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Are Caribbean Countries Diverging or Converging? Evidence from Spatial Econometrics

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Abstract

This paper utilizes the concepts of convergence to examine whether or not disparities in per capita GDP of selected CARICOM countries have diminished. Results from descriptive and spatial statistical methods show no evidence of correlation between the spatial distribution of the level and growth of per capita GDP. Also various econometric tests of beta-convergence and sigma-convergence, based on panel spatial econometrics proved that, since the early 1980s, there is an absence of convergence for CARICOM countries. However, the phenomenon of club convergence within the OECS group, which are linked in a quasi-monetary union framework, was found.

Keywords: ***Convergence, Spatial Econometrics, Caribbean***

JEL No: ***C21, F43, N75***

1. Introduction

Caribbean societies consist of a diverse set of cultures, systems of government and their people speak several types of languages. In addition, they differ in surface area and population, as well as in the level of economic development which range from the poor (Haiti) to the more developed territories like Barbados. The unequal development among Caribbean countries has invoked the question, "Is there convergence of the gaps between real per capita gross domestic product (GDP) among these countries?"

The convergence hypothesis is a prediction of the standard neoclassical growth models of Solow (1956) and Swan (1956), and more recently, the 'new growth theories' (Romer 1990; Barro and Sala-i-Martin 1995) and the new economic geography (Krugman 1991). The validity of this hypothesis has been conducted using cross-sectional, time series or panel data.

Recently, however, the econometric research has shifted to the incorporation of space in the economic growth models. Therefore, instead of assuming the independence of the cross sectional data collected, explicit modelling of the spatial properties of geographic observations is included in the econometric models and tests of autocorrelation and spatial heterogeneity are undertaken (see Beaumont et al. 2000; Le Gallo 2000; Toral 2002).

Despite the voluminous research on the empirical analysis of the convergence process in developed economies (see Moreno and Trehan 1997; Durlauf and Quah 1998), and less developed countries (Nagaraj et al. 1999; AKanni-Honvo 2003; Parikh and Shibata 2004; Dramani 2007), little work has been done on Caribbean economies. In fact, for the Caribbean, one can only identify the research of Atkins and Boyd (1998), Birchwood (2005), Moreira and Mendoza (2006) and Giudici and Mollick (2008), but their econometric methodologies assumed independence of the cross sectional data collected.

This paper is a continuation of these studies with two major differences: (1) the period of investigation and the selection of countries are larger; and (2) the econometric models and tests incorporate the spatial properties of geographic observations. It is divided into four sections. Section 2 provides a descriptive analysis of the economic performance of the sample Caribbean countries. Section 3 briefly reviews the concepts of convergence and the pertinent issues concerning the spatial effects in the Caribbean data. The results of the spatial econometric tests of convergence are reported and discussed in section 4. Section 5 concludes the paper.

2. The Economic Performance of Caribbean Countries

As shown in table 1, the levels of GDP per capita in the 22 countries exhibit variation, especially if one considers GDP per capita (2000 International (INT) $). According to the World Bank (2005)'s income ranking, 12 countries (Anguilla, Belize, Cuba, Dominica, Grenada, Guyana, Jamaica, the Dominican Republic, Montserrat, Saint Lucia, Saint Vincent and the Grenadines, Suriname) are in the lower bracket, with a GDP per capita of between INT$3,000 and INT$7,500, while 5 economies (Antigua and Barbuda, Barbados, Saint Kitts and Nevis, Netherlands Antilles, Trinidad and Tobago) are in the upper bracket, with GDP per capita ranging from INT$7,500 to INT$15,000. The intermediate group is flanked, on one extreme, by Haiti, one of the poorest countries in the world, with GDP per capita less than INT$1500, and on the other, by the richest islands, The Bahamas, Guadeloupe, Martinique, Aruba, British Virgin Islands and the United States (US) Virgin Islands whose GDP per capita is higher than INT$15,000.

Table 1: GDP Per Capita and the Unemployment Rate in the Caribbean in 2006

	GDP per capita 2006 (2000 International $)	GDP per capita (US$ 2003)	Unemployment rate
Anguilla	7485*	n.a	8.0*
Antigua and Barbuda	12318	11124	8.1
Aruba	19884	n.a	6.9*
Bahamas	16359	16691	10.2
Barbados	11646*	9651	7.6
British Virgin Islands	35821*	n.a	3.6
Cuba	3000*	n.a	2.5
Dominica	6047	3554	23.1*
Dominican Republic	7618	1825	18.4
Grenade	7378	4103	13.0
Guadeloupe	19500*	n.a	26.9
Haiti	1479	460	55.0
Jamaica	3907	2962	11.7
Martinique	21600 *	n.a	23.5
Montserrat	5250*	n.a	13.0
Netherlands Antilles	10794*	n.a	14.5*
Saint Kitts and Nevis	12521	7641	5.0*
Saint Lucia	6482	4048	21.0
Saint Vincent and the Grenadines	6056	3329	19.8*
Trinidad and Tobago	14708	7836	10.4
Belize	6460	3891	11.6
Guyana	4204	911	11.7
Suriname	7231	2470	15.0
US Virgin Islands	18512*	n.a	6.0

Source: World Bank (2005), CARICOM: http://www.caricomstats.org , INSEE (2004) for (*)
Note: n.a means not available.

It should be noted that the World Bank (2005) classification is in line with that of the Caribbean Community - CARICOM - (2005) which found the following 4 clusters: Relatively High Middle Income countries – Antigua and Barbuda, The Bahamas, Barbados, Saint-Kitts and Nevis and Trinidad and Tobago; Medium Middle Income economies - Belize, Grenada, Saint Lucia and St. Vincent and the Grenadines; Low Middle Income territories - Dominica, Guyana, Jamaica and Suriname; and, Low Income islands - Haiti.

In terms of a country's economic weight, measured by the percentage of a country's GDP to CARICOM's total GDP, size does not appear to be a significant factor, with the exception of Jamaica. In fact, the countries are ranked in the following order: Trinidad and Tobago, Jamaica, The Bahamas, Barbados, Belize, Guyana, and Montserrat. Size is even less important if the barometer employed is income per capita. The Bahamas, Antigua and Barbuda, Barbados and Montserrat, in that order, rank much higher than the largest countries (Suriname, Guyana and Jamaica).

2.1. The Evolution of GDP Indicators during 1978-2006

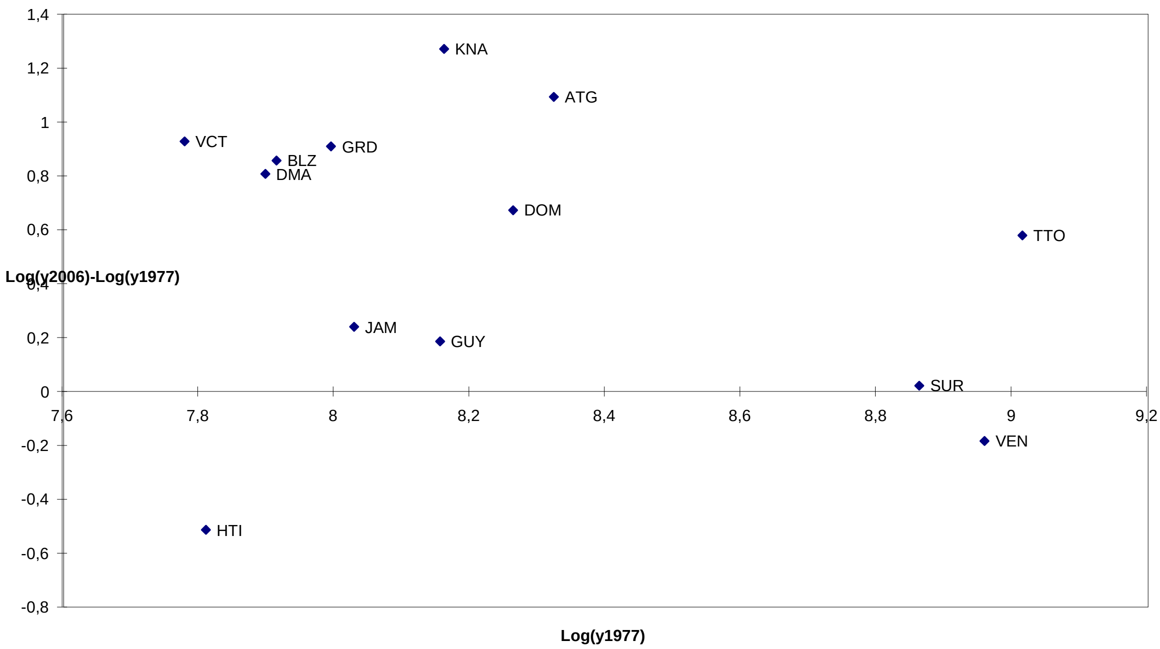
Table 2 and figure 1 show per capita GDP in the initial period (1977) and its average growth between 1978 and 2006. Recognising that GDP per capita in table 2 is in ascending order, countries with low GDP per capita have a net average growth rate below those of leading countries in 1977. Notice also that the observed values for the average growth rates of the Organisation of the Eastern Caribbean States (OECS) are within a relatively narrow range (from 2.42 (DOM) to 4.57 (KNA)), reflecting the fact that these islands have been part of a quasi monetary union since 1981 (see Jessamy 2003).

Table 2: Per Capita GDP in 1977 and the Average Growth Rate between 1978 and 2006

Country	$GDPpc_{i,1977}$	g_i
VCT	2393.93	3.31
HTI	2470.95	-1.67
DMA	2696.74	2.99
BLZ	2741.67	3.1
GRD	2970.96	3.26
JAM	3074.61	0.88
GUY	3490.87	0.76
KNA	3511.43	4.57
DOM	3887.59	2.42
ATG	4128.36	3.91
SUR	7078.69	0.26
VEN	7793.49	-0.45
TTO	8240.41	2.18

Notes: g_i = mean of the GDP growth rate for the period 1978-2006. VCT=St. Vincent and the Grenadines; HTI= Haiti; DMA=Dominican Republic; BLZ=Belize; GRD=Grenada; JAM=Jamaica; GUY=Guyana; KNA=St. Kitts and Nevis; DOM=Dominica; ATG=Antigua; SUR=Suriname; VEN=Venezuela; and TTO =Trinidad and Tobago.

Figure 1: GDP Per Capita Growth Rate Verses Initial GDP



The simple correlation coefficient calculated for the two distributions in table 2 is -0.29. By omitting Haiti, a value of -0.56 is obtained. When the focus is on the 11 CARICOM countries, a value of -0.39 is derived. These negative values are consistent with the hypothesis of convergence but do not necessarily imply convergence or divergence. Figure 1 also seems to roughly indicate a negative relationship between the two variables. However, too many countries lie in the extreme positions of the sample to validate the proposition that the poor countries in the early period grew faster than the rich countries.

2.2. Spatiotemporal Structure of GDP per Capita during 1978-2006

The description of the process of convergence that accounts for spatial patterns among countries involves the simultaneous study of the inter-annual and intra-annual variability of GDP per capita. Thus a multivariate statistical technique is applied to the growth dynamics of the Caribbean countries. In particular, Principal Component Analysis (PCA) which is a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components is employed. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component represents as much of the remaining variability as possible.

The results of the PCA show that the first two principal components account for nearly 90% of the total variance of the correlated variables, of which 71.86% relates to the first principal component. The circle of correlations (the first graph in figure 2) provides a picture of the countries and their relationships during the period 1977 to 2006. The second graph in figure 2 helps to determine visually the temporal structure of the average level of GDP per capita by highlighting trends and breaks. Looking at the contributions of the individual variables in each country and the contribution of each country in each year (these results are available on request) it is seen that the F1 axis shows more contrast between the extreme years of the period 1977 to 2006. Unlike the F1 axis, the F2 axis only represents 17.7% of the total initial information and does not provide as clear a picture of the positions of the countries and the years. Additionally, the order structure over the years is very different to that of the F1 axis; the extreme years are very similar and opposite to the break period 1987 to 1990.

For a good exposition on using and interpreting PCA in an Excel format see the website : http://www.xlstat.com/en/support/tutorials/principal-component-analysis-pca.htm.

3. Theoretical and Methodological Foundations

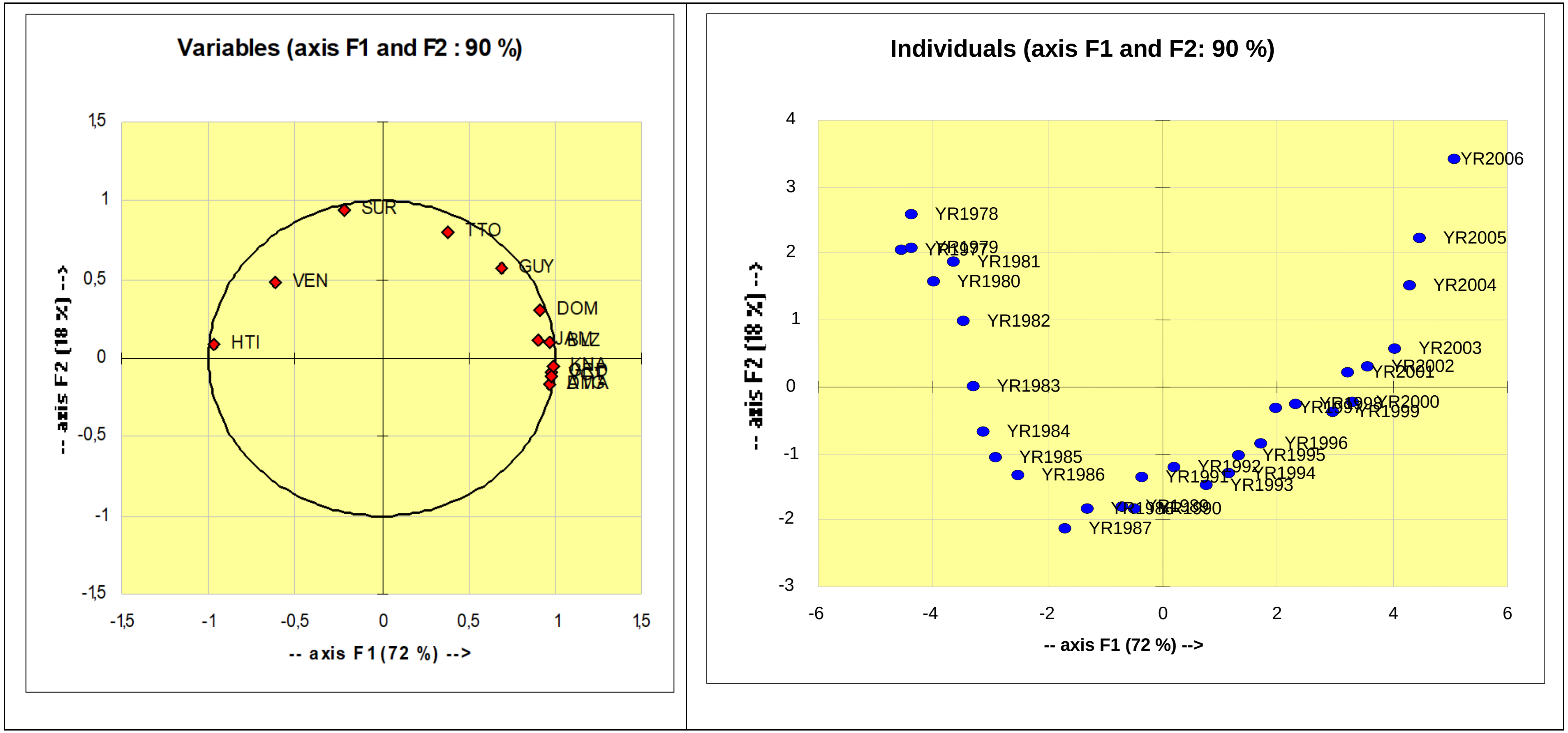
3.1. Theoretical Framework of Convergence

The concepts of convergence proposed for analyzing and measuring the process of convergence of different economies to the same level of development, or the phenomenon of catch-up in living standards among countries, are based on the neoclassical growth model. The Solow-Swann model of exogenous growth was the first formal framework to study the evolution of per capita GDP growth among regions or countries. Mathematically, it can be written as

$$\frac{1}{T-t}\ln\left(\frac{y_{i,T}}{y_{i,t}}\right)=\alpha-\left(\frac{1-e^{-\beta T}}{T-t}\right)\ln\left(\frac{\hat{y}^{*}}{y_{i,t}}\right) \qquad (1)$$

where y_t and y_T are per capita GDP of the first (t) and last year (T), respectively, α and β are parameter coefficients to be estimated and In is natural logarithms. It states that the rate of per capita growth for a country will be much higher than it is from its path of long-term

Figure 2: Graphs of the Circle of Correlations and the Screening of Individuals in the Principal Plane



equilibrium. As highlighted by Bensidoun and Boone (1998, p.97), this result does not "consider that the absolute convergence of per capita income between countries was an implication of the Solow model. Rather, it calls for understanding convergence as the convergence of each economy to its own equilibrium path." This concept of convergence has been called "conditional convergence" to distinguish it from absolute convergence.

The endogenous growth models have also led to clear advances in the study of the phenomena of catching up and convergence of groups of economies. Barro and Sala-i-Martin (1991) have used these models to refine the concepts of convergence. They define absolute beta-convergence as the per capita GDP of poor countries (or regions) growing faster than those of rich countries (or regions), when the initial conditions involve countries with similar economic structures (natural resources, technologies, etc.). On the contrary, when the initial conditions of countries are different, the convergence process is called beta-conditional convergence. In practice, empirical tests of the beta-convergence hypothesis are made from the traditional growth regression:

$$\frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right)=\alpha+\beta\log\left(y_{i,0}\right)+\varepsilon_i \qquad (2)$$

where $y_{i,0}$ and $y_{i,T}$ denote GDP per capita of the country or region *i*=1,..., *N*, at the initial year 0 and the final year *T*, respectively, and $\varepsilon_i \sim i.i.d\left(0,\sigma_\varepsilon^2\right)$. In equation (2), a negative and statistically significant value of β validates the hypothesis of β-absolute convergence, confirming that the poorest regions or countries have higher growth rates. From this estimated value of β, the speed of convergence, defined as $\theta=-\ln\left(1+T\beta\right)/T$, can also be calculated.

By introducing X_i, a vector of explanatory variables that maintain the state of the economy *i* to its constant level, the hypothesis of conditional beta-convergence can be tested using the following model:

$$\frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right)=\alpha+\beta\log\left(y_{i,0}\right)+\Pi X_i+\varepsilon_I \qquad (3)$$

A simpler measure of the convergence phenomenon consists of examining whether the dispersion of income per head is reduced. According to Barro and Sala-i-Martin (1991), sigma-convergence occurs when a strengthening of per capita income relative to the average level of all countries (or regions) is observed from one period to another. By designating the standard deviation of per capita GDP of the N countries at time t by σ_t, the condition of sigma-convergence between the period t and t + h is:

$$\sigma_{t+h}<\sigma_t \qquad (4)$$

with $\sigma_t^2 = \frac{1}{n}\sum_{i=1}^{n}\left[\ln\left(Y_{i,t}\right) - \mu\right]^2$ and $\mu = \frac{1}{n}\sum_{i=1}^{n}\ln\left(Y_{i,t}\right)$. By calculating the variance using equation (1), it is easy to show that the link between the beta and sigma convergence is as follows:

$$\sigma_t^2 \cong (1-\beta)^2 \sigma_{t-1}^2 + \sigma_\varepsilon^2 \qquad (5)$$

The evolution of σ_t is stationary if and only if $0 < \beta < 1$. This implies that beta-convergence is a necessary but not a sufficient condition for sigma-convergence.

3.2. Modelling Spatial Effects

Researchers like Montouri and Rey (1999), Beaumont et al. (2000), Le Gallo (2000) and Toral (2002) have explicitly considered the role of spatial effects by observing that the geographical distribution of the phenomena of growth among countries or within regions of a country is related to the dissemination of technologies and factor mobility and other factors often found in the endogenous growth literature. The main foundation underlying the specification of spatial models is the construction of a weighted matrix that positions the observations relative to each other according to their sizes and structures. To measure these characteristics, a simple binary contiguity matrix *W* such that w_{ij} =1 if the regions *i* and *j* share a border and w_{ij} =0 otherwise, is often employed. However, this is not suitable to describe the space interactions among countries or states such as those found in Europe or the US, respectively, because of a lack of connection among some countries or states. In the case of the Caribbean using the criterion of contiguity is even more of a problem since it leads to a sparse matrix, which shows an absence of interactions among the majority of the countries. As a result, the degree of interaction between two areas *i* and *j* must be measured utilising general weighted matrices derived from various functional forms like the inverse exponential or the inverse of the distance. Formally, one can define the matrix *W* in these two cases respectively as follows:

$$w_{ij} = e^{-\delta d_{ij}}$$

$$w_{ij} = \begin{cases} 1/d_{ij}^{\gamma} & \text{if } d_{ij} < \bar{d} \\ 0 & \text{else} \end{cases} \qquad (6)$$

with d_{ij} being the distance between region *i* and *j* and δ and γ are parameters, fixed a priori. Other generalizations of the matrix *W* disregard physical distance completely in favour of particular representations of the spatial dependence.

This choice of the matrix *W* is a crucial step because, as pointed out by Anselin (1988), the results of the tests for spatial dependence can vary with the regional unit of analysis and the spatial weights chosen. It is also important to note that the matrix W must be selected to ensure its exogeneity, that is, each country is connected to a set of neighboring countries through the spatial structure introduced exogenously in the matrix W. Thus, the content of W is not based on a variable that is itself defined in the model. Anselin and Bera (1998) and Keller (2002) have indeed shown that the distances must be exogenous in order to avoid the empirical model becoming highly nonlinear.

Once this choice of W is made, then the estimate of convergence is based on the different classes of spatial models (see Anselin 1988, 2001). The most widely used of these specifications is utilised here, that is, those based on extending the beta convergence equation with a spatial autoregressive specification on the dependent variable or on the error term. Equation (7) below represents the spatial autoregressive process of order 1:

$$\frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha + \beta \log(y_{i,0}) + \varepsilon_i \qquad (7)$$

$$\varepsilon_i = \lambda W \varepsilon_i + \eta_i$$

where $\eta \sim N(0,\sigma^2 I)$ and λ is a parameter that represents the intensity of the spatial autocorrelation between the residuals of the regression. With model (7), called the Spatial Error Model – SEM -, a random shock in a region i affects GDP per capita in this region plus in those areas that are within the vicinity and away from i.

The second class of models assumes that the rate of growth of a region depends directly on those regions in its neighbourhood, through the processes of spatial diffusion. Thus, starting from the specification (2), the lagged variable is also included as an explanatory variable to obtain equation (8) which is known as the Spatial Autoregressive Model – SAR:

$$\frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha + \beta \log(y_{i,0}) + \rho W\left[\frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right)\right] + \varepsilon_i \qquad (8)$$

with Wy_G being the lagged endogenous variable for the weight matrix *W*. It reflects the idea that the observation for country *i* is explained by the values given to the countries in its neighbourhood $(Wy_G)_i$. Incorporating this autoregressive structure reveals that spatial correlation is more complex than temporal correlation. Indeed, it is not only unidirectional as in a time series model but rather multidirectional since it is also based on the dimensions associated with each geographical unit. The coefficient of spatial autocorrelation must be considered, and where it is significantly different from zero, a positive (negative) coefficient reveals a positive (negative) spatial autocorrelation in the convergence process.

Two other families of models are those that represent spillovers through incorporating the variables of the space environment. The first model is given in equation (9) below. This is called the Spatial Cross-regression Model which differs from the SAR model discussed above in that it introduces spatial dependence at the initial GDP per capita level rather than through the growth rate of GDP per capita (see Montouri and Rey 1999):

$$\frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha + \beta \log(y_{i,0}) + \tau W \log(y_{i,0}) + \varepsilon_i \quad (9)$$

The second model is given by equation (10), which incorporates two types of spillover effects that influence the growth rate of GDP per capita of country i: first, the growth rate of GDP per capita of countries in the neighbourhood of i and the other hand, the initial GDP per capita of countries in the neighbourhood of i:

$$\frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha + \beta \log(y_{i,0}) + \rho W\left[\frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right)\right] + \tau W \log(y_{i,0}) + \varepsilon_i \quad (10)$$

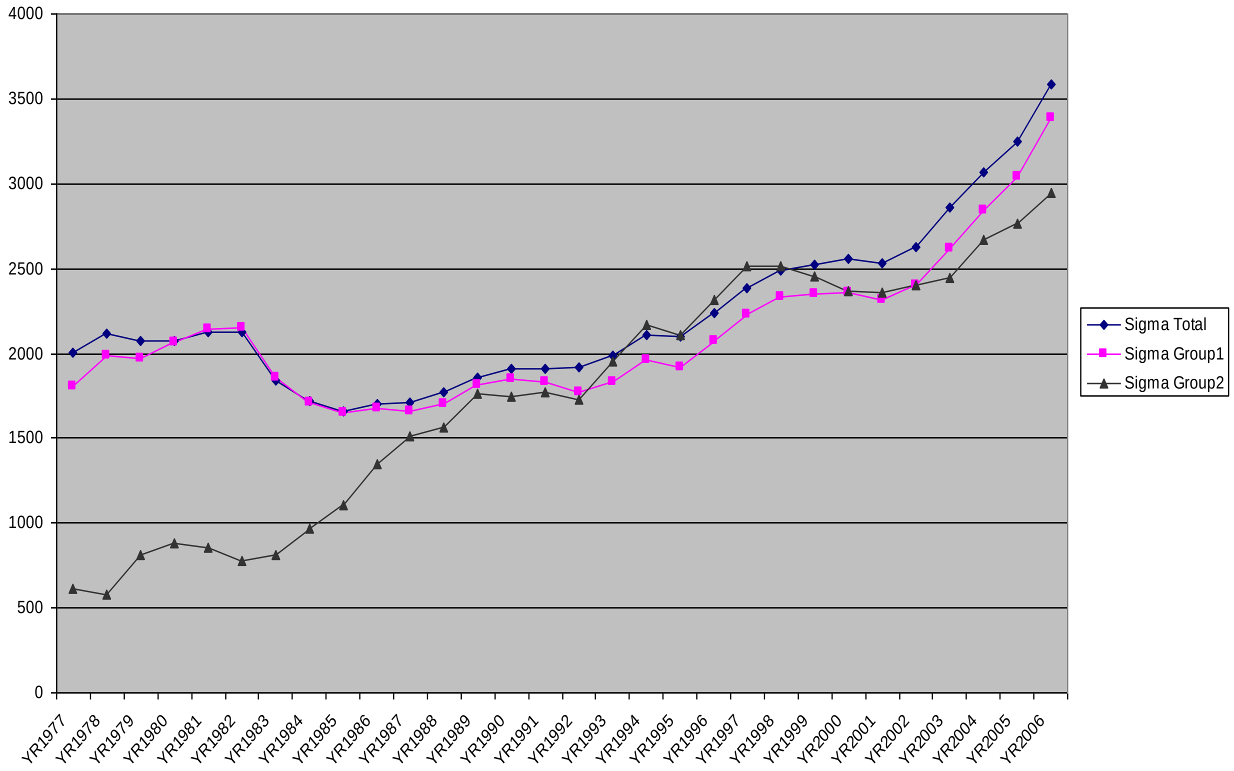
4. Econometric Analysis of Convergence in the Caribbean

4.1. Classical Tests

Data on GDP per capita were calculated using purchasing power parity (PPP), national GDP (constant 2000 international $) and population. It is important to note that the GDP series utilised is expressed in international dollars, which is based on the concept of PPP. More precisely, the international dollar, also called Geary-Khamis dollar, is a monetary unit with the same purchasing power characteristic as the US dollar in the United States. So it is a currency that allows comparison of gross national income per capita for several countries. The data is sourced from the World Bank.

This section continues with an analysis of sigma-convergence utilising three groups of Caribbean countries: all thirteen countries, eleven countries excluding Haiti and Venezuela and the five countries of the OECS (Antigua and Barbuda, Dominica, Grenada, St. Kitts and Nevis, St. Vincent and the Grenadines), that is, Sigma Total, Sigma Group 1 and Sigma Group 2, respectively (see figure 3). A look at the figure reveals alternating periods of convergence and divergence. Between 1977 and 1982 there is divergence between groups 1 and 2 but episodes of convergence within the OECS grouping. From 1982 to 1995, a powerful trend towards convergence between groups 1 and 2 exists. However, during this same period, for the OECS countries, the dispersion of GDP per capita rose steadily from 1982 to 1989 and remained stable between 1989 and 1992, expanding again over the period 1992 to 1995. During the period 1995 to 2000, for the three groups of countries, the curve is like a reversed U shape, indicating an episode of increased standard deviation of GDP per capita (1995 to 1998) and then an episode of decrease (1998 to 2001). Finally, from 2002, the countries of the OECS are again much lower than that observed in the other two groups. These results are comparable to those highlighted by Giudici and Mollick (2008) who studied the convergence process in the OECS for the period 1977 to 2000 by applying the panel econometric methods of Islam (1995). They have shown that "if the whole set of countries is considered, there is a permanent gap in income among the members, which corresponds to a spread of about 44% of the average income. If the richer countries of Antigua and Barbuda and St. Kitts and Nevis are omitted; the remaining islands maintain a steady spread of only 12%. At the same time, the richer islands are converging to each other at a very fast rate. This indicates that the islands are growing as two distinct convergence clubs."

Figure 3: Sigma Convergence - Standard Deviation of the Log of GDP Per Capita



4. 2. Spatial Analysis

The convergence process is analysed by examining the role of spatial dependence instead of considering each country in isolation. In fact, it is not difficult to find certain aspects of interdependence among countries in the Caribbean, for example, in the area of intra-regional trade, health, education and migration. Referring to the latter several authors have stressed that the movement of intra-regional population is multifaceted and reflect essentially the hierarchy of living standards across countries (see table 1 and Borda et al. 2008). Furthermore, Guzman et al. (2006) noted that "intra-regional movements are especially evident in countries where labour markets and education offer the most opportunities and where, in general, the level of social protection is higher." These countries, consisting principally of Barbados, The Bahamas, Guadeloupe, French Guiana, Martinique, Trinidad and

Tobago and Puerto Rico are termed "receivers". Conversely, the nations with intra-regional movement away from them are called 'issuers' and are usually affected by the most difficult economic or political situations. Examples of these include Haiti, Cuba, Dominica, Grenada and St. Vincent and the Grenadines.

Notwithstanding the positive developments, in reality, it appears that the dynamic spatial relationships among Caribbean countries are quite weak. For instance, the share of intra-CARICOM trade, for most members' states, is still low, representing less than 10%.

Regional co-operation in its present context still faces both political and economic obstacles. Development strategies of Caribbean countries remain more competitive than complementary. The size of the market offers reduced opportunities, which allows for an understanding of the paradox noted by Duhamel and Calero (2003) concerning CARICOM: "One feature of this grouping is that it is among the largest in terms of membership but also among the smallest in geographic and economic terms. "

These observations point to a measure of the degree of dependence of GDP per capita that relates to the geographic location of the countries which is mapped out in figure 4. Do these groupings of countries have similar characteristics? Or are they a random distribution of countries with different GDP per capita? These issues raise the problem of positive spatial autocorrelation if countries with similar GDP per capita (low or high) also have a strong geographical proximity and negative spatial autocorrelation if the countries' GDP per head vary in relation to location.

4.2.1. The Spatial Weights Matrices

The diversity of factors mentioned above to describe the processes that connect the countries of the Caribbean lead naturally to the use of several spatial weighting matrices. The weight matrix is an important part of spatial modeling and is defined as the formal expression of spatial dependence between observations (Anselin 1988). The literature on the specification of weight matrices is quite extensive and can be divided into three streams: (1) completely exogenous constructs; (2) data – determined methods; and (3) estimating approaches. The first group is often based on the geographical relations of observations or spatial units that contain these observations. Examples of weight matrices used in this set up are those determined by spatial contiguity, inverse distance, share of common border, centroids, *N* nearest neighbors, etc. (Cliff and Ord 1981; Anselin 1988; Anselin and Bera 1998). Next to geographical consideration, several specifications were suggested which arise from social networks and economic distance (Case et al. 1993; Conley and Ligon 2002; Leenders 2002). For the weight matrices that are determined by the data, Getis and Aldstadt (2004), for example, propose one based on the distance beyond which there is a specific change in the nature of the spatial association. Aldstadt and Getis (2006) further develop an algorithm which constructs a spatial weight matrix using empirical data and simultaneously identifies the geometric form of spatial clusters. Finally, with regards to the weight matrices that are estimated, due to the large number of weight matrix elements compared to the number of observations, certain limits have to be imposed. For instance, Bhattacharjee and Jensen-Butler (2006) developed a nonparametric method based on consistent estimators for the spatial autocovariances that is constrained to be symmetric, which in many cases does not represent the real-life situation. Going further, there even are attempts to get rid of weight matrices by using structural equations models with latent variables to estimate spatial dependence (Folmer and Oud 2008).

Three definitions of the matrix *W* are proposed in this paper which is derived from three measures of bilateral distances (dist, distw and distwces). The first is based on the spherical distance between the centroids of Caribbean countries, with the element w_{ij} calculated from the geographical coordinates (latitude and longitude) of the principal city of each country and applying the formula for the great circle distance. The other two relies on the concept of distance introduced by Head and Mayer (2002) and expressed by the following formula:

$$d_{ij} = \left(\sum_{k \in i} (pop_k / pop_i) \sum_{l \in j} (pop_l / pop_j) d_{kl}^{\theta} \right)^{1/\theta} \quad (11)$$

with *i* and *j* being the two countries concerned, pop_k is the population of the metropolitan *k* belonging to country *i* and θ is a parameter for measuring the sensitivity of trade flows with

respect to bilateral distance d_{kl}. This definition thus accounts for the geographical

distribution of populations within countries as well as the intensity of trade they maintain. The parameter θ is set equal to 1 for the distance measure *distw* and, it takes the value -1 for the distance measure *distwces*. In this latter case, it corresponds to the standard distance coefficient estimated from gravity equations.

The presence of islands across geographies is considered an additional constraint which adds to any exercise of spatial econometrics for areas such as the Caribbean, the Pacific or the Mediterranean. Indeed, it encourages the use of distance matrices which is more complex than the binary adjacency matrix or the weight matrices of the k-nearest neighbours, due to the discontinuity, exemplified by the many rows and columns of zeros.

The extraction of information from the database "distance" (see the website of the Centre for Prospective Studies and International Information http://www.cepii.fr/) allowed for the building of the three matrices described above. The investigation was conducted using spdep in the software package R 2.9.0 (Bivand 2006). In order to apply the relative distance and not the absolute distance, each of the matrices was normalised by standardizing. Leaving aside the critical threshold that appears in equation (6), matrices that connect all the countries in the sample can be obtained. It should be noted that, in all countries, a high proportion of the matrix coefficients (dist, distw distwces) show differences but some countries like Cuba and St. Kitts and Nevis revealed relatively moderate disparities.

4.2.2. Global Spatial Autocorrelation

Moran's I (1950) is the first and most widely available tests to detect the presence of spatial autocorrelation. It is based on the ratio between the covariance of spatial units and the total variance:

$$I_t = \frac{N}{S_0} \times \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}\left(y_{it}-\bar{y}_t\right)\left(y_{jt}-\bar{y}_t\right)}{\sum_{i=1}^{N}\left(y_{it}-\bar{y}_t\right)^2} \qquad (12)$$

with N being the number of spatial units, y_{it} is GDP per head of unit i at time t, $\bar{y}_t$ is the average of y_{it} and $S_0 = \sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}$ is a standardization factor. Thus, by definition, the I statistic is similar to the coefficient of the regression of $W\tilde{y}$ on $\tilde{y}$, $\tilde{y}$ is the centred variable $y-\bar{y}$. It is asymptotically distributed as a normal distribution with mathematical expectation $E\{I\} = -1/(N-1)$. Equality between I and $E\{I\} = -1/(N-1)$ suggests a lack of spatial autocorrelation. A value significantly above $-1/(N-1)$ reveals positive spatial autocorrelation, and in the opposite case, negative autocorrelation is implied.

Table 3: Moran's I Statistic for Variables 1977, 2006 and 1977 to 2006 by Weight Matrices

Variable GDP per capita, 1977				
Matrix	I	Variance	Standardised	p-value
dist	-0.114415418	0.003926312	-0.8285	0.7963
distw	-0.117206849	0.003637229	-0.9071	0.8178
distwces	-0.094340711	0.004429977	-0.4784	0.6838
Variable GDP per capita, 2006				
Matrix	I	Variance	Standardised	p-value
dist	-0.045207785	0.003983168	0.274	0.3920
distw	-0.049189481	0.003689295	0.2191	0.4133
distwces	-0.002224846	0.004494885	0.899	0.1843
Variable GDP growth, 1977-2006				
Matrix	I	Variance	Standardised	p-value
dist	0.089049764	0.003927844	2.4181	0.0078
distw	0.044021416	0.003638632	1.7659	0.03871
distwces	0.072193277	0.004431727	2.0233	0.02152

The calculated values of Moran's I statistic with the three weight matrices reported in Table 3 are all below its expected value $E\{I\} = -1/(N-1)$ = -0.0625. They indicate that the observed geographic links between the vector of per capita GDP $\tilde{y}$ and the offset vector space $W\tilde{y}$ are relatively weak. The negative values for the two extreme years of the observation period are

consistent with a negative spatial autocorrelation, but tests of significance of Moran's I statistic lead to rejection of the finding of spatial autocorrelation between per capita GDP of Caribbean countries. Overall, the dominant trend is that each country has a per capita income that is different from those observed in neighbouring countries.

The Moran's I statistic calculated on the rate of growth of GDP per head shows a positive spatial autocorrelation but remains low. These results reflect the close connection between the geographical grouping of countries with high growth rates and countries with low growth rates. Also, these results appear consistent with those of subsection 4.1.

4.2.3. Local Spatial Autocorrelation

The configuration of the local interactions described above is analysed by examining the units that contribute most to the overall spatial autocorrelation. The diagram of Moran is the standard tool to do this analysis. It depicts four quadrants related to the four possibilities of local spatial association between an entity and its neighbours: HH is a unit that displays high GDP per capita and is bordered by units characterized by high GDP per head; LL is a unit with a low GDP per capita but is surrounded by units with low GDP per capita; in the third quadrant (HL), a unit has a high per capita income but bordered by units with low income per capita; and, in the fourth quadrant (LH), a unit characterized by a low income per head is surrounded by units with high per capita incomes. In terms of interpretation, the HH and LL quadrants which have clusters of similar values are representative of a situation of positive autocorrelation. Conversely, the LH and HL quadrants which comprise dissimilar values reflect negative autocorrelation. If the information is dispersed in the four quadrants, there is no spatial autocorrelation.

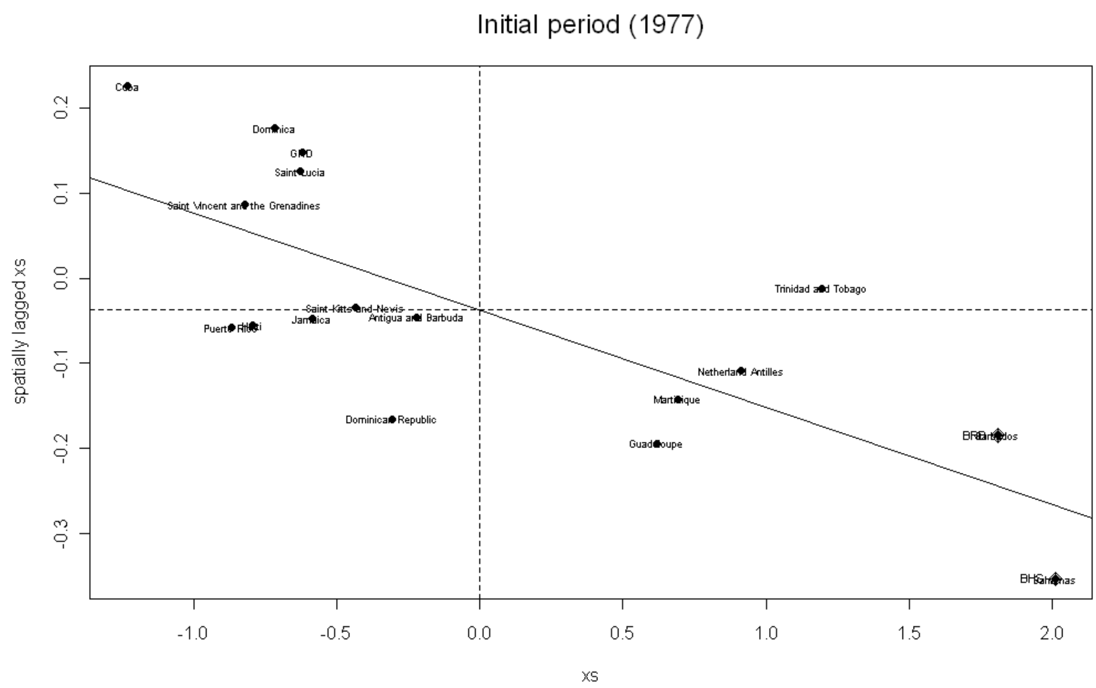
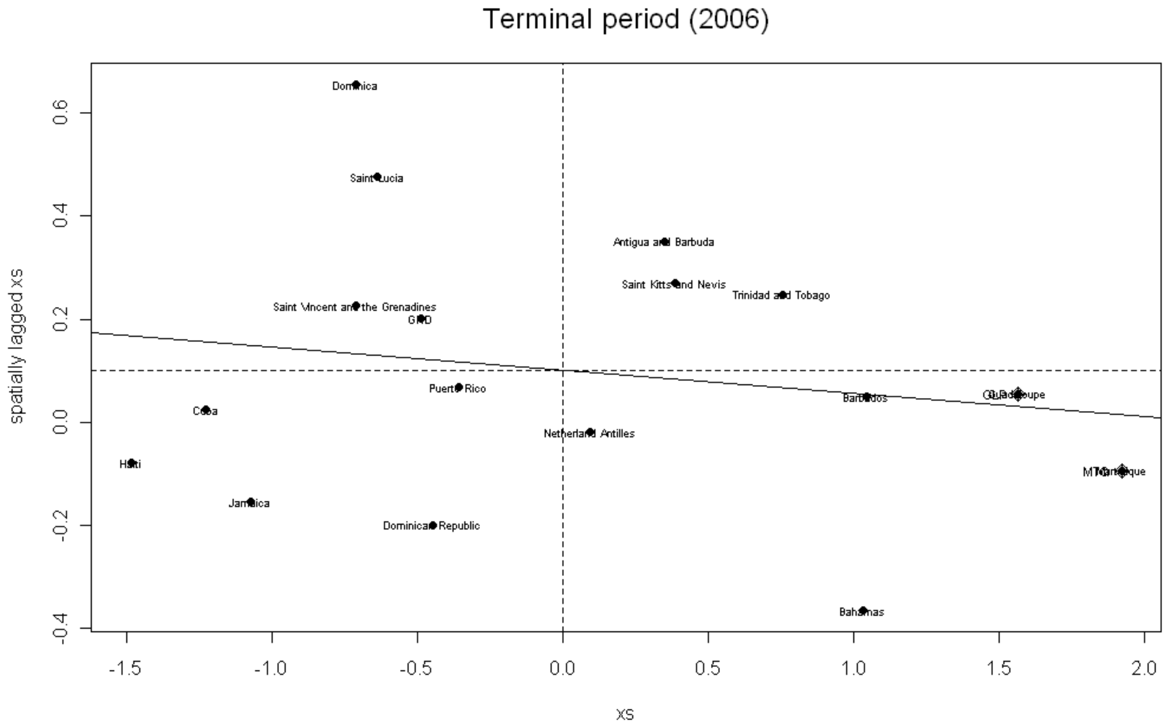
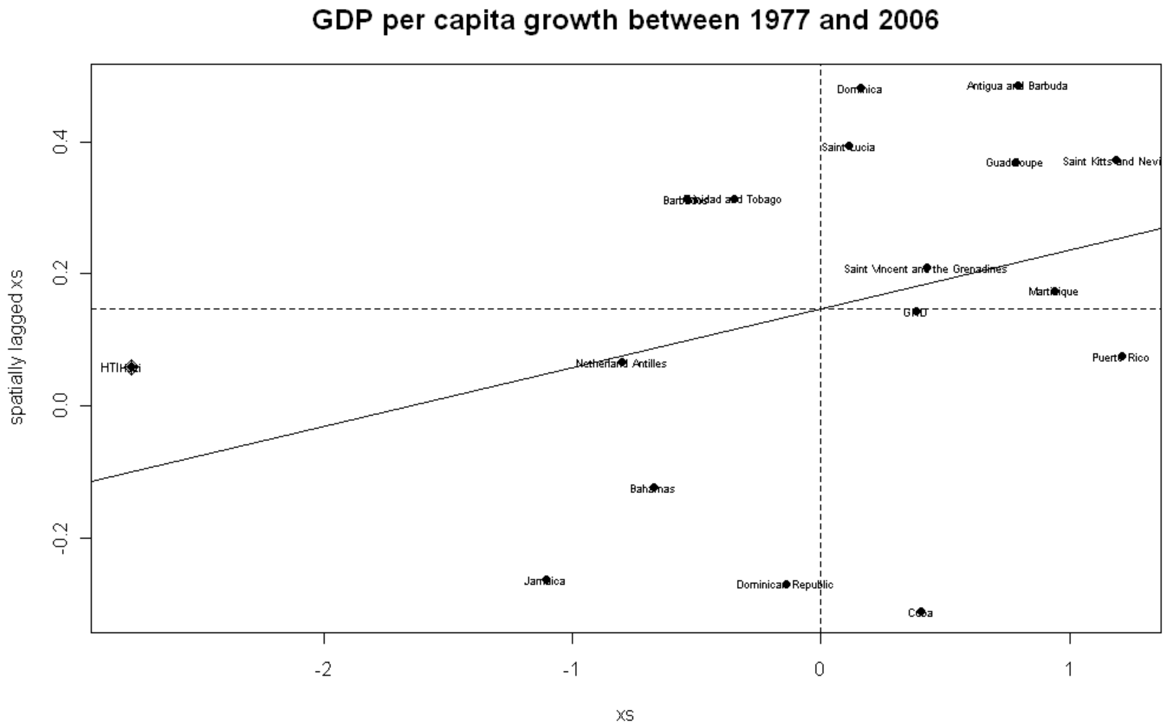

Initial period (1977)
spatially lagged xs
xs
0.2
0.1
0.0
-0.1
-0.2
-0.3
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Cuba
Dominica
GRD
Saint Lucia
Saint Vincent and the Grenadines
Trinidad and Tobago
Saint Kitts and Nevis
Jamaica
Antigua and Barbuda
Puerto Rico
Haiti
Dominican Republic
Netherlands Antilles
Martinique
Guadeloupe
BRB
Barbados
BHS
Bahamas

Figure 4: Moran Diagram for the Weight Matrix Dist

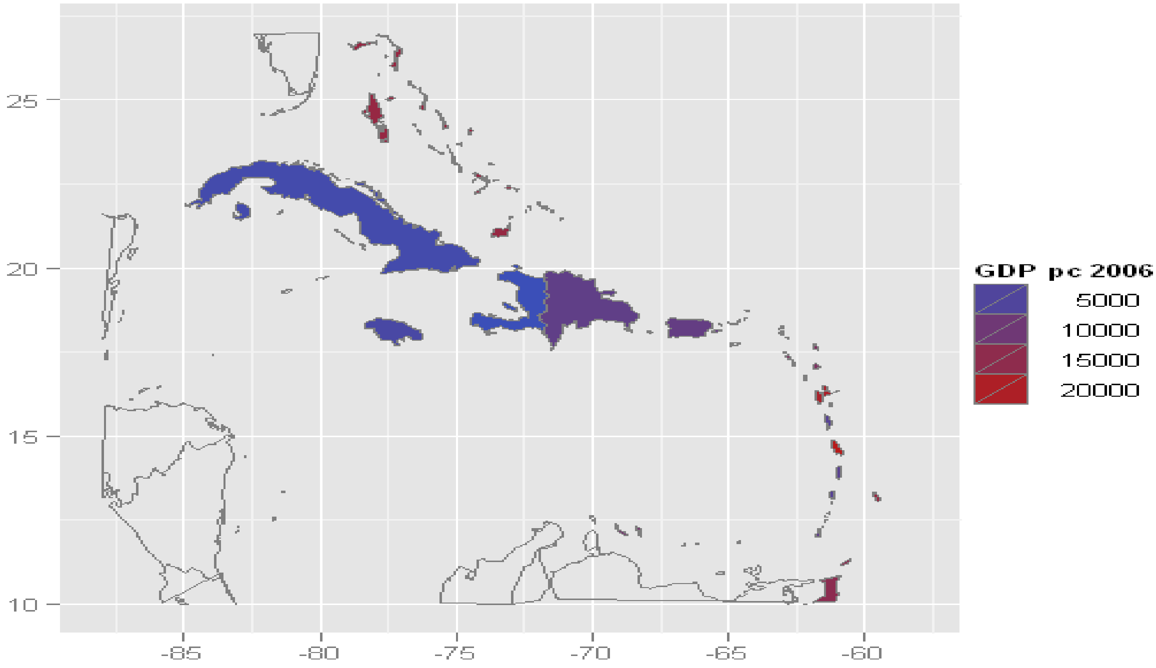




The diagrams (figure 4 above) on three data sets of GDP per capita - the initial date (1977), the final date (2006) and the average growth rate over the 'whole period 1977-2006 - are constructed to take into account the dynamics of each country and their neighbours. Several observations can be made when examining these graphs. One, at the initial period, the distribution of countries in the four areas of the diagram is as follows: 2 (11.7%) and 5 (29.4%) are, respectively, in quadrant HH and BB while 4 (23.6%) and 6 (35.3%) are in quadrants HB and BH, respectively. Also, the majority of Caribbean countries exhibited an unusual combination of income per capita; only 41.2% of the countries appeared to have similar GDP per capita values. Two, the configuration in the final year shows a distribution with some differences: 1 (5.9%) and 5 (29.4%) countries are classified in quadrant HH and BB and 5, each, are associated with HB and BH. Three, in both 1977 and 2006, the group composed of Haiti, Cuba, Dominican Republic, Puerto Rico and Jamaica - the low GDP per head countries that are surrounded by other countries with low GDP per head - form a spatial concentration that persists over time. Four, in the beginning and end of the study period, the overall pattern of spatial association is that of negative autocorrelation, with the exception of three countries, St. Lucia, Dominica and The Bahamas. Also, it appears that St. Lucia and Dominica are islands with low GDP per head bordered by countries with higher GDP per capita and Barbados, Guadeloupe, Martinique and The Bahamas have the HB type; that is to say, they are high-income territories surrounded by islands with low per capita income. Five, it is important to note that the map of the Caribbean (see Figure 5) is consistent with the position of countries and geographical classification given by the diagram of Moran.

Cartographic representations of GDP per capita of the initial and final periods provide the real image of the Moran indices. Between 1977 and 2006, they show little change in the spatial pattern of the standard of living of the countries, whether considered separately or by neighbouring subgroups. Hence only the map for 2006 is reported (see figure 5). As illustrated in the colour name legend on this map, there are stable "images of clusters of neighbours" using the criterion level of GDP per capita. Thus, within the arc of the Lesser Antilles, Barbados, Guadeloupe and Martinique are a combination of HB type, the neighbours St. Lucia, Dominica, Grenada, Saint Vincent and the Grenadines have not benefited from the diffusion process of growth.

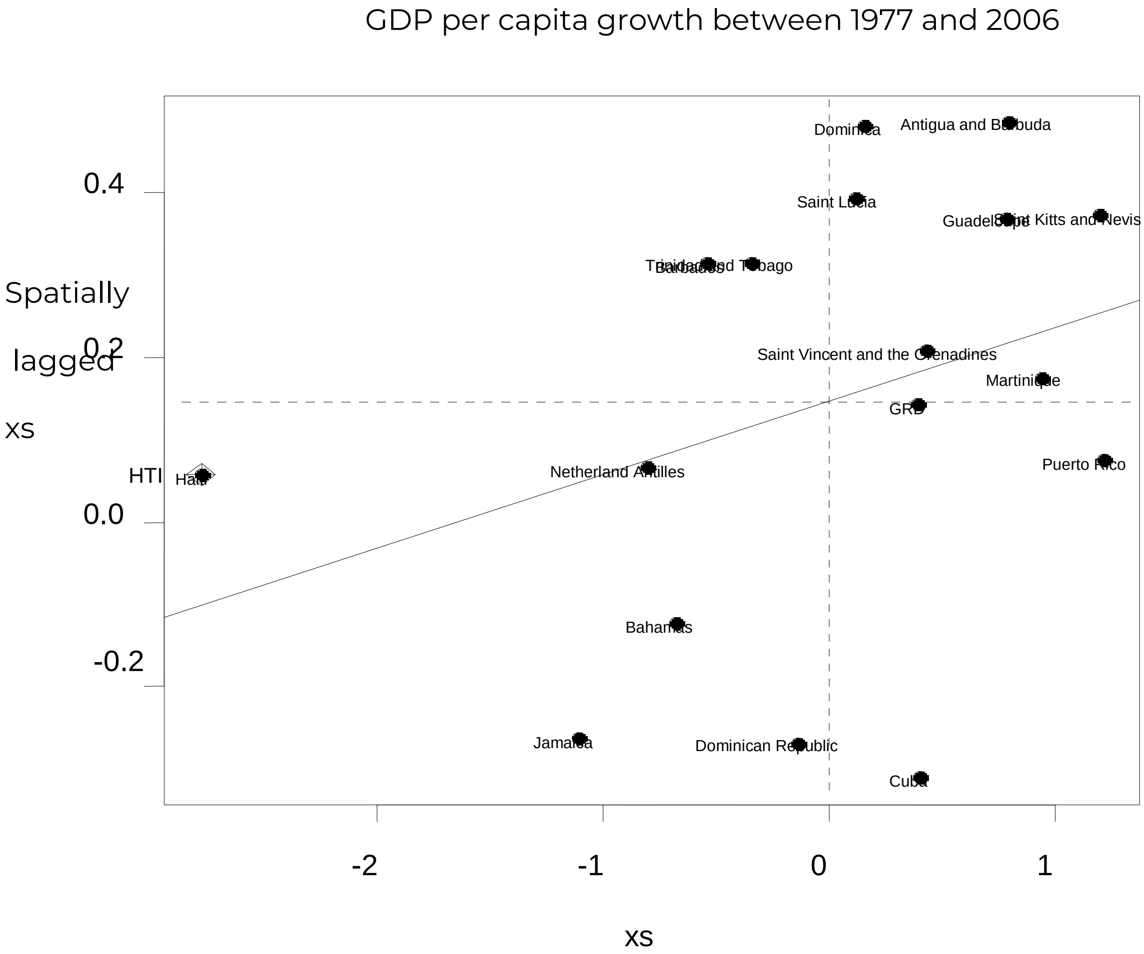
Figure 5: Maps of the per-capita GDP in 2006



To further explore the statistical pattern of local spatial association, one needs to construct the diagram of Moran for the growth rate of GDP per capita over the period 1977-2006 in order to compare it with the diagram of Moran's GDP per capita in 1977. The main findings (see table

3 and figure 6) arising from the above can now be stated. One, Haiti, Jamaica and the Dominican Republic, located in quadrant BB of Moran 1977 diagram remain positioned in the same quadrant when considering their average growth rate over the period 1977-2006. This result shows once more the poor performance of these three countries. Two, The Bahamas, which belonged to the HL group in 1977, was in the BB group when its average growth rate is assessed. These positions are consistent with a phenomenon of the growth slowdown of The Bahamas. Three, Barbados and Trinidad and Tobago, which were attached respectively to the HL and HH quadrants of Moran diagram in the early period belong to the type LH grouping when examining their growth. These two nations should also be interpreted as countries that experienced lower growth. Four, Martinique and Guadeloupe who was in the HL group during the initial part, is in, contrast, part of the HH quadrant diagram of the growth rate. It appears that in the French islands, strong growth is unrelated to the performance of their immediate neighbours but is rather dependent on external factors like the importance of public transfers allocated by France and the European Commission in the training of their populations. Five, St. Lucia, Dominica, Antigua and Barbuda, St. Vincent and the Grenadines, Grenada, and St. Kitts and Nevis are located in quadrant LL and LH in 1977 and HH of the diagram of growth as they formed groups of space. This result provides further evidence of the phenomenon of convergence of the OECS countries mentioned above.

Figure 6: Moran Scatter Plot for the Weight Matrix "dist"



To take into account the sensitivity of Moran's I statistic to the criterion used to measure spatial proximity, the diagrams of Moran are replicated with two other weight matrices. Due to space considerations these results are not presented here but are available on request. They revealed that whatever the weight matrices considered, the Moran diagrams gave generally the same configurations and conclusions as those discussed above.

4.2.4. Results of the spatial beta-convergence model

The results of the spatial statistical analysis presented in the preceding paragraphs highlight the overall persistence of disparities in living standards among countries in the Caribbean and at the same time, the formation of a convergence club comprising countries in the OECS. It is important to complete the empirical applications by performing the estimation of econometric models of β-convergence described above in Section 3.

The investigation is conducted using the software R 2.9.0 and the package spdep (Bivand, 2006). Specifically, three models commonly utilised in spatial econometrics - SAR, SEM and Durbin - are estimated. Table 4 summarises the estimation results obtained for the main spatial regression models. For the SAR and SEM specifications, the coefficient β is very small with the expected sign; the estimated coefficients (and their standard errors) are globally in the same order of magnitude; however, all the estimated coefficients are insignificant and there is no spatial autocorrelation even when account is taken of the different patterns of spatial externalities introduced by the three weight matrices and; the spatial Durbin model with the last two weights gives several significant coefficients at the 10% level. Additionally, the various models are estimated by the robust method proposed recently by Kelejian and Prucha (2010) that allows for the presence of heteroskedastic errors. The results obtained are also generally poor. As shown in Table 5, even though the parameter λ is significant in all three regressions and the coefficient β is significant at the 10% level for the regression matrix distw, the findings still indicate an overall conclusion of no or extremely low convergence.

As might be expected, the important conclusion coming from the above findings is the lack of validity of a relationship of spatial dependence in the process of economic growth in the Caribbean Basin. It can therefore be noted that despite the existence of a phenomenon of club convergence among the countries of the OECS, the dynamic interactions across the wider Caribbean were not substantial enough to create a movement of 'homogenization' of living standards among countries. This latter result is consistent with other studies including Bertram (2004) who advances the hypothesis that the per capita GDP of small island economies, and its growth through time, are explained to a large extent by two variables: the closeness of the political linkages tying each island to a corresponding metropolitan patron, and the level of per capita GDP in the metropolitan patron economy. Small islands thus converge to the income levels of their patrons, not to each other. This accounts for the absence of evidence supporting within-region convergence among island economies in the literature to date.

Table 4: Spatial Model Estimates

	ML Lag SAR	ML Error SAR	Spatial Durbin
Matrix dist			
Constant	0.0412 (0.38)	0.052 (0.24)	-0.4162 (0.34)
lnGDP_1977	-0.0035 (0.53)	-0.0036 (0.50)	0.0025 (0.74)
W.LnGDP_1977			0.0496 (0.29)
ρ	0.4797 (0.34)		0.2914 (0.63)
λ		0.4881 (0.32)	
Log. Likelihood	48.35	48.38	48.82
Matrix distw			
Constant	0.0438 (0.37)	0.0542 (0.24)	-0.7371 (0.07)
lnGDP_1977	-0.0034 (0.55)	-0.0037 (0.51)	0.0074 (0.33)
W.LnGDP_1977			0.0851 (0.049)
ρ	0.3579 (0.52)		-0.2317 (0.77)
λ		0.38153 (0.48)	
Log. Likelihood	48.11	48.15	49.39
Matrix distwces			
Constant	0.0459 (0.35)	0.0619 (0.18)	-1.0826 (0.00019)
lnGDP_1977	-0.0038 (0.51)	-0.0046 (0.39)	0.0099 (0.081)
W.LnGDP_1977			0.1253 (8.873e-05)
ρ	0.3901 (0.47)		-0.4656 (0.49)
λ		0.4573 (0.39)	
Log. Likelihood	48.17	48.28	52.95

Table 5: Spatial Model Estimates with Heteroskedastic Innovations

	Matrix dist	Matrix distw	Matrix distwces
Constant	0.0179 (0.72)	0.0235 (0.64)	0.0208 (0.70)
lnGDP_1977	-0.0078 (0.11)	-0.0084 (0.098)	-0.0080 (0.16)
λ	2.6589 (0.001)	2.7328 (0.001)	2.6739 (6.94e-06)
ρ	-0.9000 (0.46)	-0.9000 (0.50)	-0.9000 (0.37)

Conclusion

The focus of this paper is to analyse and verify empirically whether the process of convergence of per capita GDP exists among countries in the Caribbean. It was shown, based on descriptive statistical methods, and statistical and econometric tests of beta-convergence and sigma-convergence, that there was an absence of convergence for CARICOM countries since the early 1980s. This is so even in the OECS group which are linked in a quasi monetary union framework.

The above results suggest that there is a need to enhance the regional development policies to facilitate the integration of Member States. This is particularly so since the Caribbean is now facing several new challenges including the new rules of international trade where the preferential agreements once granted by the European Union (EU) to Caribbean countries are being gradually suppressed. Moreover, the extension of the EU to include the countries of Western Europe is synonymous with new requests for aid and investment, thus reducing the share allotted to Caribbean countries.

Despite these difficulties, a possible solution for the future development of the Caribbean economies is the completion of the integration project, which involves the reduction and harmonisation of tariffs, the restructuring of financial sectors, the harmonisation of investment incentives and fiscal systems, the coordination of agricultural policies, and the adoption of common strategies for commercial trade. All of these objectives must be met if these countries are to arrive at ways and means of getting involved in international trade, in the best possible conditions.

Finally, the origin and answer to this question of why the absence of convergence among the economies of the Caribbean should be developed and discussed by all of those who are interested in the economic development of the region. The persistence of disparities can be explained by the unequal endowment in natural resources: For instance, Trinidad and Tobago has substantial oil reserves and most of the other islands are dependent on tourism but at the same time have exhibited uneven performances. The particular policy choice adopted by these countries has also impacted on the maintenance of these disparities. Lack of mobility of capital and labour as well as the unequal distribution of skilled workers are two more explanations for the differences among GDP per capita in the Caribbean.

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