of conditional β-convergence integrating two types of spatial variables: the lag endogenous variable and lag exogenous variables.

We can remark that the restrictions in the parameters involving growth rates and the initial conditions match those in our specification (equation 5), but in the spatial model of Durbin the spatial lag of the variables affecting the steady state (summarised by the constant in the empirical specification) influences growth rates. In contrast, in our model, the letter variable does not exert any direct influence.

II.2. Definition of weight matrix W:

The concept of weight matrix constitutes a fundamental element in Spatial Econometrics because it permits to model the interactions between observations. Generally, two principal conceptions are reserved to the determination of the elements of the weight matrix, respectively founded on the principle of contiguity and on the principle of distance.

The matrix of contiguity reposes on the sharing of a common frontier between spatial unities. Formally, a contiguity matrix represents each localisation of spatial system in line and in column. The "spatial weights" (elements of weight matrix) w_{ij} of matrix of contiguity W are then defined by the following expression:

$$w_{ij} = \begin{cases} 1 & \text{if regions i and j are contiguious for order 1.} \\ 0 & \text{else.} \end{cases} \quad [10]$$

Moreover, a same contiguity matrix can represent different arrangements of spatial units: this is the problem of topological invariance (Cliff et Ord, 1981, p. 21). Then, others weight matrices appear useful.

The matrix of distance reposes on the idea that two spatial units know high (respectively low) interaction that the distance between them is low (respectively high). Cliff and Ord (1973, 1981) are the first ones that used this type of specification, by combining a function of the reverse of the distance that separates two localisations and the relative length of their common frontier. However, recently the most current specifications in the empirical studies use expressions more simple for the spatial weights.

In our work, we carry a simple matrix of distance based on the reverse of the distance that separate spatial units. In this case the elements of this matrix w_{ij} are defined as following:

$w_{ij} = 1/d_{ij}$, where d_{ij} is the distance that separate the centroids of countries i and j. [11]

However, the matrices of weights are standardised in lines for facilitating interpretation of spatial parameters after estimation. Thus, each line i of matrix of weight W is divided by the sum of elements w_{ij} that compose it and the resulting spatial weights are:

$$w_{ij}^{s} = \frac{w_{ij}}{\sum_{j} w_{ij}} \qquad [12]$$

The standardisation of the matrix of weights permits to compare the spatial parameters issued from different models.

IV. EMPIRICAL EVIDENCE FROM THE EUROMEDITERRANEAN COUNTRIES

In this section we estimate the equation of convergence with spatial externalities derived from Mankiw, Romer and Weil (1992) model. We will expose results of empirical validation on a specific sample of Euro Mediterranean countries that is composed from:

1) First, the fifteen countries of the European Union those are: Germany, France, Italy, Luxembourg, Netherlands, Greece, Spain, Portugal, Ireland, Denmark, Sweden, Finland, Austria, Belgium and United Kingdom.

2) Second, the eleven south Mediterranean countries those are: Algeria, Tunisia, Cyprus, Egypt, Israel, Lebanon, Jordan, Morocco, Turkey, Syria and Malta.

NB: for the reason of the absence of data availability, the country « Autonomy Palestinian Territory » will be excluded from the analysis.

The period of our analysis is 1995-2004. This period is particularly interesting for the analysis of the impact of spatial externalities on economic convergence, since it corresponds to crescent economic integration between the Euro Mediterranean countries, marked by acceleration of liberalisation of exchanges and by a widening of market. It corresponds also, after the reform of structural founds, to the existence of important regional political aiming to harmonise the potentialities of territories development.

The data that we use in this empirical validation are obtained from "World Indicator Data;W.I.D" version 2006. For cross section data, we use thus the variable "growth of labour productivity on the period 1995-2004" as an endogenous variable. Annual data on labour productivity are obtained by dividing yearly data of "GDP at constant price 2000" by yearly data of "number of population in employment".

Results of spatial dependence tests and results of estimation of spatial models will be plot using the contiguity matrix (equation 10) and distance matrix (equation 11).

III.1. Estimation of absolute β -convergence model:

Although our empirical specification incorporates the spatial dependence, the first step of our empirical work consists to estimate the absolute β -convergence model in cross section estimated bye the OLS:

$$g_y = \alpha - \left(1 - e^{-\beta T}\right)\ln y_0 + \varepsilon \qquad [13]$$

Our objective is to determine that the omission of introduction of spatial external effects constitute an insufficiency of absolute β -convergence model.

Results of estimation by OLS method are resumed in table 1.

- We obtain positive and statistically significant absolute convergence, but law enough. The speed of convergence is 1.8%. This value is near to 2% usually funded in the analysis of international convergence (Barro et Sala-I-Martin, 1995).

- The test of White (1980) and the test of Breusch-Pagan (1979) lead to reject the hypothesis of homoscedasticity.

III.2. Diagnostics of spatial dependence[4]:

Diagnostics of spatial dependence are presented in table 2 using the matrix of distance (first column) and using the matrix of contiguity (second column). We report five tests of specification for spatial dependence: test I of Moran adopted for regression residues (Cliff and Ord, 1981) and tests of Multiplier Lagrange and their robust versions LM_{LAG}, LM_{ERR}, RLM_{LAG} and RLM_{ERR}.

Results confirm the presence of spatial dependence in the equation of convergence. This chows that omission of introduction of spatial externalities constitutes an insufficiency of absolute β -convergence model. Details below explicit this confirmation:

- The test *I* of Moran is positive and statistically significant; indicating that residues obtained from regressions of OLS are spatially autocorrelated and that equation of convergence is not well specified.

- The test LM_{ERR} (respectively RLM_{ERR}) is more significant than LM_{LAG} (respectively RLM_{LAG}).

[4] Details on tests of spatial dependence in convergence equation are presented in annexe 2 of this paper.

The equation of convergence with spatial autocorrelation in errors seems to be the more appropriate specification. In the next step of our work we present results of estimation of this specification.

III.3. Estimation of absolute β -convergence model with spatial autocorrelation in errors:

In table 3, we present results of estimation of absolute β -convergence model with spatial autocorrelation in errors (equation 6), with maximum likelihood method, using the matrix of distance (first column) and the matrix of contiguity (column 2). The interpretation of these results is as following:

- We note a slight increase of speed of convergence that attends 2.5% with the matrix of distance and 2.3% with matrix of contiguity. This result suggests that effects of proximity favour slightly the regional convergence process, but the letter remains relatively law.

- The estimation chows strong and positive spatial autocorrelation in error terms: $\hat{\lambda}$ =0,783 with the matrix of distance and $\hat{\lambda}$ =0.523 with the matrix of contiguity.

- Although the spatial parameter is high and statistically significant, the test of common factor indicates that the restriction $\lambda\left(1-e^{-\beta}\right)+\tau$ can't be rejected[5], showing that the model with spatial autocorrelation in errors can be rewritten as a spatial model of Durbin constraint[6]. **This result confirms that our empirical specification (equation 8) resembles to the spatial model of Durbin constraint.**

[5] Details on this restriction are presented in the annexe 2.
[6] The test on the constraint of parameters is done with the test of ratio likelihood of common factor (Burridge, 1981).

On this base, it is than possible to estimate our empirical specification more efficiently, for analysing the impact of spatial externalities on economic convergence in Euro Mediterranean countries.

III.4. Estimation of empirical specification:

Table 4 resumes results of estimation of the equation of convergence with lag endogenous and lag exogenous variables (equation 8), with maximum likelihood method. Interpretation of these results is the following:

- We note that parameters of model are positive and statistically significant and they are higher than values funded in the model with spatial autocorrelation in errors. This confirms that our empirical specification is the most appropriate to analysis the effect of spatial externalities on economic convergence in the Euro Mediterranean space.

- The estimation of this model permit to quantify a double effect of geographic spillovers: first, by the level of growth in neighbouring countries ($\hat{\lambda}$=0.80 using the matrix of distance and $\hat{\lambda}$= 0.72, using the matrix of contiguity). Second, by the level of initial labour productivity in neighbouring countries ($\hat{\tau}$ =0.02, using the matrix of distance and $\hat{\tau}$ =0.01, using the matrix of contiguity).

  This result confirms the theoretical predictions which suppose that the initial level of income in neighbouring countries affects the growth of a country by the effect of pecuniary and technological externalities. This effect can be considered us « **supply-side externalities** ». Also, growth in a country is high (respectively law), if the growth of neighbouring countries is also high (respectively law). This effect can be related to « **demand-side externalities** », as a consequence, for instance, of demand from neighbours for final goods or inputs produces in a country.

- Concerning the speed of convergence, we remark that its value doesn't increase significantly after the introduction of spatial externalities, as in the case of spatial model with autocorrelation of errors.

- Finally, the test of Breusch-Pagan is not significant, indicating the absence of heteroscedasticity. Thus, the heteroscedasticity funded in the absolute β -convergence model estimated by OLS is due to the spatial autocorrelation.

CONCLUSIONS

In this paper, we analysed the impact of spatial externalities on the economic convergence in the Euro Mediterranean countries. We started by developing the model of Mankwi, Romer and Weil (1992) that introduces externalities between economies due to accumulation of human capital and physical capital. We have deduced from this model an equation of convergence that explains that the convergence to the steady state is related to externalities between countries.

For testing the existence of these externalities and estimating their impact on economic convergence we are referred to recent methods of spatial econometrics.

We have starting our empirical analysis by estimating the absolute β -convergence model, our aim is to verify if the omission if the omission of spatial externalities constitutes an insufficiently of this model. Results of estimation have shown a low speed of convergence that takes value near to 2% usually funded in the analysis of international convergence (Barro and Sala-I-Martin, 1995).

Besides, using the matrix of contiguity and the matrix of distance, the proceeding of research of spatial specification permit to confirm that the empirical specification resembles to the spatial model of Durbin, and thus we estimated our specification more efficiently.

The estimation of this model by the maximum likelihood method has shown that the growth in a country is positively affected by **the investments and existents stocks in**

neighbouring countries. Also, results show that the introduction of spatial externalities hasn't affected the increase of speed of convergence in the Euro Mediterranean area.

These results have lines with theoretical conclusions evoked by "Geography-Growth synthesis" [Baumont and Huriot, 1999]. We think that the economic integration favour dynamic agglomeration by intermediate of regional interactions, but au contrary, the letter strengthens a cumulative agglomeration process.

Therefore, the political integration of markets can't favour the convergence between countries. The diminution of interaction costs (costs of transport and costs of transaction) makes more important the role of localised factors.

This accentuates the weights of initial conditions and contributes to the aggravation of cumulative divergence process and to persistence of diagrams "centre-periphery", that is traduced by a total geographical concentration of R&D activities and of human capital and by a differentiated repartition of goods and services between countries. The specialisations of nations in innovation or in the fabrication of homogenous and traditional goods are flowed. Thus, the effects of economic integration in the Euro Mediterranean countries have engender an economic divergence process between the north and south countries due to the absence of sufficiently coordinate and interactions between them.

On this base, the efficacy of political integration amid the Euro Mediterranean space in sight of economic convergence will necessitate reinforcement of interactions between the north and south of Mediterranean, for example grace to a best application of Agreements of Barcelona and the New European Political of Neighbourhood and by the application of the proposition of the Union for the Mediterranean.

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ANNEXE 1

Table 1 : Estimation of absolute β -convergence model (equation 13)

β	0.018 (0.000)
Test of BREUSCH PAGAN Test of WHITE	14.23 (0.000) 20.007 (0.000)

Note: Estimation by OLS method. The values of critical probabilities are between parentheses. Level of significantly = 5%

Table 2: Tests of spatial dependence in absolute β -convergence model

tests	Matrix of distance	Matrix of contiguity
MORAN	18.77 (0.000)	14.58 (0.000)
LM_{ERR}	13.47 (0.000)	11.85 (0.000)
LM_{LAG}	11.12 (0.000)	10.32 (0.000)
RLM_{ERR}	9.76 (0.000)	8.56 (0.000)
RLM_{LAG}	8.23 (0.000)	6.15 (0.000)

Note: The values of critical probabilities are between parentheses. Level of significantly = 5%.

<u>Table 3</u>: Estimation of absolute β -convergence model with spatial dependence in error (equation 6)

	(1)	**(2)**
β	0.025 (0.000)	0.023 (0.000)
λ	0.63 (0.000)	0.57 (0.000)
Test of BREUSCH PAGAN	0.14 (0.707)	0.229 (0.632)
Test of common factor	0.701 (0.192)	0.972 (0.168)

Note: Estimation by Maximum Likelihood method. The values of critical probabilities are between parentheses. Level of significantly = 5%

Table 4: Estimation of empirical specification (equation 8)

	(1)	**(2)**
β	0.029 (0.000)	0.025 (0.000)
λ	0.80 (0.000)	0.72 (0.000)
$\lambda\left(1-e^{-\beta}\right)$	0.02 (0.000)	0.01 (0.000)
Test of BREUSCH PAGAN	0.16 (0.222)	0.13 (0.132)

Note: Estimation by Maximum Likelihood method. The values of critical probabilities are between parentheses. Level of significantly = 5%.

ANNEXE2

Tests of spatial dependence in absolute β -convergence model

The spatial dependence in residues of absolute β -convergence model can be modelled with different manner. However, the choice between different specifications (model with lag endogenous variable or model with spatial error) necessitates a series of tests such as the alterative hypothesis offers an explicit spatial specification. These proceedings of test can be founded on principles of likelihood Ratio, Wald or Lagrange Multiplier, the letter presenting the interest because it necessitate only the estimation of the absolute β -convergence model, by OLS method, facilitating thus statistical inference considerably.

a. Test *I* of Moran for omission of spatial dependence:

The test I of Moran (1948, 1950) for absence of spatial dependence is the first test of specification proposed in spatial econometrics, but it doesn't give indication on the potential form of spatial dependence[7]. The statistic of test is the following[8] :

$$I = \frac{n}{s}\left(\frac{\varepsilon' W \varepsilon}{\varepsilon' \varepsilon}\right) \qquad [1]$$

Were ε is the vector of residues of estimation of a-spatial model with OLS, *W* is the weight matrix, *n* is the size of the sample and *s* a factor of standardisation corresponding to the sum of elements of *W*. Cliff and Ord (1981) have demonstrated that under the hypothesis of normal distribution for the vector ε, and under the hypothesis null, the average and the variance of statistic I of Moran are written as:

$$E(I) = \frac{n}{s} tr \frac{(MW)}{n-K} \qquad [2]$$

[7]The test *I* of Moran doesn't specify the alternative hypothesis for the absence of spatial autocorrelation.

[8] For a standardised weight matrix in lines, we have : *s*=*n* and the statistic of test is rewritten us: $I = \varepsilon' W \varepsilon / \varepsilon' \varepsilon$. This statistic is very similar to that of the test of temporal autocorrelation of Durbin and Watson (1950).

And $$V(I)=\left(\frac{n}{s}\right)^2 \frac{\left\{tr(MWM'W')+tr(MW)^2+[tr(MW)]^2\right\}}{(n-K)(N-K-2)}$$ [3]

Where, $M = I-(X(X'X)^{-1}X')'$

Thus, they derived the asymptotic distribution of the statistic I, and the test reposes on the centred and reduced variable Z_I such us:

$$Z_I = \frac{I-E(I)}{\sqrt{V(I)}} \rightarrow N(0,1)$$ [4]

b. Test of omission of spatial dependence in error:

This test reposes on the hypothesis of omission of autoregressive spatial process in errors ε, such as $\varepsilon = \lambda W\varepsilon + \mu$, in absolute β-convergence model. It deals to test the hypothesis: $H_o : \lambda = 0$. The statistic of test is thus the following (Cf. Burridge [1980]):

$$LM_{ERR} = \frac{\left[\tilde{\varepsilon}' W_1 \tilde{\varepsilon} \,/\, \tilde{\sigma}^2\right]}{T}$$ [5]

Where, T = $tr[(W'+W)W]$. $\tilde{\varepsilon}$ and $\tilde{\sigma}^2$ are estimations obtained under the hypothesis null.

Since there is only constraint: $LM_{ERR} \rightarrow \chi_1^2$.

c. Test of omission of lag endogenous variable :

This test reposes on the hypothesis of omission of a lag endogenous variable in the in absolute β-convergence model.

Supposing, $g_y = \alpha - \left(1-e^{-\beta T}\right)\ln y_0 + \rho W g_y + \varepsilon$

The test deals to test the hypothesis null H_o : $\rho = 0$. The statistic associated to this test has been proposed by Anselin [1988],

$$LM_{LAG} = \frac{\left[\tilde{\varepsilon}' W g_y \big/ \tilde{\sigma}^2\right]}{\tilde{T}_1} \qquad [7]$$

Where, $\tilde{T}_1 = \left[(WX\tilde{\beta})\left(I - X\left(X'X\right)^{-1}X'\right)(WX\tilde{\beta}) + T\tilde{\sigma}^2\right] / \tilde{\sigma}^2$. $under H_0 : LM_{LAG} \xrightarrow{D} \chi_1^2$

d. Robust tests :

This approach is considered by Bera and Yoon (1993), and taken again by Anselin *et al.* (1996). It consists to use robust tests for a bad local specification. For example, it consists to adjust LM_{ERR} in order that its asymptotic distribution resists a centered χ^2, even in the presence of ρ. This test is carried out from residues of absolute β-convergence model.

The modified statistic for the test $H_0 : \lambda = 0$, is:

$$RLM_{ERR} = \frac{\left[\tilde{d}_\lambda - T_{12}\tilde{\sigma}^2 D^{-1}\tilde{d}_\rho\right]}{T_{22} - (T_{12})^2\tilde{\sigma}^2 D} \qquad [8]$$

$$\Rightarrow RLM_{ERR} = \frac{\left[\tilde{d}_\lambda - T\tilde{\sigma}^2 D^{-1}\tilde{d}_\rho\right]}{T\left(1 - T\tilde{\sigma}^2 D\right)} \qquad \text{si } W_1 = W_2 = W \qquad [9]$$

Were, $\tilde{d}_\lambda$ and $\tilde{d}_\rho$ are respectively the scores by proceeds of λ and ρ evaluated under the hypothesis null and $T_{ij} = tr\left[W_i W_j + W_i' W_j\right]$, $D = (W_1 X\tilde{\beta}) M (W_1 X\tilde{\beta}) + T_{11}\tilde{\sigma}^2$,

Similarly, we test $H_0 : \rho = 0$ in local presence of λ, we have than:

$$RLM_{LAG} = \frac{\left[\tilde{d}_\rho - T_{12}T_{22}^{-1}\tilde{d}_\lambda\right]^2}{\tilde{\sigma}^{-2}D - (T_{12})^2 T_{22}^{-1}} \quad [10]$$

$$RLM_{LAG} = \frac{\left[\tilde{d}_\rho - \tilde{d}_\lambda\right]^2}{\tilde{\sigma}^{-2}D - T} \quad \text{si} \quad W_1 = W_2 = W \quad [11]$$

e. Test of common factor :

The test of common factor permits to choice between the model with spatial autocorrelation in errors (equation [6] in the paper) and the spatial model of Durbin (equation [9] in the paper).

The spatial model of Durbin can be estimated by:

$$g_y = (I - \lambda W)\alpha - \left(1 - e^{-\beta T}\right)\ln y_0 + \lambda W g_y + \tau W \ln y_0 + \mu \quad [12]$$

Thus, we must test the following hypothesis: $H_0 : \lambda(1 - e^{-\beta}) + \tau = 0$

The test on constraints of parameters is done with one of traditional tests: test of Wald, test of likelihood ratio or the test of Lagrange Multiplier. In the three cases, the distribution of test is a χ^2 with k-1 degree of freedom. For example the form of the test of Wald is:

$$W = g'\left[G'VG\right]^{-1} g \quad [13]$$

Where, $g = \lambda\left(1 - e^{-\beta}\right) + \tau$; $G = \partial g' / \partial\theta$; $\theta' = [\lambda\ \delta\ \tau]$; V is the estimated matrix of variances-covariances of model.