Spatial dependence and economic growth: Evidence from a panel of countries[1]

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ABSTRACT

The empirical literature about economic growth has usually ignored spatial interdependence among countries. This paper uses spatial econometrics to estimate a growth model that includes cross-country interdependence, in which a country's economic growth depends on the growth rate of its neighbors. Based on a sample of 98 countries over three decades (1965-75, 1975-85, 1985-95) we find that spatial relationships across countries are quite relevant. A country's economic growth is indeed affected by the performance of its neighbors and then influenced by its own geographical position. This result suggests that the spillover effects among countries are important for growth. Our results indicate that spatial interrelation can not be ignored in the analysis of economic growth. Ignoring such relationships can result in model misspecification.

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1. INTRODUCTION

The relationship between economic growth and its determinants has been studied extensively in economic literature. So far there is some agreement regarding the factors that determine growth. A large number of empirical studies, using cross-country data sets, have found that economic growth is related to initial income, human capital, investment, physical infrastructure and institutions. However, the role of geography in economic growth is an empirical issue that has been taken into consideration just only recently. Some authors like, Sachs and Warner (1995), Gallup, Sachs and Mellinger (1999), Hall and Jones (1999), Sachs (2001), and McArthur and Sachs (2001)[2], among others, have used indicators such as climate, landlocked, distance from the equator, absolute value of latitude, land area, tropics, among others, in order to demonstrate that geography, is an element that affects economic growth in the long run.

Spatial effects are important in explaining economic growth. Countries can interact strongly with each other through channels such as trade, technological diffusion, capital inflows, and common political, economic and social policies. In such cases, externalities can spillover the limits among countries, contributing in the explanation of growth. Trade is a typical example of interdependence among countries. Agreements among neighboring economies, such as the Andean Pact, NAFTA, MERCOSUR and the European Economic Union (EEU), among others, have been designed to promote trade and, consequently, growth. Technological diffusion between neighboring economies may be even more important. According to Ciccone (1996), the aggregate level of technology in each country may not only rely on externalities originated by capital accumulation within the country, but also on the aggregate level of technology of its neighbors.

Evidence of spatial relationship across geographically close economies can also be taken from the recent contagion literature. Calvo and Reinhart (1996) argue that one channel in which contagion can be spread among regions is through technological factors and/or political instability. This way, a shock in any country can alter not only its own fundamentals but also those of its neighbors, and consequently have an impact on its neighbors' economic performance. Spatial dependence may also be influenced by the political stability of the region. For instance, foreign investment decisions towards a country may depend on both the internal country's conditions and the region's political stability. Then, there are issues that make investors do not discriminate between different macroeconomic fundamentals among countries. According to the authors, even if the fundamentals of a country have

[2] McArthur J. and J. Sachs (2001) made a comment on Acemoglu, D, S. Johnson and J. A. Robinson (2000)'s paper. The latter authors suggest that variations in the levels of economic development are correlated to weak institutions but not to physical geography. McArthur and Sachs using similar determinants show that both institutions and geographically related variables are strongly linked to income per capita (see their Table 1).

not been affected by a shock that occurs in a neighboring country, it is probable that this country will observe a reduction of foreign investment because investors tend to classify all countries that are located close to the economy that suffers from the adverse shock, as risky.

Spatial effects have been largely ignored in the traditional economic growth literature that pool data for large samples of countries. The main exception is Moreno and Trehan (1997) who carry out a number of tests to determine if location matters for growth. They show that a country's growth rate is positively influenced by the growth rate of neighboring countries. Few previous studies have addressed also this issue. Among them, Chua (1993) states that countries can gain from increased economic activity in their neighboring countries. Barro and Sala i Martin (1995) measure economic effects from neighboring countries by adding to the growth equation the weighted average of the logarithm of per capita GDP of the surrounding countries. They find a positive, but marginal significant, coefficient, which allows them to conclude that their findings provide some support for the spillover effects from neighboring countries proposed earlier by Chua (1993)[3]. In the same line, Ades and Chua (1997) find that the spillover effect can be negatively affected by political instability, and Ciccone (1996) finds a high degree of technological interdependence across countries. Therefore productivity spreads out to neighbors for a large sample of countries.

As Moreno and Trehan (1997), this paper assumes that not only individual country geographic characteristics influence economic growth, but also that the location of the country, i.e. the country's neighbors, has an effect on the economic growth of a particular country. In this case, we argue that a country's growth rate will be related to the growth rates of its nearby countries. In this line of analysis, we do not treat each country as an independent unit. A way to approach this issue is by using spatial econometrics.

Recently, the use of spatial econometrics in the convergence and growth empirical literature has increased. However, the main focus of this application, with the exception of Moreno and Threhan (1997), has been placed in regional studies. Rey and Montouri (1999) study the spatial dependence in the US regional economic per capita income-unconditional convergence for the 1929-1994 period, using spatial econometric analysis. The authors find strong patterns of both global and local spatial autocorrelation, and show that the magnitude of the spatial effects is significant and positively correlated with US regional income. The paper also shows that while states converge in relative incomes, they do not do this process independently but rather exhibit movements similar to those observed by their regional neighbors. Magalhães et al (2000) follow closely Rey and Montouri's (1999)

[3] See R. Barro and X. Sala i Martin (1995), page 442.

approach and apply spatial econometric methodology for the Brazilian regional convergence using state data for the 1970-1995 period. Similar to the US case, the study finds strong patterns of spatial correlation among Brazilian states. In particular, the results suggest that the unconditional convergence process seems to be more a regional feature rather than a global process. From a microeconomic perspective, Escobal and Torero (2000) develop a model of Peruvian households and province consumption growth over time and use spatial econometrics to verify the presence of persistent spatial concentration that comes from geography. The results suggest that what appears to be considerable geographic differences in consumption standards in Peru, can be explained when the spatial concentration of households with observable non-geographic characteristics is taken into account.

Research on European regions' economic growth analysis is increasingly using spatial econometrics. For instance, Fingleton (1999) analyses the determinants of the European region productivity growth using information for 178 regions. He finds significant cross-region externalities as a consequence of technological change spillovers that result from capital accumulation. Vayá et al (1998) estimate a growth model that includes externalities across regional economies using data for Spain and the European regions. In their model, the levels of technology of a region depend on the level of technology of its neighbors. For both cases, the authors find that the growth rates of a region are a positive function of the stock of capital of its neighbors. Then, besides the fact that cross-region externalities raise the steady state level, growth rates are affected by investment in the neighboring economies. García de la Vega and Herce (2000) have studied the relationship between trade and growth in the European Union and have found that the European integration process has promoted trade, particularly between close neighbors, and that trade has been the channel of diffusion of interdependent growth. Paci and Pigliaru (2001) have analyzed the role of technology heterogeneity and diffusion in GDP per worker convergence across 131 European regions for the 1978-97 period, the spatial pattern of regional heterogeneity in technology and the relevance of such pattern for the econometric analysis of the regional convergence in Europe. The results indicate that technology heterogeneity is important for convergence. Given a region's current technological gap, its capacity to profit from it in terms of growth depends not only on its individual effort, but also on the neighbors' performance. López-Bazo et al (1999) analyze the disparities and convergence on both GDP per worker and per capita in the European Union applying spatial association test. Similarly, Baumont et al (2001) investigate the European regional convergence process showing that spatial dependence matter in the estimation of the β-convergence on a sample of 138 regions on 11 European countries over the 1980-1995 period.

Taking into account spatial correlations, spatial lag dependence and spatial error autocorrelation, the present paper provides some interesting empirical results. First, spatial relationships across countries are indeed quite relevant. The spatial lag model suggests that each country's growth rate is related with that of its neighboring countries. Then, the performance of a country, after controlling for other variables traditionally included in the literature, depends on the rate of growth of its surrounding countries. Also, we prove the existence of spatial error correlation. Consequently, the exclusion of spatial dependence will cause misspecification of the model. Ignoring the role of spatial relationship can underestimate spillover effects and externalities across economies. Second, the convergence rate from the spatial model is quite similar when compared to the OLS estimation, indicating that it appears not to be influenced by the omission of spatial dependence, i.e. convergence is a robust result.

The rest of this paper is organized as follows. Section 2 introduces the empirical specification. Section 3 discusses the data set. Section 4 explores cross-country spatial dependence. Section 5 presents the empirical results. Section 6 concludes and discusses policy implications.

2. EMPIRICAL SPECIFICATION

a. Spatial effects specification and estimation

Spatial econometrics has not been extensively applied in studies on cross-country economic growth, partly because the neighboring effect has not been sufficiently addressed yet. This econometric approach includes in the estimating equation information on space or localization. Following, the first law of geography proposed by W. Tobler (1979): "*Everything is related to everything else, but near things are more related than distant things*" (page 379), it is clear that spatial dependence constitutes a feature with high applicability in economic growth.

Traditionally, each economy has been considered as an independent unit and the possible space-interactions among countries have been largely ignored (Rey and Montouri, 1999). According to Driscoll and Kraay (1995) the assumption of independent cross sectional units is inappropriate because countries are probably going to be exposed to common disturbances which will produce correlation among errors from different cross sectional units. Anselin (1988) states that spatial correlation can be understood as the lack of independence among observations in a cross sectional or panel data set. In particular, spillover effects constitute an important element in explaining growth among countries; therefore the geographical dimension must be studied. In addition, the fact that countries or regions are divided by artificial boundaries, which do not always correspond with the real spatial dimension of the spillover effects, can lead to a measurement error problem that need to be take into account (Magalhães et al, 2000).

Spatial correlation can occur when spatial dependence is fundamental to the model, known as spatial lag model, and when errors are spatially correlated, known as spatial error model[4].

i. Spatial Lag Model

In this case, a spatial lag of the dependent variable is included in the set of control variables. Thus, a country's growth rate will be associated to those rates in its nearby countries after controlling by other determinants.

The formulation for a pooled data set that includes a spatial lag model is the following:

$$y_{it} = \alpha + \rho\, W y'_{it} + \beta x'_{it} + \varepsilon_{it} \qquad (1)$$

$$\forall\ t=1,\ldots,T$$

$$\forall\ i=1,\ldots,n$$

where:

$$\varepsilon_{it} \sim iid,\ N(0,\sigma^2)$$

i represents the geographical units, in this case the countries.
α is a constant term.
y is the per capita income rate of growth.
x is the set of other control variables.
W is the spatial weighted matrix.
ρ is the coefficient of the "spatially lagged" dependent variable.

The W matrix represents a weight matrix associated with the autoregressive spatial process of the dependent variable. The specification of this matrix is *ad-hoc* since we do not estimate this matrix within the model. There is not a single procedure to select it. One way to specify such matrix correctly is by taking into account the theory behind the model. In our case we select the contiguity matrix and the second order contiguity matrix. The first one is a simple symmetric matrix that records 1 when country i and j share a common boundary and 0 otherwise. The second one represents a spatial lag of the contiguity matrix. That is, it introduces information of the neighbors' neighbors. This type of matrix

[4] For an introduction to the spatial econometric methods see for instance L. Anselin (1988), and J. LeSage (1999).

is useful when we use pooled data and assume the presence of spatial diffusion process through time. Subsequently, the initial effects in a specific country can affect not only its neighboring countries, but through time also its neighbors' neighbors. More complex specifications of weight matrices can take into account such as a spatial weight matrix with geographical distance with or without a critical cut-off. Other specifications that include economic and social issues for example trade relationships, capital flows and migration across countries are more difficult to implement since the weights should be exogenous at the model. However, these types of weights can be chosen if their endogeneity is considered explicitly in the model specification. The inclusion of these types of matrices in the growth equation will be part of our future research agenda.

ii. Spatial Error Model

The second form of spatial dependence in a regression model concerns the residual. In this case, the spatial correlation between error terms is considered. Spatial dependence could be present in the residuals when there are some omitted unobservable variables that can be spatially correlated. An example that illustrates this point could be the case of a river that is important in the economic activity of a particular country that not only goes through this country but also goes through the territory of its surrounding countries. Other omitted variables that are included in the error term and could be spatial correlated are weather and land fertility, among others. As Rey and Montouri (1999) state, a random shock in a country will not only affect the growth rate in that country but also the growth rates of other countries because of the presence of the spatial error dependence (equation 3).

The formulation for the spatial error model is given by:

$$y_{it} = \alpha + \beta x'_{it} + \varepsilon_{it} \qquad (2)$$

$$\forall \text{ t=1,…,T}$$

$$\forall \text{ i=1,…,n}$$

and the error exhibits the following spatial autoregressive process:

$$\varepsilon_{it} = \lambda W \varepsilon'_{it} + \mu_{it} \qquad (3)$$

where: $y_{it,}$, $x_{it,}$ and W are defined in the same way as before, and λ is the spatial error coefficient. Now, ε_{it} has no longer the usual diagonal variance matrix and consequently OLS estimates are not efficient.

Joining equations (2) and (3), the spatial error model can be expressed as:

$$y_{it} = \alpha + \beta x'_{it} + (I - \lambda W)^{-1} \mu_{it} \quad (4)$$

where:

$$\mu_{it} \sim iid,\ N(0,\sigma^2)$$

b. A Standard Growth Model with Interdependence across Countries

This section presents a simple growth model that includes interdependence across countries throughout the productivity term. We assume the traditional production function:

$$Y_{i,t} = K_{i,t}^{\alpha} N_{i,t}^{\phi} (Q_{i,t} L_{i,t})^{1-\alpha-\phi} \quad (5)$$

where:

Y_{it}: is the GDP of country *i* in time *t*.

K_{it}: includes both physical and human capital for country *i* in time *t*.

N_{it}: includes physical and social infrastructure for country *i* in time *t*.

L_{it}: labor of country *i* in time *t*.

Q_{it}: is defined below.

α, ϕ are positive parameters

Equation (5) expressed in per capita terms yields:

$$y_{i,t} = k_{i,t}^{\alpha} n_{i,t}^{\phi} Q_{i,t}^{1-\alpha-\phi} \quad (6)$$

and we suppose that spatial relationships among countries can be modeled explicitly as:

$$Q_{i,t} = A_{i,t} [Z_{i,j,t}]^{\rho} \qquad i \neq j \quad (7)$$

where: *i* and *j* are countries and A_{it} is the level of technology for country *i* which is assumed to be exogenous and constant across countries to simplify terms. Then, $A_{i,t} = A_t$.

Let *S* be the set of the *n* countries considered, such as

$$\forall_i \in S; \quad Z_{i,j,t} = \prod_{j \in S} \left(y_{j,t} / Y_{j,0} \right)^{W_j} \quad (7')$$

and,

$W_j = 1$ if $j \in S_i$, where S_i = {countries neighboring country i} and $S_i \subset S$.
$W_j = 0$, otherwise

As a result, the level of productivity of country *i* will be influenced by an exogenous and constant level of productivity and by the economic performance of its neighbors:

$$Q_{i,t} = A_t \left\{ \prod_{j \in S} \left({y_{j,t}} / {Y_{j,0}} \right)^{W_j} \right\}^{\rho} \quad (7'')$$

and ρ is a measure of the neighbor effect (ρ>0).

On the other hand, expression (6) can be expressed in logs terms as:

$$\ln y_{i,t} = \alpha \ln k_{i,t} + \phi \ln n_{i,t} + (1 - \alpha - \phi) \ln Q_{i,t} \quad (8)$$

and taking derivatives with respect to *t* yields:

$$\gamma y_{i,t} = \alpha \gamma k_{i,t} + \phi \gamma n_{i,t} + (1 - \alpha - \phi) \gamma Q_{i,t} \quad (9)$$

where the dynamic equations for *k* and *n* are given by:

$$\gamma k_{i,t} = sk_{i,t} (k_{it}^{\alpha - 1} n_{it}^{\phi} Q_{it}^{1-\alpha-\phi}) - (\ell + \delta) \quad (10)$$

or

$$\gamma k_{it} = sk_{i,t} e^{(\alpha - 1)\ln k_{it} + \phi \ln n_{it} + (1-\alpha-\phi)\log Q_{it}} - (\ell + \delta)$$

and

$$\gamma n_{it} = sn_{i,t} (k_{it}{}^{\alpha} n_{it}^{\phi - 1} Q_{it}^{1-\alpha-\phi}) - (\ell + \delta) \quad (10')$$

or

$$\gamma n_{it} = sn_{i,t} e^{\alpha \ln k_{it} + (\phi - 1)\ln n_{it} + (1-\alpha-\phi)\log Q_{it}} - (\ell + \delta)$$

$\ell = \dot{L} / L$, δ is the depreciation rate,[5] $sk_{i,t}$ and $sn_{i,t}$ are the shares of gross investment in physical and human capital in output and gross investment in infrastructure in output, respectively.

[5] For simplicity, the depreciation rates of *k* and *n* are assumed to be the same.

In order to express the above equations as a linear approximation in the neighborhood of the steady state we take a first order Taylor expansion of (10) and evaluate it in the steady state:[6]

$$\gamma k_{it} = (\alpha - 1)(\ell + \delta)(\ln k_{it} - \ln k^*) + \phi(\ell + \delta)(\ln n_{it} - \ln n^*) + (1 - \alpha - \phi)(\ell + \delta)(\ln Q_{it} - \ln Q^*) \quad (11)$$

$$\gamma n_{it} = \alpha(\ell + \delta)(\ln k_{it} - \ln k^*) + (\phi - 1)(\ell + \delta)(\ln n_{it} - \ln n^*) + (1 - \alpha - \phi)(\ell + \delta)(\ln Q_{it} - \ln Q^*) \quad (11')$$

and,

$$\ln k_{it} - \ln k^* = (\ln k_{i0} - \ln k^*)e^{\beta t} \quad (12)$$

$$\ln n_{it} - \ln n^* = (\ln n_{i0} - \ln n^*)e^{\beta t} \quad (12')$$

$$\ln Q_{it} - \ln Q^* = (\ln Q_{i0} - \ln Q^*)e^{\beta t} \quad (12'')$$

$$\ln y_{it} - \ln y^* = (\ln y_{i0} - \ln y^*)e^{\beta t} \quad (12''')$$

where, $\beta = -(\ell + \delta)(1 - \alpha - \phi)$. Note that the speed of convergence depends on the traditional parameters but does not depend on the interrelationship across countries. Re-writing (12''') we can obtain the regression equation:

$$\ln(y_{it} / y_{io}) = (1 - e^{\beta t}) \ln y^* - (1 - e^{\beta t}) \ln y_{i0} \quad (13)$$

and, $\ln y^* = \alpha \ln k^* + \phi \ln n^* + (1 - \alpha - \phi) \ln Q^*$

$$\ln y^* = \frac{\alpha}{1 - \alpha - \phi} \ln sk_{i,t} + \frac{\phi}{1 - \alpha - \phi} \ln sn_{i,t} - \frac{\alpha + \phi}{1 - \alpha - \phi} \ln(\ell + \delta) + (\alpha + \phi) \ln Q_{it} + (1 - \alpha - \phi) \ln Q^* \quad (14)$$

substituting the steady state value of *y* in (13*)* we obtain:

$$\ln(y_{it} / y_{i0}) = -(1 - e^{\beta t}) \ln y_{i0} + (1 - e^{\beta t})[\frac{\alpha}{1 - \alpha - \phi} \ln sk_{i,t} + \frac{\phi}{1 - \alpha - \phi} \ln sn_{i,t} - \frac{\alpha + \phi}{1 - \alpha - \phi} \ln(\ell + \delta) + (\alpha + \phi) \ln Q_{it} + (1 - \alpha - \phi) \ln Q^*] \quad (15)$$

From (7'') we have that $Q_{i,t} = A_t \left\{ \prod_{j \in S} \left(y_{j,t} / Y_{j,0} \right)^{W_j} \right\}^{\rho}$ then:

[6] The steady state is indicated by the term in asterisk (*).

$$\ln(y_{i,t} / y_{i,0}) = -(1-e^{\beta t})\ln y_{i0} + (1-e^{\beta t})[\frac{\alpha}{1-\alpha-\phi}\ln sk_{i,t} + \frac{\phi}{1-\alpha-\phi}\ln sn_{i,t} - \frac{\alpha+\phi}{1-\alpha-\phi}\ln(\ell+\delta) + (\alpha+\phi)\ln A_t + (\alpha+\phi)\rho(\sum_j w_j \ln(y_{jt} / y_{j0})) + (1-\alpha-\phi)\ln A^* + (1-\alpha-\phi)\rho(\sum_j w_j \ln(y_{jt} / y_{j0})^*)] \tag{16}$$

Equation (16) gives the regression expression for the growth rate of per capita GDP as a function of the parameters of the model, the initial level of income and the rate of growth of the neighboring countries.[7] The last term of the equation can be treated as a constant since in the steady state the rate of growth of *y* is constant.

Finally, we can express equation (16) in matrix form as follows[8]:

$$\begin{bmatrix} \ln\left(\frac{y_{1,t}}{y_{1,0}}\right) \\ \vdots \\ \ln\left(\frac{y_{n,t}}{y_{n,0}}\right) \end{bmatrix} = -(1-e^{\beta t})\begin{bmatrix} \ln(y_{1,0}) \\ \vdots \\ \ln((y_{n,0}) \end{bmatrix} + (1-e^{\beta t})\left[\frac{\alpha}{1-\alpha-\phi}\begin{bmatrix} \ln sk_{1,t} \\ \vdots \\ \ln sk_{n,t} \end{bmatrix} + \frac{\phi}{1-\alpha-\phi}\begin{bmatrix} \ln sn_{1,t} \\ \vdots \\ \ln sn_{n,t} \end{bmatrix} - \frac{\alpha+\phi}{1-\alpha-\phi}\ln(\ell+\partial) + (\alpha+\phi)\ln\begin{bmatrix} A_t \\ \vdots \\ A_t \end{bmatrix} + (\alpha+\phi)\rho\begin{bmatrix} w_1 & \cdots & w_n \\ \vdots & \ddots & \vdots \\ w_n & \cdots & w_n \end{bmatrix}\begin{bmatrix} \ln\left(\frac{y_{1,t}}{y_{1,0}}\right) \\ \vdots \\ \ln\left(\frac{y_{n,t}}{y_{n,0}}\right) \end{bmatrix}\right]$$

where: w_j is equal to 1 when *j* shares borders with *i*, and w_j is equal to 0 otherwise.

3. DATA

To estimate the growth equation we pool cross sectional units from 98 countries and time series information over three decades (1965-75; 1975-85; 1985-95). Altogether we have 270 complete observations, because some information is not available. The data sources and variable definitions are listed in the appendix as well as the list of countries considered.

The data set includes some of the traditional variables used in growth regressions. The macroeconomic variables included in the right-hand side are: i) the initial value of the per-capita GDP; the sign and size of this coefficient indicate the speed of adjustment of an economy's per capita income in reaching its own steady state values; ii) the investment-GDP ratio; higher values of this variable will lead to an increase in the economy's steady state levels and will encourage economic growth; iii) government's consumption ratio by turn has an inverse relationship with economic growth; one reason could be that government size is associated with inefficiency and corruption, as well as it implies a crowding out effect on private consumption which is more income elastic; iv) black market premium on the foreign exchange rate is an indicator of market distortions, and iv) terms of trade is an

[7] The papers of M. L. García de la Vega et al (2000) and E. Vayá et al (1998) provide a good explanation of how spatial econometric techniques can be applied to a specification based on theoretical growth models, see page 16 and pages 9 to 11, respectively.

[8] Note that we already dropped the last term of equation (16).

instrument to enhance export efficiency and it is a source of growth as it has been pointed out in the trade literature.

Regarding demographic variables, the estimated equation includes fertility rate and life expectancy at birth. The former has a negative impact on economic growth while life expectancy is anticipated to have a positive effect. Higher values of life expectancy could indicate good quality health, good nutrition and adequate work habits, among others.

Concerning stock variables, an adequate provision of infrastructure is an important factor that helps to explain economic growth. Esfahani and Ramírez (Forthcoming) show that the contribution of infrastructure services to GDP growth is significant and, in general, surpasses the costs of provision of those services. We include as a proxy for physical infrastructure the rate of growth of per capita telephone lines that prove to be very significant in their estimation. In addition, improvements in education imply human capital accumulation and augmented labor technical change. The schooling variable used in the estimation is the gross enrollment ratio for secondary education. We use this variable rather than others frequently used in the literature such as average number of years of secondary education achieved by the population of age 25 years and older because we have information for more countries. A common caveat is that we do not control for quality of education.

The institutional variables play a central role in economic growth. The chosen variables reflect, on one side, the political aspect of a country and, on the other, the quality of its institutions. A democracy index is a proxy for the first institutional feature. However, the effect of this variable on economic growth has been ambiguous in the empirical growth literature. For instance, Kormendi and Meguire (1985), Scully (1988), Pourgerami (1988) have found a positive relation between democracy and growth while Barro (1996), and Landau (1986) have found a negative correlation. Others such as Levine and Renelt (1992) and Alesina et al (1996) do not find any correlation. The second variable is an index related to government's credibility and commitment (*contract enforcement*). We expect a positive sign since this index reflects a country's institutional characteristics that make policy-makers fulfill the government's obligations and should produce appropriate incentives for investments.[9] The last variable considered is the bureaucratic quality. Higher quality implies favorable conditions to grow.

[9] See, H. Esfahani and M.T. Ramírez (Forthcoming).

4. EXPLORING SPATIAL DEPENDENCE ACROSS COUNTRIES

An intuitive and useful way to start analyzing spatial dependence is by looking at Figure 1, which shows a map in which we classify countries in three groups according to their per capita income in 1995: high, middle and low income. Some spatial clusters are evident. First, high income countries are concentrated in Europe, North America and Australia while low income countries are mostly located in Sub-Saharan Africa and East and South Asia. Second, almost all countries are surrounded by countries with the same level of income. The main exceptions are North African and Middle Eastern countries, middle income countries which have poor neighbors, and Japan and Korea, rich countries, surrounded by middle income countries.

Given the evidence of income clustering provided by the map, the next step is to test whether there is spatial dependence across countries' economic growth, by using spatial econometrics[10]. We first carry out some tests to detect the presence of spatial dependence using the two types of weighting matrices mentioned above, the contiguity and the second order contiguity matrices. The first test is the global Moran I for the GDP per capita growth rate using information for the three decades. This index allows us to estimate the effect of spatial proximity by computing an index of spatial autocorrelation that measures the interrelationship of economic growth across neighboring countries[11]. The index is defined as:

$$I = \frac{n\sum_{i,j}^{n} w_{i,j} z_i z_j}{\sum_i \sum_j w_{i,j} \sum_{i=1}^{n} z_i^2} \qquad i \neq j \qquad (21)$$

where: $z_i = x_i - \mu$ and $z_j = x_J - \mu$, are the observations on a variable (x) for country i and j, respectively, expressed as deviation from the mean (μ). In this case x is a country's GDP per capita growth rate, $w_{i,j}$ is an element in row i and column j of a spatial weights matrix (W) such as $w_{i,j} = 1$, if country i and j share a border and zero if not, and n is the sample size. If the *z-value* for the Moran's I is positive and significant a positive spatial autocorrelation exists, then similar values of x are spatially clustered. Contrary, a negative and significant *z-value* indicates the presence of a negative spatial autocorrelation, i.e. no clustering.

[10] The exploration analysis was carried out using the software *SpaceStat*, version 1.91 (L. Anselin, 2001).

[11] See L. Anselin et al (1995) for more details.

The *z-value* of the global Moran coefficient, reported in Table 1a, is highly significant and positive; it clearly suggests the presence of spatial autocorrelation. That means that GDP per capita growth rates across countries are clustered over the whole period under analysis. Thus, countries with high (low) GDP per capita growth rates are localized near to other countries with high (low) GDP per capita growth rates.

The other tests are an extension of Moran's I to measure spatial autocorrelation in regression residuals and two Lagrange Multiplier (LM) tests for both error and spatial lag dependence with their respective robust versions. LM tests are asymptotic and follow a χ^2 distribution with one degree of freedom. These tests test the null hypothesis of no spatial dependence against the alternative hypothesis of spatial dependence. According to Anselin and Florax (1995), the use of Lagrange Multiplier tests provides a good guide to decide which specification, between spatial error and spatial lag, is the most appropriate[12].

Table 1b presents the results. The Moran's I coefficient is very significant which confirms the presence of spatial error autocorrelation. According to the χ^2 statistic from the Lagrange Multiplier tests, in all models, we can clearly reject the null hypothesis of non-spatial dependence, indicating the presence of spatial correlation arising from both the errors and the dependent variable. Since both tests are highly significant, it is difficult to conclude which is the most appropriate specification. However, the robust tests suggest that the spatial lag model could be the appropriate one since the robust Lagrange Multiplier for the spatial lag is highly significant while the robust Lagrange Multiplier for the spatial error is not.

To complete the diagnostics and to visualize the spatial clustering we depict some Moran scatterplots. To simplify the interpretation we present four set of graphs (Figure 2). The first ones correspond to the Moran scatterplot for the log per capita GDP for the average 1965-95 and for the Moran scatterplot for GDP per capita growth rate for the average 1965-95, respectively. The second are the scatterplots for the above variables using information from the last decade (1985-95), the next ones are for the period (1975-85) and the last graphs employ information for the first decade (1965-75).

The Moran scatterplots display the spatial lag *Wx*, in the vertical axis, against *x*, in the horizontal axis, both standardized. As we mentioned above, the *x* variable corresponds to the log per capita GDP or to the GDP per capita growth rate, in each case, and *Wx* is the weighted average of the neighboring

[12] Since these tests require normality, it is important to mention that normality is satisfied in all cases. Errors are normally distributed.

values. As Anselin (1995) states the Moran's I can be interpreted as the slope coefficient in a linear regression of *Wx* on x since the *x* are in deviations from the mean. This interpretation offers a way to observe the association between *x* and *Wx* in a bivariate scatterplot[13].

The four quadrants of the graphs identify the relationship between a country and its neighbors as follows: i) Quadrant I, located at the top on the right, a country with high economic growth surrounded by countries with high economic growth (HH), ii) Quadrant II, in the top left, a country with low economic growth bordered by high economic growth countries (LH), iii) Quadrant III, in the bottom left, a country with low economic growth surrounded by countries with low economic growth (LL), and Quadrant IV, in the bottom right, a country with high economic growth bordered by countries with low economic growth (HL). The same definition holds when *x* is the log of initial per capita GDP. The type of relationship in Quadrants I and III is the positive spatial autocorrelation indicating the association between similar values while the relationship in Quadrants II and IV is the negative spatial autocorrelation indicating the association between dissimilar values. If the information is dispersed in the four quadrants, there is not spatial autocorrelation.

Figure 2 indicates in all cases the presence of a positive spatial association among countries. This result suggests the existence of some kind of *spatial clubs*[14]. To illustrate this result, in the first set of graphs, those that take the average value between 1965 and 1995, we observe that the spatial clustering is evident. For the log per capita GDP, 40 countries are in Quadrant I, HH clustering type, and 40 countries belong to Quadrant III, LL clustering type. Only 18 out 98 countries exhibit a spatial association of dissimilar values, 9 in Quadrant II (LH) and 9 in Quadrant IV (HL). For the GDP per capita growth rate the HH and LL types of clusters are also predominant. In this case, 32 countries are in Quadrant I (HH) and 34 countries are located in Quadrant III (LL). The remaining countries are located in Quadrant II (14) and in Quadrant IV (18).

The results presented in this section suggest the existence of a strong spatial dependence pattern in the sample under analysis. Then, it is necessary to include the spatial effects in the estimation of the growth equation. The presence of spatial correlation makes the OLS estimates inefficient. Ignoring spatial dependence can result in significant model misspecification. To assess this problem we apply spatial econometric techniques.

[13] For details see L. Anselin (1995), pages 38-41.

[14] In Appendix 2, we present the classification of the spatial association for all the countries in the sample using both the log of per capita GDP and the GDP per capita growth rate. We also present their respectively Moran I coefficient.

5. RESULTS

To compare the results from the spatial models to those obtained from the standard model we first present in Table 2 the results from the per capita GDP growth equation estimated by simple OLS (robust) and by 2SLS (robust)[15]. Given that some of the right hand side variables are endogenous the 2SLS estimation is more appropriate[16]. In general, in both estimations, the coefficients are significant and show the expected sign, with the exception of democracy, education and bureaucracy quality. As we mentioned above, the role of democracy in economic growth estimations has been controversial. Our results suggest a positive relationship but not a significant one. Regarding education, its coefficient is positive but insignificant[17]. The non-significance of education in empirical estimations of macro growth model is not an unusual result[18]. Krueger et al (2000) state that the fact that recent studies have found that increments in education attainment are not correlated to economic growth seems to be a spurious result coming from the high rate of measurement error in the cross-country education database.

The remaining results are similar to others obtained in the literature. The convergence rate is about 2% in the estimations. Per capita growth rate increases with investment rate, terms of trade, credibility and commitment to honor government's obligations (*contract enforcement*),[19] life expectancy and physical infrastructure. On the contrary, per capita GDP growth declines with market distortions, high fertility rates and government consumption.

Given the evidence of spatial interrelationship between countries provided by the previous section, the results from the OLS and 2SLS regression are biased since we are omitting a significant explanatory variable in the regression model. Also the estimations are no longer efficient, because the correlation between error terms is ignored.

Even though the exploration analysis suggests that the appropriate model is the spatial lag we present in this section the results from both specification. Tables 3 and 4 summarize the results from the

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[15] Heteroscedasticity and normality tests were carried out on all estimations, both OLS and spatial. In the case of heteroscedasticity the test rejects the null hypothesis of constant variance. In the second case, the test can not reject the null of normality then, errors are normal.

[16] The instruments include some of the original variables and lags of the other variables.

[17] We also use the average number of years of secondary education achieved by the population of age 25 years and older. Using this indicator of education does not change the results, i.e. its coefficient is not significant in the regressions.

[18] An interesting discussion of the role of education in economic growth and its lack of significance in empirical studies is presented in W. Easterly (2002), Chapter 4, p.p. 71-84.

[19] H. Esfahani and M.T. Ramirez (Forthcoming) found that contract enforcement is one of the main institutional variables that affect significant and positively both economic growth and infrastructure growth, see their Tables 2 and 4.

estimations of the growth equation taking into account the spatial lag model and the error spatial model, respectively[20]. For comparison purpose, besides the spatial effects, the estimations presented in these tables include the same set of control variables than those reported in Table 2. In the first case, we are considering that economic growth of each country is affected by the economic growth of its neighboring countries, and consequently it is influenced by its own geographical position, in the second case we assume that spatial dependence emerges from the error term.

The regressions were carried out including the contiguity W matrix and the second order contiguity matrix; the results from both specifications are quite similar. However, spatial effects are slightly higher when the second order contiguity matrix is taking into account. This matrix could be more relevant because it includes a broad spectrum of spatial correlations. For instance, contagious and trade relationship among a set of countries could be more explicit in this type of matrix. In addition, given that the dataset includes information for three periods (decades) for each country, the second order matrix has the advantage that it involves dynamic relationships among countries within a geographical region.

The estimation of the spatial lag model is performed by Maximum Likelihood (ML) estimation and by Instrumental Variables (IV). According to Table 3, the parameter associated with the spatially lagged dependent variable, ρ, is highly significant. Then, a country's economic growth is indeed affected by the performance of its neighbors. For instance, as it is implied by the value of ρ, from the first and second column of Table 3, an increase of 1 percent point in the weighted growth rate of countries neighboring country i, will produce an increase of 0.19 points in the growth rate of that country after controlling for the other determinants, in the case of the contiguity matrix, and of 0.23 points, in the case of the second order contiguity matrix. This effect is even larger in the IV estimations.

With respect to the other explanatory variables, the results regarding signs and significance are similar than those presented in Table 2, although there are some changes in the regression coefficients. The rate of convergence obtained by the spatial specifications (between 2.17% and 2.28% in ML and 1.98% and 2.37% in IV) is quite similar that the one found in the original specification (2.28% in OLS and 2.34% in 2SLS), which suggests that the rate of convergence is a robust result.

The log likelihood (LIK) and the R^2 indicate that the fit of the model improves considerably when the spatial lag is included in the model. The LIK increases from 694 for the OLS to 701 for the spatial lag, and the adjusted R^2 from 0.475 to 0.530, respectively. The LM test on spatial error dependence

[20] The results were obtained using the spatial econometric software *SpaceStat*, version 1.91 (Anselin, 2001).

indicates that the spatial lag model is the appropriate one since no spatial dependence remains in the residuals, except for the model estimated in column 3.

The estimation of the spatial error model is carried out by Maximum Likelihood (ML) estimation and by 2SLS (Table 4). The spatial error parameter (λ) is highly significant in all cases confirming the results of the exploration section. Relative to OLS estimates, the spatial error model has a better fit as its LIK is 698.9 compared with 694 for OLS. However, this fit is inferior to that of the spatial lag model. There are some changes in the coefficients compared to the results of the standard model, but the results regarding signs and significance are similar. Concerning the rate of convergence, it is very similar than those obtained by the spatial lag model and by the standard model. Finally, the results from the common factor hypothesis test, using the contiguity matrix, indicate that the spatial error model is inappropriate as it was suggested in the exploration analysis.

In short, the spatial coefficients, ρ and λ, are positive and statistically significant in both models. This result combined with the spatial correlation tests, reiterates the relevance of taking into account spatial relationships across countries in economic growth models. The results indicate that economic growth is indeed explained by geographical factors.

From the convergence point of view, the results suggest that the rate of convergence is robust to changes in the specification of the model. This fact indicates that the exclusion of spatial dependence in the traditional growth regressions does not affect considerably this rate. This result is the same than the reported in other studies such as Rey and Montouri (1999), Magalhães et al (2000) and Vayá et al (1998), who find a slightly lower rate of convergence estimated under the presence of spatial relationships. Baumont et al (2001) under the spatial error model find a convergence speed of 1.2%, higher than the unconditional β convergence speed of 0.85% estimated by OLS. However, in spite of the slightly improvement in the convergence speed once the spatial effects are controlled for, the convergence process in the European region remains weak. In addition, the authors find two spatial regimes can be interpreted as spatial convergence clubs, the north regime (rich regions surrounded by rich regions) and the south regime (poor regions surrounded by poor regions), which have different convergence process. Using the spatial error model the authors find that there is no a convergence process for the northern regions and a weak one for the southern regions.

6. CONCLUSIONS

This paper uses spatial econometrics to estimate a standard growth model that includes cross-country interdependence, in which a country's economic growth depends on the growth rate of its neighbors. Based on a sample of 98 countries over three decades (1965-75, 1975-85, 1985-95) the paper finds some interesting results. First, spatial relationships across countries are quite relevant. A country economic growth is indeed affected by the performance of its neighbors and therefore it is influenced by its own geographical position. This result suggests that the spillover effects among countries are important for growth. Taking into account spatial correlations we correct for the exclusion of spatially dependent explanatory variables. Our results indicate that spatial interrelation across countries cannot be ignored in the analysis of economic growth. Ignoring such relationships can result in significant model misspecification.

Second, the convergence rate from the spatial model is quite similar when compared to the OLS estimation. Then, this rate appears not to be influenced by the omission of the spatial autocorrelation, suggesting that the speed of convergence of 2% is a robust result.

Third, as a policy implication, the estimations indicate that cooperation agreements among countries will be beneficial for the economic growth of the regions. This cooperation could be in the form of improving trade relationships, sharing technological knowledge and innovations, facilitating communications, among others. Reaching political stability in a region will also be beneficial for the countries that conform it, because it will spur investment and, consequently, growth in those countries.

For future research it might be interesting to use spatial econometric techniques to explore and understand possible linkages between integration and economic growth. In addition, it might be interesting to address the robustness of our findings when more complex specifications of the weighting matrix are considered; alternative specifications would explicitly incorporate economic issues such as trade relationships, capital movements, distance weighted by income and migration across countries.

TABLE 1a
DIAGNOSTICS FOR SPATIAL DEPENDENCE
GLOBAL MORAN'S I TEST FOR SPATIAL AUTOCORRELATION
(normal approximation)

	Contiguity weight Matrix	**Second order contiguity Matrix**
Moran's I	0.3701	0.3067
z-value	6.7780	6.2995
probability	0.0000	0.0000

TABLE 1b
DIAGNOSTICS FOR SPATIAL DEPENDENCE

I. Contiguity weight matrix, row-standardized weights

Test	MI/DF	Value	Probability
Spatial Error Correlation			
Moran's I	0.1508	3.0725	0.0021
Lagrange Multiplier	1	7.4056	0.0065
Robust Lagrange Multiplier	1	0.3626	0.5470
Spatial Lag Dependence			
Lagrange Multiplier	1	13.9027	0.0002
Robust Lagrange Multiplier	1	6.8597	0.0088

II. Second order contiguity matrix, row-standardized weights

Test	MI/DF	Value	Probability
Spatial Error Correlation			
Moran's I	0.1362	3.0536	0.0022
Lagrange Multiplier	1	7.5293	0.0061
Robust Lagrange Multiplier	1	0.7276	0.3936
Spatial Lag Dependence			
Lagrange Multiplier	1	18.2213	0.0000
Robust Lagrange Multiplier	1	11.4196	0.0007

Ho: No spatial dependence

TABLE 2
PER CAPITA GDP GROWTH EQUATION
OLS and 2SLS ESTIMATIONS

Estimation Method	**OLS (1)**	**2SLS (2)**
Number of observations	270	270
LIK	694.32	
R^2- adj.	0.4757	0.4915
Variables	**Coefficient/Stdr. Dev (in parenthesis)**	
Constant	0.0491 (0.0592)	0.0056 (0.0607)
Log of Initial GDP per capita	-0.0228 (0.0034)	-0.0234 (0.0036)
Log of Investment-GDP ratio	0.0094 (0.0027)	0.0053 (0.0031)
Log of Government Expenditures	-0.0119 (0.0036)	-0.0095 (0.0042)
Log of (1+ Black Market Foreign Exchange Premium)	-0.0053 (0.0023)	-0.0058 (0.0025)
Terms of Trade	0.1461 (0.0237)	0.1555 (0.0233)
Log of Fertility Rate	-0.0110 (0.0065)	-0.0114 (0.0065)
Log of Life Expectancy at Birth	0.0304 (0.0156)	0.0406 (0.0153)
Telephones Growth	0.1452 (0.0381)	0.1570 (0.0384)
Gross Enrollment ratio for Second. Education	0.0109 (0.0106)	0.0105 (0.0105)
Contract Enforcement	0.0032 (0.0009)	0.0035 (0.0009)
Bureaucracy Quality	0.0007 (0.0012)	0.0009 (0.0012)
Democracy Score	0.0005 (0.0005)	0.0005 (0.0005)

TABLE 3

PER CAPITA GDP GROWTH EQUATION: SPATIAL LAG MODEL ESTIMATIONS

Estimation Method	**SPATIAL LAG- ML**		**SPATIAL LAG- IV (2SLS)**	
W-Matrix	Contiguity (1)	2nd Order Contiguity (2)	Contiguity (3)	2nd Order Contiguity (4)
Number of observations	270	270	270	270
LIK	701.086	702.484		
R^2-adj	0.5304	0.5350	0.5212	0.5330
Variables	**Coefficient/Stdr Dev (in parenthesis)**			
Spatial Lag (ρ)	0.1934 (0.0519)	0.2303 (0.0571)	0.4111 (0.1018)	0.2990 (0.0894)
Constant	0.0264 (0.0564)	0.0191 (0.0562)	-0.0219 (0.0614)	-0.1738 (0.0606)
Log of Initial GDP per capita	-0.0217 (0.0028)	-0.0228 (0.0027)	-0.0198 (0.0033)	-0.0237 (0.0032)
Log of Investment-GDP ratio	0.0083 (0.0024)	0.0084 (0.0024)	0.0050 (0.0030)	0.0057 (0.0029)
Log of Government Expenditures	-0.0104 (0.0032)	-0.0107 (0.0032)	-0.0062 (0.0040)	-0.0082 (0.0039)
Log of (1+ Black Market Foreign Exchange Premium)	-0.0053 (0.0028)	-0.0058 (0.0028)	-0.0059 (0.0029)	-0.0063 (0.0029)
Terms of Trade	0.1295 (0.0197)	0.1307 (0.0195)	0.1149 (0.0223)	0.1337 (0.0209)
Log of Fertility Rate	-0.0094 (0.0055)	-0.0090 (0.0055)	-0.0079 (0.0058)	-0.0091 (0.0057)
Log of Life Expectancy at Birth	0.0336 (0.0143)	0.0366 (0.0143)	0.0416 (0.0154)	0.0465 (0.0153)
Telephones Growth	0.1347 (0.0280)	0.1336 (0.0278)	0.1307 (0.0299)	0.1367 (0.0293)
Gross Enrollment ratio for Second. Education	0.0095 (0.0100)	0.0117 (0.0099)	0.0063 (0.0106)	0.0119 (0.0104)
Contract Enforcement	0.0026 (0.0011)	0.0029 (0.0011)	0.0021 (0.0011)	0.0030 (0.0011)
Bureaucracy Quality	0.0009 (0.0012)	0.0009 (0.0012)	0.0011 (0.0013)	0.0010 (0.0012)
Democracy Score	0.0004 (0.0004)	0.0004 (0.0004)	0.0004 (0.0004)	0.0005 (0.0004)
Spatial Lag Dependence Test - Likelihood Ratio Test				
Value	13.5318	16.3286		
Probability	0.0002	0.0000		
Lagrange Multiplier Test on Spatial Error Dependence				
Value	0.7230	1.5945	4.3335	1.1069
Probability	0.3951	0.2067	0.0374	0.2928

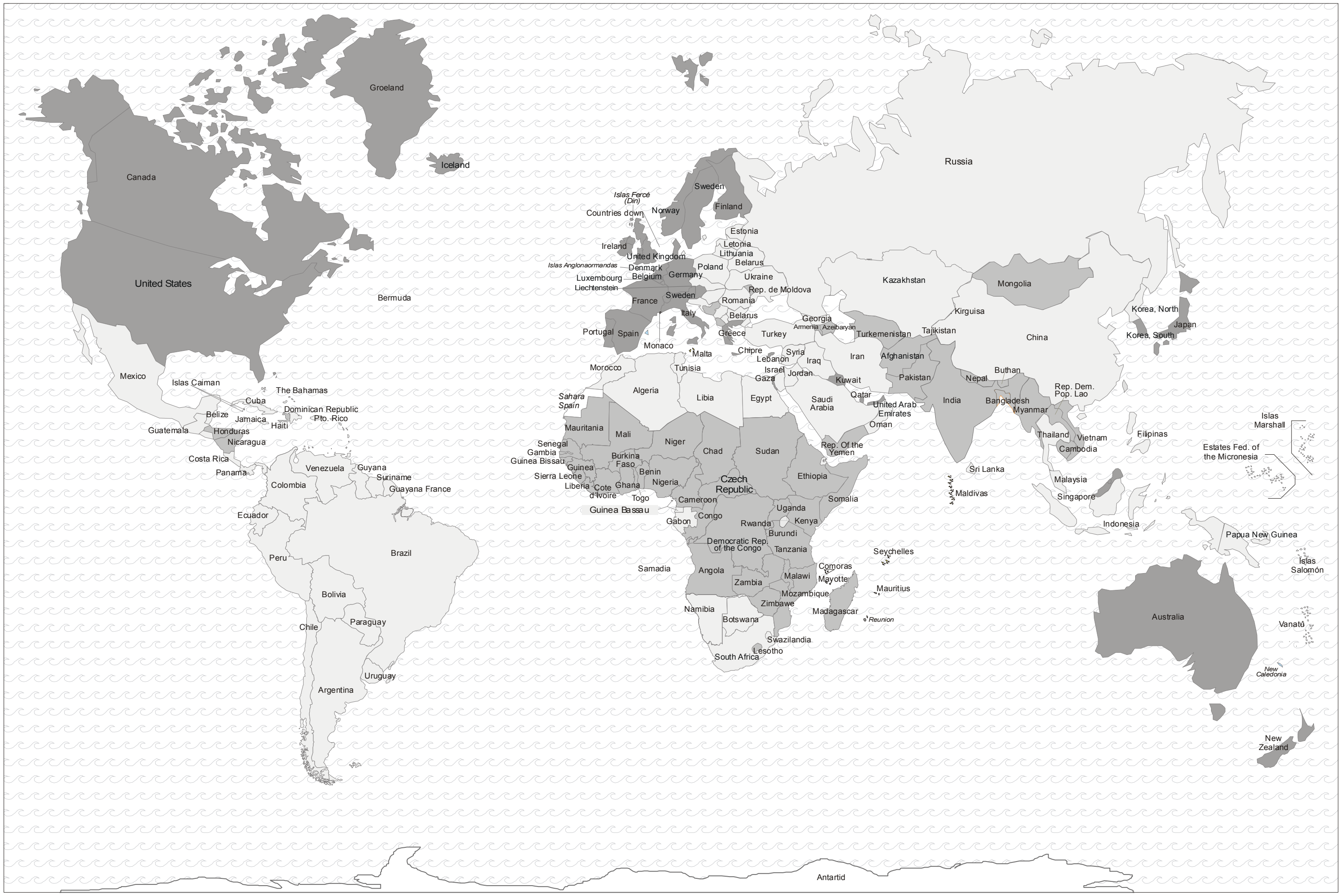
TABLE 4

PER CAPITA GDP GROWTH EQUATION: SPATIAL ERROR MODEL ESTIMATIONS

Estimation Method	**SPATIAL ERROR- ML**		**SPATIAL ERROR- 2SLS**	
W-Matrix	Contiguity (1)	2^{nd} Order Contiguity (2)	Contiguity (3)	2^{nd} Order Contiguity (4)
Number of observations	270	270	270	270
LIK	698.92	700.55		
R^2	0.4946	0.4971	0.4343	0.4164
Variables	**Coefficient/Stdr Dev (in parenthesis)**			
Spatial Error (λ)	0.2193 (0.0618)	0.2360 (0.0751)	0.3076 (0.000)	0.3525 (0.000)
Constant	0.0356 (0.0609)	0.0289 (0.0591)	-0.0017 (0.026)	-0.0069 (0.0649)
Log of Initial GDP per capita	-0.0244 (0.0029)	-0.0218 (0.0028)	-0.0250 (0.0036)	-0.0216 (0.0033)
Log of Investment-GDP ratio	0.0083 (0.0025)	0.0086 (0.0024)	0.0046 (0.0032)	0.0063 (0.0029)
Log of Government Expenditures	-0.0126 (0.0034)	-0.0102 (0.0033)	-0.0109 (0.0044)	-0.0057 (0.0042)
Log of (1+ Black Market Foreign Exchange Premium)	-0.0048 (0.0028)	-0.0062 (0.0028)	-0.0050 (0.0029)	-0.0063 (0.0029)
Terms of Trade	0.1337 (0.0206)	0.1324 (0.0199)	0.1344 (0.0222)	0.1307 (0.0213)
Log of Fertility Rate	-0.0139 (0.0058)	-0.0113 (0.0057)	-0.0152 (0.0062)	-0.0124 (0.0062)
Log of Life Expectancy at Birth	0.0381 (0.0152)	0.0346 (0.0149)	0.0482 (0.0166)	0.0445 (0.0163)
Telephones Growth	0.1339 (0.0282)	0.1283 (0.0284)	0.1381 (0.0298)	0.1253 (0.0302)
Gross Enrollment ratio for Second. Education	0.0089 (0.0103)	0.0077 (0.0103)	0.0080 (0.0110)	0.0040 (0.0113)
Contract Enforcement	0.0025 (0.0011)	0.0032 (0.0011)	0.0025 (0.0012)	0.0032 (0.0011)
Bureaucracy Quality	0.0010 (0.0013)	0.0007 (0.0012)	0.0012 (0.0013)	0.0009 (0.0013)
Democracy Score	0.0004 (0.0004)	0.0003 (0.0004)	0.0004 (0.0004)	0.0003 (0.0004)
Spatial Error Dependence Test - Likelihood Ratio Test				
Value	9.1994	12.4542		
Probability	0.0024	0.0004		
Lagrange Multiplier Test on Spatial Lag Dependence				
Value	1.5835	4.8620		
Probability	0.2082	0.0274		
Test on Common Factor Hypothesis-Likelihood Ratio Test				
Value	37.6029	17.3323		
Probability	0.0002	0.1375		

FIGURE 1:
Per capita income in 1995

High Income more than $9.656 | **Low Income up to** $785
NA | **Middle Income** from $786 to $9.655



Source: The income information was taken form World Bank, World Development Report, 2000.

FIGURE 2
MORAN SCATTERPLOTS

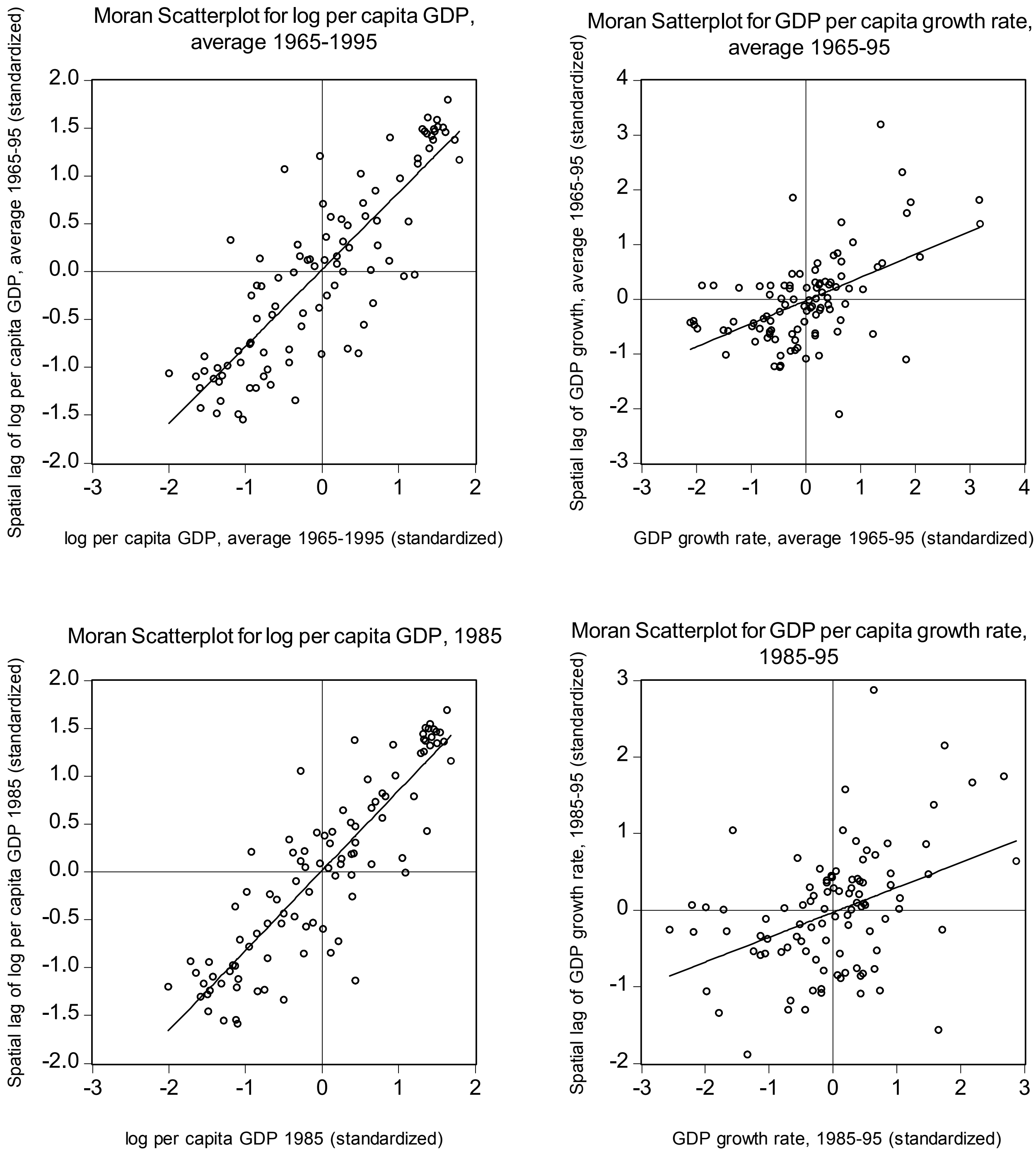
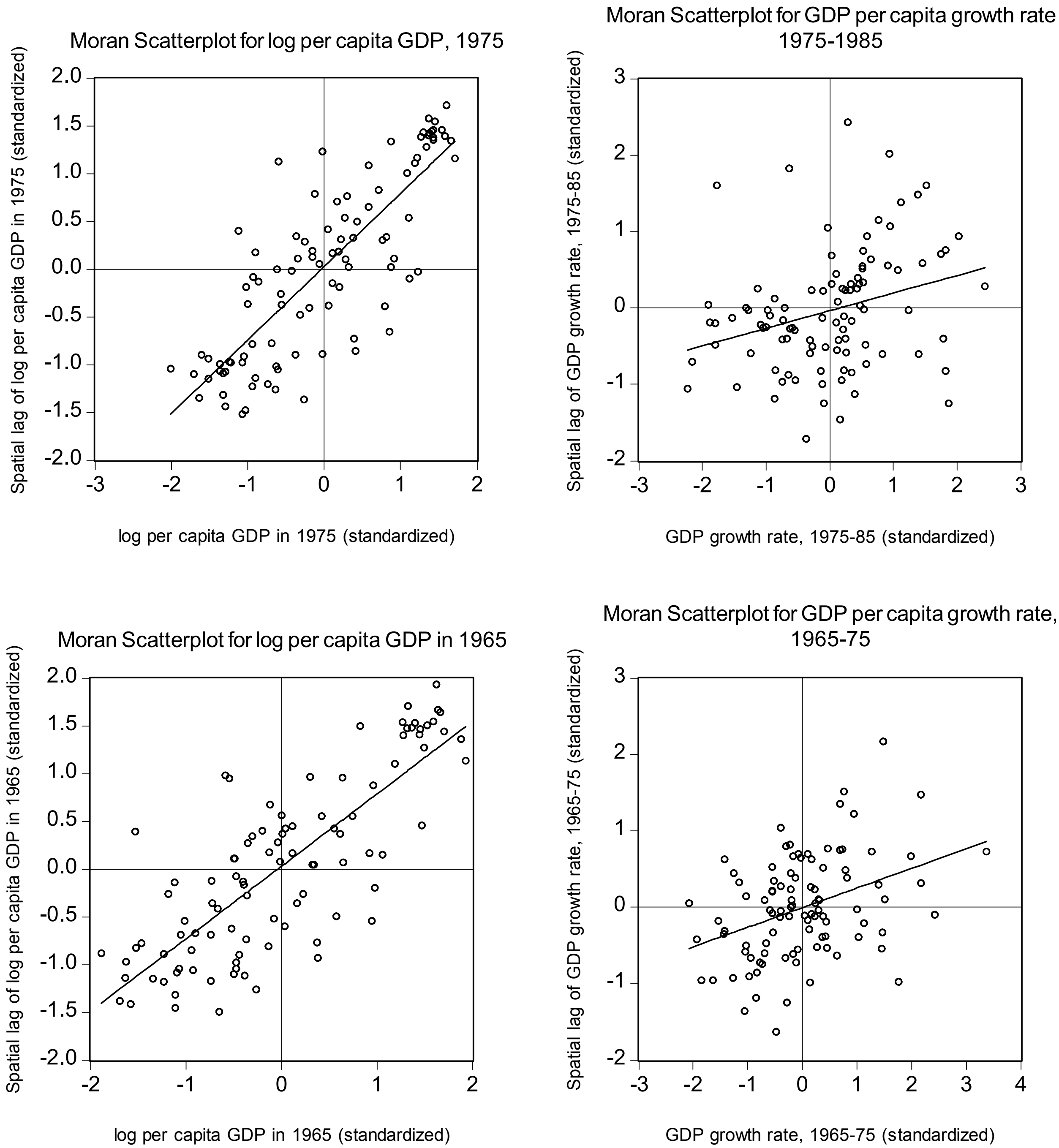


FIGURE 2 (Cont')
MORAN SCATTERPLOTS



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APPENDIX 1

The data for per capita GDP, investment rate, government consumption, education, black market premium on foreign exchange and terms of trade were obtain from Barro and Lee (1994), *Penn World Tables 5.6 dataset*, "World Development Indicators (WDI) CD-ROM" from the *World Bank*, and "World Currency Year Book", 1996 (published by Currency Data & Intelligence, Brooklyn, NY). Infrastructure came from *International Telecommunication Union Publications* (several years) and WDI CD-ROM. Life expectancy and fertility rate were taken also from the "World Development Indicators (WDI) CD-ROM" from the *World Bank*. For democracy, the data base of Jaggers and Gurr's *Polity III* (1996) was used; this index is a grade obtained from the average of eight indexes that classify the process of election of the policy makers of a country and the restrictions imposed over them. Commitment and credibility (*contract enforcement*) came from the *International Country Risk Guide (ICRG)* data file (1995); this index is based on survey information and shows the country's institutional characteristics that motivate its leaders to respect the duties of the government (the higher the value of the variable, the higher the level of commitment). Finally, for the bureaucratic quality the ICRG and the *Business Environmental Risk Intelligence* (taken from Knack and Keefer, 1995) datafiles were used; this variable is based on survey information and indicates autonomy from political pressures and decision and control to rule without drastic policy changes or disruptions in the services brought by the government.

Summary Statistics of Variables Included in Estimation

Variable	Mean	Std. Dev.	Minimum	Maximum
Growth rate of GDP per capita	0.0164	0.0262	–0.0548	0.1112
Log of initial GDP per capita	7.7630	1.0236	5.6699	9.7153
Growth rate of per-capita telephones	0.0525	0.0433	–0.0805	0.2244
Gross enrollment ratio for second. education	0.3908	0.2898	0.0100	1.0000
Log of investment as percentage of GDP	–1.9976	0.6972	–4.3135	–0.9826
Terms of trade change	0.0061	0.0615	–0.0832	0.3214
Democracy store	4.2111	4.3929	0.0000	10.0000
Bureaucracy quality	3.2712	1.7071	0.5000	8.5000
Contract enforcement	5.9393	1.9797	1.0000	10.0000
Log(1+ exch. rate black market premium)	0.2340	0.4440	0.0000	4.8454
Log of government expenditure	-1.7690	0.4016	-2.7704	-0.7022
Log of fertility rate	1.4419	0.5082	0.2546	2.0794
Log of life expectancy at birth	4.0621	0.2001	3.5860	4.3477

APPENDIX 1b

Countries included in the estimations and data availability

Country	Data Availability		
	1965-1975	1975-1985	1985-1995
1. Algeria	Complete data	Complete data	Black Market Premium not available
2. Argentina	Complete data	Complete data	Complete data
3. Australia	Complete data	Complete data	Complete data
4. Austria	Complete data	Complete data	Complete data
5. Bangladesh	Growth rates of telephones per capita and democracy not available	Complete data	Complete data
6. Belgium	Complete data	Complete data	Complete data
7. Bolivia	Complete data	Complete data	Complete data
8. Botswana	Complete data	Complete data	Complete data
9. Brazil	Complete data	Complete data	Complete data
10. Burkina-Faso	Education not available	Education not available	Education not available
11. Burundi	Education, commitment and bureaucracy not available.	Education, commitment and bureaucracy not available.	Education, commitment and bureaucracy not available.
12. Cameroon	Complete data	Complete data	Complete data
13. Canada	Complete data	Complete data	Complete data
14. Chad	Education, commitment and bureaucracy not available.	Education, commitment and bureaucracy not available.	Education, commitment and bureaucracy not available.
15. Chile	Complete data	Complete data	Complete data
16. Colombia	Complete data	Complete data	Complete data
17. Congo	Complete data	Complete data	Complete data
18. Costa Rica	Complete data	Complete data	Complete data
19. Cote d'Ivoire	Complete data	Complete data	Complete data
20. Cyprus	Complete data	Complete data	Complete data
21. Denmark	Complete data	Complete data	Complete data
22. Dominican Rep.	Complete data	Complete data	Complete data
23. Ecuador	Complete data	Complete data	Complete data
24. Egypt	Complete data	Complete data	Complete data
25. El Salvador	Complete data	Complete data	Complete data
26. Ethiopia	Complete data	Complete data	Complete data
27. Finland	Complete data	Complete data	Complete data
28. France	Complete data	Complete data	Complete data
29. Germany	Complete data	Complete data	Complete data
30. Gabon	Education not available	Education not available	Education not available
31. Gambia	Education, commitment and bureaucracy not available.	Education, commitment and bureaucracy not available.	Education, commitment and bureaucracy not available.
32. Ghana	Complete data	Black Market Premium not available	Complete data
33. Greece	Complete data	Complete data	Complete data
34. Guatemala	Complete data	Complete data	Complete data

Country	Data Availability		
	1965-1975	1975-1985	1985-1995
35. Guinea	Education not available	Education not available	Education not available
36. Haiti	Complete data	Complete data	Complete data
37. Honduras	Complete data	Complete data	Complete data
38. Iceland	Black Market Premium, commitment and bureaucracy not available	Black Market Premium, commitment and education not available	Black Market Premium, commitment and bureaucracy not available
39. India	Complete data	Complete data	Complete data
40. Indonesia	Complete data	Complete data	Complete data
41. Iran, I.R. of	Complete data	Complete data	Complete data
42. Iraq	Complete data	Complete data	Black Market premium, not available
43. Ireland	Complete data	Complete data	Complete data
44. Israel	Complete data	Complete data	Complete data
45. Italy	Complete data	Complete data	Complete data
46. Jamaica	Complete data	Complete data	Complete data
47. Japan	Complete data	Complete data	Complete data
48. Jordan	Complete data	Complete data	Complete data
49. Kenya	Complete data	Complete data	Complete data
50. Korea	Complete data	Complete data	Complete data
51. Lesotho	Commitment and bureaucracy not available	Commitment and bureaucracy not available	Terms of Trade, commitment and bureaucracy not available
52. Madagascar	Complete data	Complete data	Complete data
53. Malawi	Complete data	Complete data	Complete data
54. Malaysia	Complete data	Complete data	Complete data
55. Mali	Complete data	Complete data	Complete data
56. Malta	Democracy, commitment and bureaucracy not available	Democracy, commitment and bureaucracy not available	Democracy, commitment and bureaucracy not available
57. Mauritania	Education , commitment and bureaucracy not available	Education , commitment and bureaucracy not available	Education , commitment and bureaucracy not available
58. Mauritius	Black Market Premium, commitment and bureaucracy not available	Black Market Premium, commitment and bureaucracy not available	Black Market Premium, commitment and bureaucracy not available
59. Mexico	Complete data	Complete data	Complete data
60. Mozambique	Complete data	Democracy not available	Black Market Premium not available
61. Morocco	Complete data	Complete data	Complete data
62. Nepal	Complete data	Complete data	Complete data
63. Netherlands	Complete data	Complete data	Complete data
64. New Zealand	Complete data	Complete data	Complete data
65. Nicaragua	Complete data	Complete data	Complete data

Country	Data Availability		
	1965-1975	1975-1985	1985-1995
66. Niger	Complete data	Complete data	Complete data
67. Nigeria	Complete data	Complete data	Black Market Premium not available
68. Norway	Complete data	Complete data	Complete data
69. Pakistan	Complete data	Complete data	Complete data
70. Panama	Complete data	Complete data	Black Market Premium not available
71. Paraguay	Complete data	Complete data	Complete data
72. Peru	Complete data	Complete data	Black Market Premium not available
73. Philippines	Complete data	Complete data	Complete data
74. Portugal	Complete data	Complete data	Complete data
75. Rwanda	Education not available	Complete data	Complete data
76. Senegal	Complete data	Complete data	Complete data
77. Singapore	Terms of trade change not available	Complete data	Complete data
78. Somalia	Education not available	Education not available	Education not available
79. South Africa	Complete data	Complete data	Complete data
80. Spain	Complete data	Complete data	Complete data
81. Sri Lanka	Complete data	Complete data	Complete data
82. Sweden	Complete data	Complete data	Complete data
83. Switzerland	Complete data	Complete data	Complete data
84. Syria	Complete data	Complete data	Black Market premium not available
85. Tanzania	Complete data	Complete data	Complete data
86. Thailand	Complete data	Complete data	Complete data
87. Togo	Complete data	Complete data	Complete data
88. Trinidad & Tobago	Black Market Premium not available	Complete data	Complete data
89. Tunisia	Complete data	Complete data	Complete data
90. Turkey	Complete data	Complete data	Complete data
91. Uganda	Complete data	Complete data	Complete data
92. United Kingdom	Complete data	Complete data	Complete data
93. United States	Complete data	Complete data	Complete data
94. Uruguay	Complete data	Complete data	Complete data
95. Venezuela	Complete data	Complete data	Complete data
96. Zaire	Democracy not available	Complete data	Complete data
97. Zambia	Complete data	Complete data	Complete data
98. Zimbabwe	Complete data	Complete data	Complete data

APPENDIX 2
Classification of Spatial Association using Log of per capita GDP average 1965-95 (standardized)

High-High : Positive spatial association	Low-Low: Positive spatial association
Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Cyprus, Denmark, Ecuador, Finland, France, Germany, Greece, Iceland, Iraq, Ireland, Italy, Japan, Jordan, Korea, Malta, Mexico, Netherlands, New Zealand, Norway, Panama, Peru, Portugal, Spain, Sweden, Switzerland, Syria, Trinidad &Tobago, Turkey, United Kingdom, United States, Uruguay, Venezuela	Algeria, Bangladesh, Botswana, Burkina-Faso, Burundi, Cameroon, Chad, Congo, Cote d'Ivoire, Dominican Rep, Ethiopia, Gambia, Ghana, Guinea, Haiti, Honduras, India, Kenya, Madagascar, Malawi, Mali, Mauritania, Mozambique, Morocco, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Philippines, Rwanda, Senegal, Somalia, Sri Lanka, Tanzania, Togo, Uganda, Zaire, Zambia, Zimbabwe.
High-Low: Negative spatial association	**Low-High: Negative spatial association**
Costa Rica, Gabon, Iran, Israel, Jamaica, Malaysia, Mauritius, Singapore, South Africa.	Bolivia, Egypt, El Salvador, Guatemala, Indonesia, Lesotho, Morocco, Paraguay, Thailand, Tunisia.
Moran I: 0.8048 Z-value: 8.775 Probability:0.0000	

Note: High income more than US$2.200 per capita in average 1965-95, Low income less than US$2.200 per capita.

Classification of Spatial Association using GDP per capita growth rate, average 1965-95 (standardized)

High-High : Positive spatial association	Low-Low: Positive spatial association
Austria, Belgium, Canada, Cyprus, Denmark, Egypt, France, Germany, Greece, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Malaysia, Malta, Morocco, Nepal, Netherlands, Norway, Panama, Portugal, Singapore, Spain, Sri Lanka, Thailand, Tunisia, United Kingdom, United States.	Algeria, Bolivia, Burkina-Faso, Burundi, Cameroon, Chad, Costa Rica, Cote d'Ivoire, El Salvador, Ethiopia, Gambia, Ghana, Guatemala, Guinea, Honduras, Iran, Kenya, Madagascar, Malawi, Mali, Mauritania, Mozambique, Nicaragua, Niger, Rwanda, Senegal, Somalia, Tanzania, Togo, Trinidad & Tobago, Uganda, Zaire, Zambia, Zimbabwe.
High-Low: Negative spatial association	**Low-High: Negative spatial association**
Australia, Botswana, Brazil, Chile, Colombia, Congo, Dominican Rep, Ecuador, Finland, Jordan, Lesotho, Mauritius, Mexico, Nigeria, Pakistan, Paraguay, Syria, Turkey.	Argentina, Bangladesh, Gabon, Haiti, Iraq, Jamaica, New Zealand, Peru, Philippines, South Africa, Sweden, Switzerland, Uruguay, Venezuela.
Moran I: 0.4118 Z-value: 4.6516 Probability: 0.0000	

Note: High, more than 1.6% GDP per capita growth, Low, less than 1.6% GDP per capita growth.

APPENDIX 2a

Classification of Spatial Association using Log of per capita GDP in 1985 (standardized)

High-High : Positive spatial association	Low-Low: Positive spatial association
Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Cyprus, Denmark, Ecuador, Finland, France, Germany, Greece, Iceland, Iraq, Ireland, Israel, Italy, Japan, Jordan, Korea, Malaysia, Malta, Mexico, Netherlands, New Zealand, Norway, Panama, Portugal, Spain, Sweden, Switzerland, Syria, Thailand, Trinidad &Tobago, Tunisia, Turkey, United Kingdom, United States, Uruguay, Venezuela	Bangladesh, Botswana, Burkina-Faso, Burundi, Cameroon, Chad, Cote d'Ivoire, Dominican Rep, El Salvador, Ethiopia, Gambia, Ghana, Guinea, Haiti, Honduras, India, Jamaica, Kenya, Madagascar, Malawi, Mali, Mauritania, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Philippines, Rwanda, Senegal, Somalia, Sri Lanka, Tanzania, Togo, Uganda, Zaire, Zambia, Zimbabwe.
High-Low: Negative spatial association	**Low-High: Negative spatial association**
Algeria, Congo, Costa Rica, Gabon, Iran, Mauritius, Singapore, South Africa.	Bolivia, Egypt, Guatemala, Indonesia, Lesotho, Morocco, Paraguay, Peru.
Moran I: 0.8347 Z-value: 9.0967 Probability:0.0000	

Note: High income more than US$2.700 per capita in 1985, Low income less than US$2.700 per capita.

Classification of Spatial Association using GDP per capita growth rate, 1985-95 (standardized)

High-High : Positive spatial association	Low-Low: Positive spatial association
Australia, Austria, Bangladesh, Belgium, Canada, Costa Rica, Cyprus, Denmark, France, Germany, Greece, India, Indonesia, Ireland, Italy, Jamaica, Japan, Korea, Malaysia, Malta, Nepal, Netherlands, New Zealand, Norway, Pakistan, Philippines, Portugal, Singapore, Spain, Sri Lanka, Thailand, United Kingdom.	Algeria, Botswana, Burkina-Faso, Burundi, Cameroon, Chad, Congo, Dominican Rep, Gabon, Gambia, Guatemala, Honduras, Iran, Iraq, Jordan, Malawi, Mali, Mauritania, Morocco, Niger, Nigeria, Paraguay, Rwanda, Senegal, Togo, Trinidad & Tobago, Venezuela, Zaire, Zambia, Zimbabwe.
High-Low: Negative spatial association	**Low-High: Negative spatial association**
Chile, Colombia, El Salvador, Finland, Ghana, Guinea, Israel, Lesotho, Mauritius, Mozambique, Somalia, Syria, Tanzania, Tunisia, Turkey, Uganda, United States, Uruguay.	Argentina, Bolivia, Brazil, Cote d'Ivoire, Ecuador, Egypt, Ethiopia, Haiti, Iceland, Kenya, Madagascar, Mexico, Nicaragua, Panama, Peru, South Africa, Sweden, Switzerland.
Moran I: 0.3242 Z-value: 3.6005 Probability:0.0003	

Note: High, more than 1% GDP per capita growth, Low, less than 1% GDP per capita growth.

APPENDIX 2b
Classification of Spatial Association using Log of per capita GDP in 1975 (standardized)

High-High : Positive spatial association	Low-Low: Positive spatial association
Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Cyprus, Denmark, Ecuador, Finland, France, Germany, Greece, Iceland, Iraq, Ireland, Italy, Malta, Mexico, Netherlands, New Zealand, Norway, Panama, Peru, Portugal, Spain, Sweden, Switzerland, Syria, Trinidad &Tobago, Turkey, United Kingdom, United States, Uruguay, Venezuela	Algeria, Bangladesh, Botswana, Burkina-Faso, Burundi, Cameroon, Chad, Congo, Cote d'Ivoire, Dominican Rep, Ethiopia, Gambia, Ghana, Guinea, Haiti, India, Indonesia, Kenya, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Philippines, Rwanda, Senegal, Somalia, Sri Lanka, Tanzania, Togo, Uganda, Zaire, Zambia, Zimbabwe.
High-Low: Negative spatial association	**Low-High: Negative spatial association**
Costa Rica, Gabon, Iran, Israel, Jamaica, Japan, Malaysia, Mauritius, Nicaragua, Singapore, South Africa.	Bolivia, Ecuador, Egypt, El Salvador, Guatemala, Honduras, Jordan, Korea, Lesotho, Paraguay, Thailand, Tunisia.
Moran I: 0.7679 Z-value: 8.3779 Probability: 0.0000	

Note: High income more than US$2.800 per capita in 1975, Low income less than US$2.800 per capita.

Classification of Spatial Association using GDP per capita growth rate, 1975-85 (standardized)

High-High : Positive spatial association	Low-Low: Positive spatial association
Algeria, Austria, Bangladesh, Belgium, Canada, Cyprus, Denmark, Egypt, Finland, France, Germany, Greece, Iceland, India, Indonesia, Ireland, Italy, Japan, Korea, Malaysia, Malta, Morocco, Nepal, Netherlands, Norway, Philippines, Singapore, Sri Lanka, Sweden, Switzerland, Syria, Thailand, Tunisia, United Kingdom, United States.	Argentina, Bolivia, Cote d'Ivoire, Costa Rica, Dominican, Ecuador, El Salvador, Ethiopia, Gambia, Ghana, Guinea, Haiti, Honduras, Iran, Jamaica, Kenya, Madagascar, Malawi, Mozambique, Nicaragua, Niger, Nigeria, Senegal, Somalia, South Africa, Tanzania, Togo, Turkey, Uruguay, Zaire, Zambia, Zimbabwe.
High-Low: Negative spatial association	**Low-High: Negative spatial association**
Australia, Botswana, Brazil, Burkina-Faso, Burundi, Cameroon, Chile, Colombia, Congo, Jordan, Lesotho, Mali, Mauritius, Mexico, Pakistan, Panama, Paraguay, Portugal, Rwanda, Trinidad & Tobago.	Chad, Gabon, Guatemala, Israel, Iraq, Mauritania, New Zealand, Peru, Philippines, Spain, Uganda, Venezuela.
Moran I: 0.2307 Z-value: 2.5940 Probability: 0.0095	

Note: High, more than 1% GDP per capita growth, Low, less than 1% GDP per capita growth.

APPENDIX 2c

Classification of Spatial Association using Log of per capita GDP in 1965 (standardized)

High-High : Positive spatial association	Low-Low: Positive spatial association
Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Costa Rica, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Iran, Iraq, Ireland, Italy, Mexico, Netherlands, New Zealand, Norway, Panama, Peru, Portugal, Spain, Sweden, Switzerland, Syria, Trinidad &Tobago, Turkey, United Kingdom, United States, Uruguay, Venezuela	Algeria, Bangladesh, Botswana, Burkina-Faso, Burundi, Cameroon, Chad, Congo, Cote d'Ivoire, Dominican Rep, Ethiopia, Gambia, Ghana, Guinea, Haiti, India, Indonesia, Kenya, Malawi, Malaysia, Mali, Mauritania, Morocco, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Philippines, Rwanda, Senegal, Somalia, Sri Lanka, Tanzania, Thailand, Togo, Tunisia, Uganda, Zaire, Zambia, Zimbabwe.
High-Low: Negative spatial association	**Low-High: Negative spatial association**
Gabon, Israel, Jamaica, Japan, Mauritius, Nicaragua, Singapore, South Africa.	Bolivia, Ecuador, Egypt, El Salvador, Guatemala, Honduras, Jordan, Korea, Lesotho, Madagascar, Malta, Paraguay.
Moran I: 0.7586 Z-value: 8.2768 Probability:0.0000	

Note: High income more than US$1.800 per capita in 1965, Low income less than US$1.800 per capita.

Classification of Spatial Association using GDP per capita growth rate, 1965-75 (standardized)

High-High : Positive spatial association	Low-Low: Positive spatial association
Colombia, Congo, France, Gabon, Iceland, Indonesia, Israel, Italy, Jamaica, Japan, Korea, Lesotho, Malaysia, Panama, Philippines, Portugal, Singapore, South Africa, Spain, Syria, Thailand, Tunisia, Turkey, Zimbabwe.	Argentina, Australia, Bangladesh, Burkina-Faso, Burundi, Chile, Cote d'Ivoire, Denmark, El Salvador, Ethiopia, Gambia, Ghana, Guatemala, Guinea, Honduras, India, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Nepal, New Zealand, Nicaragua, Niger, Senegal, Somalia, Sri Lanka, Trinidad & Tobago.
High-Low: Negative spatial association	**Low-High: Negative spatial association**
Algeria, Austria, Belgium, Bolivia, Botswana, Brazil, Canada, Costa Rica, Dominican, Ecuador, Finland, Greece, Iran, Ireland, Kenya, Mexico, Netherlands, Nigeria, Norway, Rwanda, Tanzania.	Cameroon, Chad, Cyprus, Egypt, Germany, Haiti, Iraq, Jordan, Morocco, Pakistan, Paraguay, Peru, Philippines, Sweden, Switzerland, Togo, Uganda, United Kingdom, United States, Uruguay, Venezuela, Zaire, Zambia.
Moran I: 0.2562 Z-value: 2.8687 Probability: 0.0041	

Note: High, more than 1% GDP per capita growth, Low, less than 1% GDP per capita growth.