growth and change

Growth and Change
Vol. 42 No. 3 (September 2011), pp. 320–350

An Alternative View of the Convergence Issue of Growth Empirics

JUAN GABRIEL BRIDA, SILVIA LONDON, LIONELLO PUNZO, AND WISTON ADRIAN RISSO

ABSTRACT In this paper, we study the dynamics of economic growth for 140 countries during the period 1951–2003. The variables representing economic performance are levels and growth rates of per capita gross domestic product. Using the concept of economic regime, we introduce a notion of distance between the dynamical paths of different countries. Then, a minimal spanning tree and a hierarchical tree are constructed from time series to help detect the existence of groups of countries sharing similar economic performance. The two main clusters that are identified over the whole-time interval can be interpreted as two groups of countries with high and low performance, respectively. The evolution of such clusters shows three main stylised facts: Certain countries move across clusters; the high-performance cluster tends to span, while the low-performance one tends to be (more) compact; and the distance between the two groups increases in time.

Introduction

Growth theories have produced a number of testable hypotheses about countries' long-run performance, measured in terms of per capita gross domestic product (GDP) levels and growth rates. In the pioneering model of growth of Solow (1956), the long-run equilibrium of a closed economy, with access to a public good type of technology, is a steady-state path. There, the rate of growth of labour productivity equals the exogenous rate of the technological progress. By implication, in the long run, capital accumulation would have no effect on

Juan Gabriel Brida is an assistant professor in the School of Economics and Management, Free University of Bolzano. He is the corresponding author, and his e-mail address is: juangabriel.brida@unibz.it. His research was supported by the Free University of Bolzano (project "Economic growth, regime convergence, and clusters analysis"). Silvia London is an associate professor in the Department of Economics at the Universidad Nacional del Sur, Bahía Blanca, Argentina. Lionello F. Punzo is a full professor of Economic Development at the University of Siena and is also affiliated to the INCT-PPED of the UFRJ, Rio de Janeiro. Wiston Adrián Risso is a research assistant at the School of Economics, University of Siena, Italy.

Submitted June 2010; revised November 2010; accepted December 2010.

productivity growth, although it affects levels of output and other macroeconomic variables.

One of the key predictions of Solow's model is that, in the long run, all countries could only converge to the same path characterised by a unique rate of labour-productivity growth. That early version of this convergence hypothesis has generated a vast literature in conjunction with other *events* in the evolution of the economic reflection over the growth experience across countries.

One such event is the birth of the so-called theory of endogenous growth, spanning a whole family of models of productivity growth generated by profit-driven activities. These models offered explanations for a variety of phenomena, among them: Why certain countries managed to grow faster than the others; how the accumulation of intangible capital (human capital and research and development among them) could enhance performance; and why imperfect competition and international trade allowed productivity gains that could not be ripped by closed economies with controlled markets.

The pluralistic view of growth that emerged, combined with the release of a large database from the World Bank, spurred a reconsideration of the bases of the theory (Romer 1994). The new database has started a vast empirical literature, in which econometric and non-econometric techniques have been applied to test mainly neoclassical predictions. The growth empirics' literature has shown the need of considering alternative definitions of convergence, yielding a number of restricted hypotheses (Baumol 1986). Then, from a methodological point of view, several studies on the empirical front tend to incorporate different techniques for testing the convergence hypothesis: the panel convergence testing (see, e.g., Apergis, Panopoulou, and Tsoumas 2010; Phillips and Sul 2009), the autocorrelation function approach (see Caggiano and Leonida 2009), cross-sectional and panel spatial models (see Carrion-i-Silvestre and German-Soto 2009; Checherita 2009; among others), simulation equation model (Cracolici, Cuffaro, and Nijkamp 2010), etc. These studies yield evidence in favour of the view that a unique interpretive model is likely to be inadequate to describe growth and development experiences. Also, that standard GDP index is unable to capture the real inequalities among countries in terms of the different dimension of the well-being of populations (Cracolici, Cuffaro, and Nijkamp 2010).

That is why, if we accept the diversity across countries or across sectors within countries and regions, we have to re-conceptualise growth. In the literature, countries would tend to form *clubs* and therefore to converge, if at all, to different (club-specific) growth paths (Quah 1996), on a variety of reasons: e.g., initial conditions, path dependency, hysteresis, and similar complex phenomena, yielding different scenarios (Durlauf and Quah 1999; Quah 1996). The club idea permitted to explain why catching up of poor countries with respect to rich ones is not a law (as instead seemed to be implied by a number of development theories of the 50s, as much as a consequence of the assumptions of the neoclassical theory). On the other hand, it accounted for the evident birth and survival of clusters of countries with relatively homogenous behaviour. A key issue has been left unexplored in this literature: the explanation of the birth of such clusters and the *mobility* across them. Nearly all research was concentrated upon the analytical issue of *how to identify them* (Durlauf and Johnson 1995; Quah 1996). This is our conceptual starting point. This paper studies the mobility across clusters but do not aim to explain why clusters come out.

The previous notions of cross-country convergence/divergence serve to make explicit the idea that a country's dynamics can be better characterised resorting to a new description based on a notion of *regime* (Brida 2008). Owen, Videras, and Davis (2009) develop a method assuming a class or regime structure in which the regimes are discrete and unordered in the usual sense (there is not a hierarchical order). However, our methodology advances over the existing literature by imposing an order on the regimes and by adopting a more adequate analytical technique called *symbolisation*.

The paper is organised as follows. In the second section, we describe the data and the methodology. The third section introduces the concepts of both the minimal spanning tree (MST) and the hierarchical tree (HT). The fourth section presents the results of the empirical application of the methodology. In the fifth section, we introduce time windows to study the evolution of the obtained clubs. The sixth section includes the cluster dynamics, and finally, the seventh section presents the conclusions and indicates directions for further research.

Data and Methodology

In this study, the dynamics of economic growth is represented by the evolution of the per capita GDP in levels and rates of growth. Annual data of per capita GDP and the corresponding growth rates are obtained from the Maddison Database. The data set includes 140 countries from 1951 until 2003. The dynamical economic performance of each country is represented by the bidimensional time series of our main variables. In the horizontal axis of the state space, we represent the levels of per capita GDP (y), and in the vertical axis, we represent the growth rates of per capita GDP (g_y). Figure 1 shows the state space and the attractor estimated by kernel regression run with STATA 10 (STATACORP, College Station, TX, USA).[1] Note that the results do not differ from the relationship obtained in the literature (see Fiaschi and Lavezzi 2003; Kalaitzidakis et al. 2001; Liu and Stengos 1999).

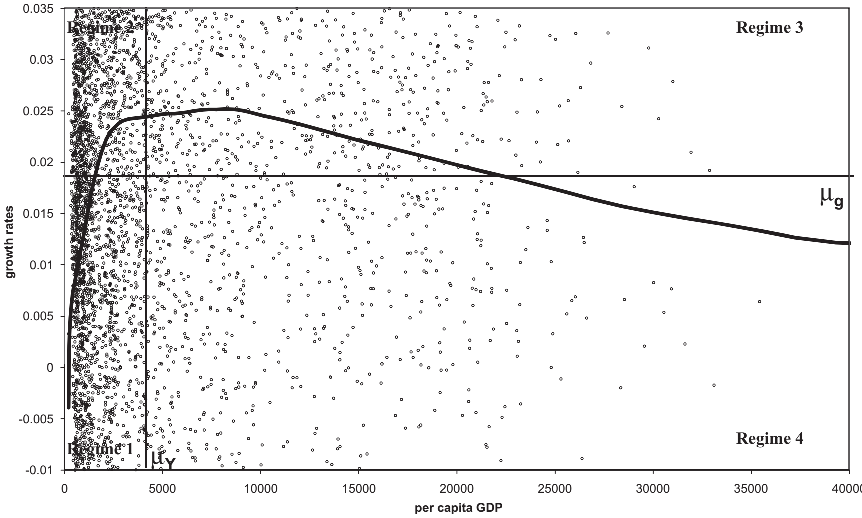

FIGURE 1. REGIMES OF ECONOMIC PERFORMANCE. THE PARTITION OF THE STATE SPACE OF LEVELS AND GROWTH RATES OF PER CAPITA GDP IS DEFINED BY THE AVERAGE VALUES μ_y AND μ_g. REGIME 1 IS THE REGION OF LOW LEVELS AND GROWTH RATES WHILE REGIME 4 IS THE REGION OF HIGH LEVELS AND GROWTH RATES OF PER CAPITA GDP. THE CLOUD OF POINTS IS DETERMINED BY ALL THE COUNTRIES OF THE SAMPLE AND TIME PERIOD. THE MAJORITY OF THE POINTS IN THE CLOUD BELONG TO REGIMES 1 AND 2. THE CURVE REPRESENTS THE KERNEL GRAPH BETWEEN THE POINT CLOUD AND SHOWS AN AVERAGE TRAJECTORY OF AN IDEAL EVOLUTION TRAVERSING REGIMES 1, 2, 3, AND 4 IN THIS ORDER.

The curve in the figure suggests the average trajectory of a country. We have also plotted the average values μ_y and μ_g of levels and rate of growth and levels of per capita GDP for all the countries and entire period. If we assume that in time an average country goes in the kernel graph from left to right, the transition is as follows: The country starts at the region of low levels and growth rack, and then it goes into a second stage where the growth rates are high, but the levels are still low. Finally, it enters in a region where both levels and growth rates are high, and it ends in the region with high levels but low growth rates. This interpretation agrees with traditional development theories.

We can describe the qualitative behaviour of a country using the notion of regime. In particular, we can describe its dynamics as a sequence of regimes.

Intuitively speaking, a regime is a qualitative behaviour usefully distinguished from other dynamical behaviours. In our case, we can divide our state space into the four regions determined by the threshold values μ_g and μ_y. We remark that the choice of the averages as thresholds is exogenous, and that the results are contingent to the exogenous cut-offs. Future research could include the replication of the exercise for different partitions using other convenient thresholds. In any case, it must be considered that dividing the state space into a large number of regions could affect the statistical significance of some results, as that we have a finite sample. Each of these regions corresponds to a particular economic performance of an economy, and then, we define our regimes in terms each of these regions and the dynamical behaviour of an economy that is living there. Any change of regime naturally signals some form of structural change. The sequential ordering of visited regimes and other parameters of the time dimension give information relevant to understand that structural change it underwent. To be more precise, we define the four regimes as the following regions:[2]

$$R_1 = \{(y, g_y):\ y \le \mu_y, g_y \le \mu_g\}$$

$$R_2 = \{(y, g_y):\ y \le \mu_y, g_y \ge \mu_g\}$$

$$R_3 = \{(y, g_y):\ y \ge \mu_y, g_y \ge \mu_g\}$$

$$R_4 = \{(y, g_y):\ y \ge \mu_y, g_y \le \mu_g\}$$

According to the estimated relationship, a country's history is, a trajectory across the regimes. Ideally, it should go from a regime of low growth rate and low per capita GDP (regime 1), passing for a regime high growth rate and low per capita GDP (regime 2), and then, a regime of high growth rate and high per capita GDP (regime 3). Finally, it should arrive to a regime of low growth rate and high per capita GDP (regime 4). Figure 2 shows the history of South Korea, the U.S., Somalia, and Iraq. There, we can see that it is not true that any economy follows the ideally sequence of regimes.

Note that South Korea, one of the four Asian Tigers, evolved from the regime 1, thought regime 2, and jumping to the third one in the nineties with the economic boom. The American economy stayed always around regimes 3 and 4 in 1951–2003 period, indicating that this economy started already with high levels of per capita GDP. On the other hand, the Somalian economy did not escape the low per capita GDP regimes (1 and 2). Finally, Iraq is an example back and forth trajectory: Note that at the end of the seventies, it jumped to regimes 3 and 4 (maybe due of increases of oil prices) and then went back to regimes 1 and 2 with the war with

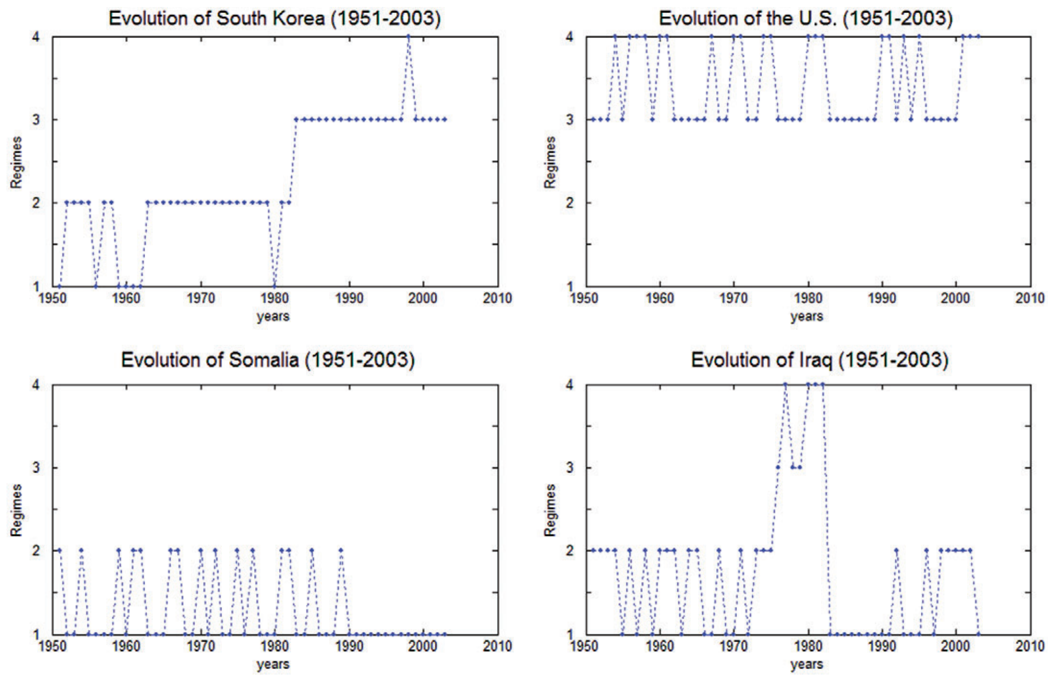

FIGURE 2. REPRESENTATION OF REGIMES DYNAMICS. THE GRAPHS SHOW THE EVOLUTION OF THE ECONOMIES AND THEIR REGIME SWITCHES. ON THE HORIZONTAL AXIS, WE REPRESENT TIME, AND ON THE VERTICAL AXIS, THE FOUR REGIMES. THE GRAPH SHOWS THE PERFORMANCE OF U.S., SOMALIA, IRAQ, AND SOUTH KOREA AS REPRESENTING SOME TYPICAL BEHAVIOURS. U.S. IS AN EXAMPLE OF A *MATURE ECONOMY* WHILE SOMALIA IS AN ECONOMY INSIDE A *POVERTY TRAP*. IRAQ SHOWS FIRST AN EVOLUTION TO BEST PERFORMANCE AND THEN A REGRESSION TO THE REGION OF LOW LEVELS OF GDP. SOUTH KOREA CAN BE VIEWED AS AN EXAMPLE OF EVOLUTION FROM A LOW TO A HIGH PERFORMANCE: *CATCHING UP*.

Iran in the eighties. Figure 3 shows the trajectories of these economies in the state space. Time evolution is represented by arrows.

The frequency of visits of each regime is represented in Figure 4. The duality between the U.S. and Somalia is highlighted in this picture.

There exists a large variety of behaviours. Syria is a country that spends roughly approximately the same time in each regime, following a path with a first stage in which it cycled between regimes 1 and 2 and then a second one with a cycle between regimes 3 and 4. Argentina and Uruguay are examples of countries evolving from regime 2 to regime 3 and then to regime 4, returning sporadically to regimes 1 and 2. Therefore, it seems that there exist many patterns and evolutions, some countries have remained in the same regimes, others have changed from one to another. This qualitative dynamics that we call regime dynamics (i.e., dynamics across regimes) can be represented in a simply way. If we label each regime R_i by the symbol i, we can substitute the original bidimensional time series $\{(y_1, g_{y1}), (y_2, g_{y2}), \ldots, (y_T, g_{yT})\}$ by a sequence of symbols $\{s_1, s_2, \ldots, s_T\}$ such that $s_t = j$ if and only if (y_t, g_{yt}) belongs to R_j. This symbolic sequence summarises all the information about regime dynamics of the country (see Brida, Puchet Anyul, and Punzo 2003 and Brida and Punzo 2003 for a detailed exposition about regime dynamics and its symbolic representation). To compare and classify the 140 countries according to their economic performances, we divide them into different clusters obtained through a non-parametric methodology based on the construction of a minimal spanning tree (MST) and a HT. To obtain these trees, we define a metric on the economic performance of different countries. We measure a “distance” between the economic performances of two countries by looking at how close are their respective regime dynamics. More formally, we introduce a distance between symbolic sequences, where each sequence represents the regimes a country goes through in time. Several distances can be postulated (see Molgedey and Ebeling 2000; Piccardi 2004; Tracy 1997; Tang et al. 1994, 1995; and Tang, Tracy, and Brown 1997). We have chosen the notion of distance for symbolic time series introduced in Brida and Risso (2008). Given the symbolic sequences $\{s_{it}\}_{t=1}^{t=T}$ and $\{s_{jt}\}_{t=1}^{t=T}$, their distance is

$$d_0(s_i, s_j) = \sqrt{\frac{\sum_{t=1}^{t=T}(s_{it} - s_{jt})^2}{T}}$$

Note that the previous formula ponders the regimes according to the natural evolution mentioned before and the relationship found between levels and growth rates of per capita GDP. Given the two countries described by their evolution, we can evaluate how different they are by means of their distance.

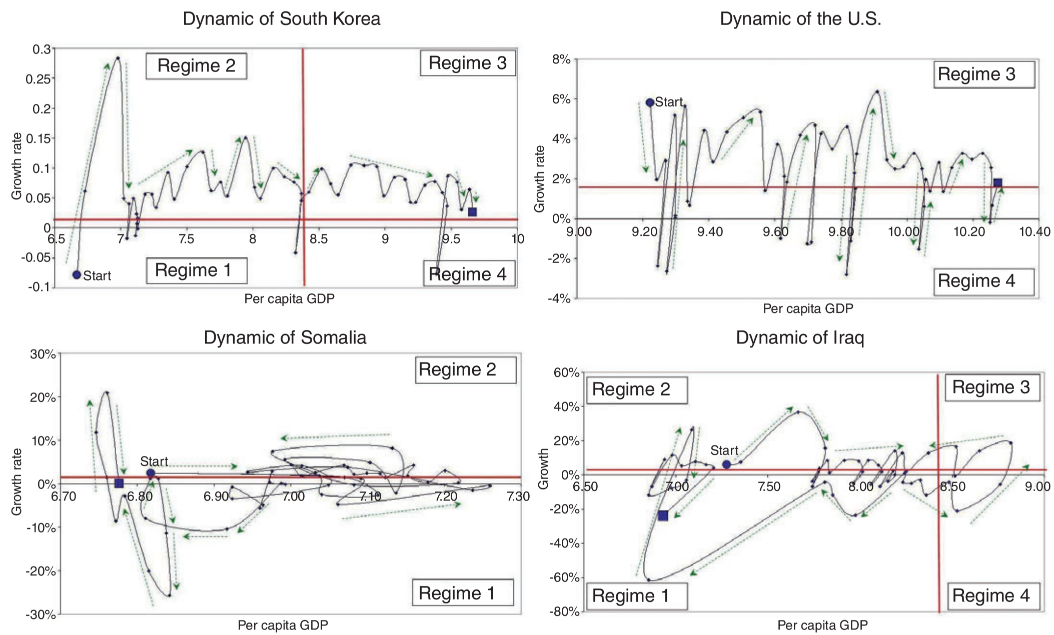

FIGURE 3. DYNAMICS OF U.S., SOMALIA, IRAQ, AND SOUTH KOREA IN THE STATE SPACE OF LEVELS AND GROWTH RATES OF PER CAPITA GDP. THE DOT INDICATES THE STARTING POINT, AND THE SQUARE INDICATES THE FINAL POSITION. SOUTH KOREA AND U.S. SHOW AN EVOLUTION TO REGIMES WITH HIGH LEVELS OF PER CAPITA GDP, WITH TRAJECTORIES MOVING FROM LEFT TO RIGHT. ON THE OTHER HAND, SOMALIA AND IRAQ HAVE VERY SIMILAR INITIAL AND FINAL LEVELS OF PER CAPITA GDP AND A VERY ERRATIC TRAJECTORY.

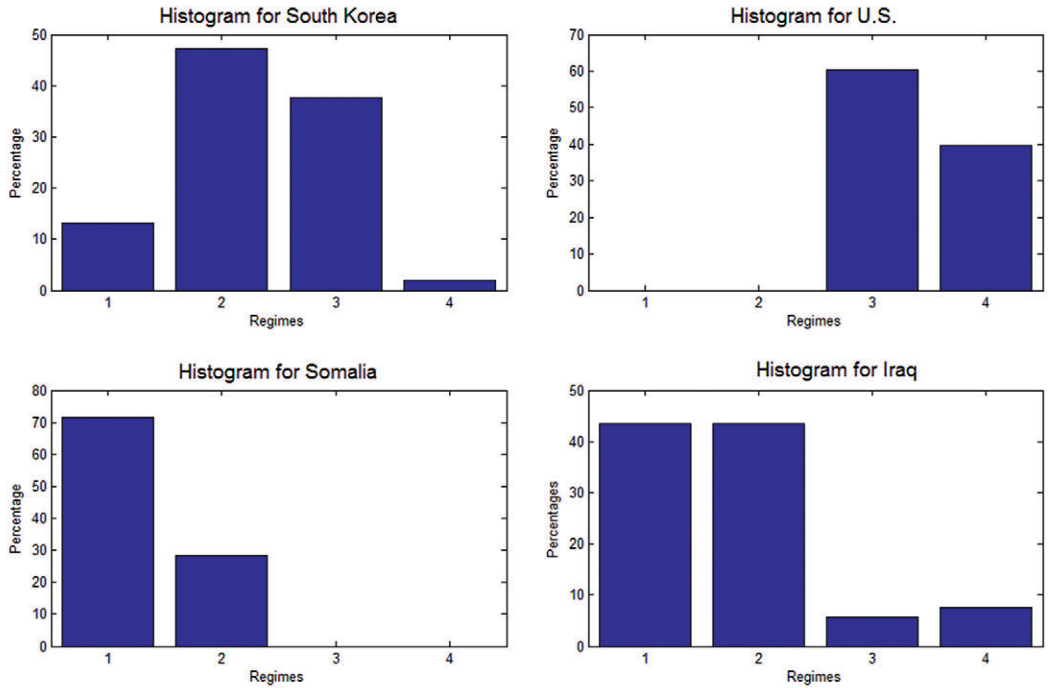

FIGURE 4. HISTOGRAMS REPRESENTING REGIMES VISITS FOR U.S., SOMALIA, IRAQ, AND SOUTH KOREA. SOMALIA HAS BEEN MORE THAN 70 PERCENT OF THE TIME IN THE REGIME 1 AND AROUND 30 PERCENT IN REGIME 2 BUT NEVER IN REGIMES 3 OR 4. U.S. PRESENTS A MIRROR BEHAVIOUR WITH 60 PERCENT OF THE TIME IN REGIME 3 AND 40 PERCENT IN REGIME 4. IRAQ AND SOUTH KOREA VISITED ALL 4 REGIMES BUT WITH DIFFERENT FREQUENCY.

TABLE 1. TEN CLOSEST DYNAMICS IN THE MST AND CONFIDENCE INTERVAL.

Link	Country *i*	Country *j*	Distance	(5%–95%)[a]
1	Canada	U.S.	0.4121	(1.000–1.141)
2	Belgium	France	0.4344	(1.055–1.149)
3	Comoro Islands	Djibouti	0.4556	(1.090–1.166)
4	Austria	Germany	0.4556	(1.107–1.174)
5	Sierra Leone	South Africa	0.4758	(1.116–1.182)
6	Liberia	Comoro Islands	0.4758	(1.124–1.182)
7	Puerto Rico	Hong Kong	0.4758	(1.133–1.190)
8	Haiti	Yemen	0.4758	(1.141–1.197)
9	Portugal	Puerto Rico	0.4758	(1.149–1.197)
10	Sweden	Belgium	0.4758	(1.149–1.197)

[a] Conducting 500 Monte Carlo simulations using MatLab 7 (Matworks, Natick, MA, USA).
Source: Based on own calculations.
MST, minimal spanning tree.

The MST and a HT

The next step is to use this distance to group the countries of the sample into different clusters according to their performance. This can be done by means of a MST and a HT, using the nearest neighbour single-linkage cluster analysis. The MST is progressively constructed by linking all the countries together in a graph characterised by a minimal distance between time series, starting with the shortest distance. The method relies upon Kruskal's (1956) algorithm of single linkage, and in our case, the tree is a graph with 140 vertices corresponding to each country and 139 links, in which the most relevant connections of each element of the set are selected. Table 1 shows the 10 shortest distances between countries ordered in increasing form that are used to construct the MST. The last column shows the confidence interval for random links (random dynamics between two countries). Because the distance between two countries does not enter in the interval, it means that the distance is significant, and the country shows a close dynamic.

In the first step, we choose a pair of time series with the shortest distance, and we connect them. In the second step, we connect a pair with the second shortest distance with an edge proportional to the previous link. We repeat this until all the given countries are connected in a unique tree. A pedagogical exposition of the determination of the MST in the contest of financial time series is provided in Mantegna (1999) and Mantegna and Stanley (2000).

Empirical Evidence

Note from Table 1 that the shortest distance is between Canada and the U.S. This means that both countries have followed the closest trajectories. The second distance is between Belgium and France. As explained in the third section, MST is constructed by linking the countries from the nearest to the farthest. Therefore, at first, we take the closest distance *d(USA,CAN) = 0.4121* and link Canada with U.S., then we take the second closest distance *d(BEL,FRA) = 0.4344* and link Belgium with France, until we obtain MST of Figure 6. A question is whether the links in the MST are random, or they mean something. We conducted 500 Monte Carlo simulations of random dynamics for 140 countries during 53 years. We compute 500 random MSTs, obtaining the simulated distribution of the distances (or links) belonging to the MST. We define the confidence interval of 5 percent and 95 percent where the random link should enter. The last column in Table 1 shows that all the distance is significant, note that no link should be considered as insignificant or random. In particular, note that whereas the distance between Canada and the U.S. is 0.4121, two random dynamics should produce a distance between 1.00 and 1.14 greater than our results. Then, there is a strong connection between these two countries. Similar results are obtained for the other countries. In Figure 5, we show the MST obtained for our set of countries.

The MST allows obtaining the (subdominant) ultrametric distance $d^{<}$ between i and j, $d^{<}(i, j)$ (see Mantegna 1999; Mantegna and Stanley 2000), which is the maximum value of any distance $d_k(l; m)$ in the shortest path connecting i and j in the MST. The ultrametric distance $d^{<}$ can then be used to construct a HT. A method to obtain it is directly through the MST method as described in Ramal, Toulouse, and Virasoro (1986). From the MST, the ultrametric distance $d^{<}(i, j)$ between two countries i and j is given by

$$d^{<}(i, j) = Max\{d_k(w_i; w_{i+1}); 1 \le i \le n-1\}$$

where $\{(w_1; w_2); (w_2; w_3); \ldots; (w_{n-1}, w_n)\}$ denotes the unique path in the MST i and j, where $w_1 = i$ and $w_n = j$. In Figure 6, we show the HT obtained for our set of countries.

In this picture, two clusters can be clearly detected as well as a third (small) group in which the dynamical behaviours are different from the average of the clusters. One of the two main clusters, for 1951–2003 period, is constituted by *CAN*, *USA*, *UK*, *AUSTRI*, *GER*, *ITA*, *AUSTRA*, *BEL*, *FRA*, *SWE*, *NET*, *SWI*, *GRE*, *POR*, *PR*, *HK*, *JAP*, *SPA*, *FIN*, *DEN*, *SAUD*, *NOR*, *HUN*, *SAE*, *IRE*, *ISR*, *VEN*, *BUL*, *POL*, *MEX*, *TRI*, *NZ*, *ARG*, *URU*, *KUW*, *QAT*, *CZE*, *SIN*, *BRA*, *TAI*, *COL*, *SK*, *THA*, *MAL*, *TUR*, *SEY*, *MAURIT*, *OMA*, and *SYR*.[3] Because these countries are most of the time in regimes 3 and 4, we call this the *high-performance* cluster. The second cluster is composed by *ALB*, *ROM*, *BOL*, *JAM*, *NIK*, *COM*, *DJI*, *LIB*, *ZAI*, *MAD*, *SL*, *SOUTH*, *MAU*, *BURU*, *ANG*, *COTE*, *SAO*, *TOG*, *TANZ*, *SOM*, *SWA*, *EGY*, *CAR*, *HAI*, *YEM*, *AFG*, *CUB*, *GUA*, *PAR*, *ZIM*, *GAM*, *GUI*, *ZAM*, *LAO*, *MALI*, *SEN*, *ECU*, *NIGERIA*, *NAM*, *SAL*, *LEB*, *MALAW*, *HON*, *GB*, *PHI*, *BEN*, *PAK*, *ALG*, *NIC*, *MOZ*, *MOR*, *MON*, *CONG*, *CHA*, *BRUM*, *VIE*, *SUD*, *RWA*, *CAME*, *SRI*, *INDO*, *UGA*, *PER*, *NEP*, *BURK*, *NIG*, *KEN*, *GHA*, *CAM*, *BAN*, *CAPE*, *DOM*, *CHIN*, *INDI*, *LES*, *ERIT*, *BOT*, *TUN*, *EQU*, and *BANK*. In this case, the countries live most of the time at regimes 1 and 2, and so we call this the *low-performance* cluster. There are 10 countries that do not belong to the two main clusters: *BAN*, *REUN*, *CHI*, *YUG*, *CR*, *PAN*, *JOR*, *GAB*, *LIBY*, *IRAN*, and *IRAQ*. Countries in this group show an evolution that can be clearly differentiated from the average of the dynamics of both main clusters. Note that countries such as Reunion, Jordan, Libya, and Iran exhibit similar evolutions as Iraq (see Figures 2 and 3).

The bottom region of the MST contains the high-performance countries. A general property that is easily noted is the presence of geographical blocks, indicating that geographical closeness is relevant for economic performance of countries. Neighbour countries such as The Netherlands, Belgium, France, Austria and Germany, the U.S. and Canada, and African countries (among others examples) occupy close positions in the tree. The economic interdependence between countries is another factor of proximity in the tree, as it is noted by the direct link between North Korea and Madagascar, countries that have a strong commercial interdependence. Some countries are linked with several countries. For instance, this is the case of Belgium that has a central position in the group of European rich countries. Note also that the U.S. links this European group with other rich countries.

Global Distance and Convergence

In the previous subsection, we have obtained information about the dynamics in the whole period of analysis. Table 2 shows qualitative differences between the initial and final mean values of the clusters. This table is constructed using the variables y and g_y. Note that an average “poor country” remains in regime 2 at the beginning and at the end of the period while an average “rich country” stays in regime 4.

In 1951, the per capita GDP of the rich countries was 4.98 times the per capita GDP of the poor countries, whereas in 2003, this ratio was 6.52. On the other hand, the growth rate reduced in both cases, and the ratio decreased from 1.68 to 1.01. But this table does not give information about the dynamics of this process.

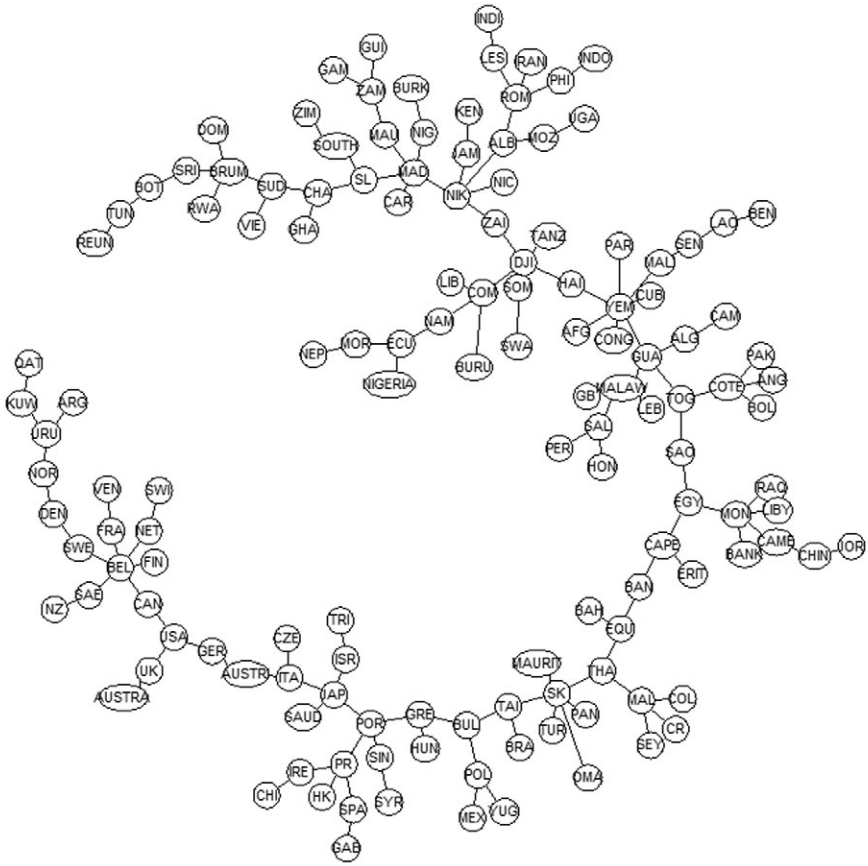

FIGURE 5. MINIMAL SPANNING TREE OF THE SET OF 140 COUNTRIES FOR THE PERIOD 1951–2003. EACH COUNTRY IS REPRESENTED BY A NODE WITH THE RESPECTIVE LABEL. THE GROUP OF NODES AT THE BOTTOM ART OF THE TREE REPRESENT COUNTRIES WITH THE BEST PERFORMANCE IN THE WHOLE PERIOD; I.E., COUNTRIES THAT MOST OF THE TIME LIVE IN REGIMES 3 AND 4. THE NODES AT THE TOP PART REPRESENT THE WORST PERFORMANCE DURING THE PERIOD, WITH COUNTRIES THAT MOST OF THE TIME LIVE IN REGIMES 1 AND 2. WE CALL THESE GROUPS *HIGH- AND LOW-PERFORMANCE CLUSTERS*. NOTE THAT AT THE HIGH-PERFORMANCE CLUSTER, WE CAN IDENTIFY A SUBGROUP THAT CONTAINS CANADA AND U.S., THE COUNTRIES PRESENTING THE CLOSEST DYNAMICS OF THE WHOLE SAMPLE.

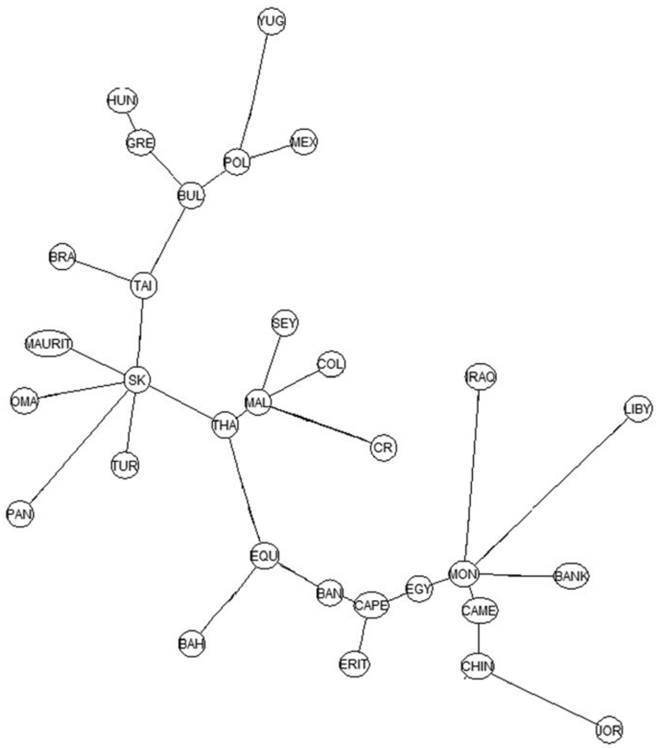

FIGURE 5. (CONTINUED) THE CENTRAL POSITIONS OF U.S., BELGIUM, AND PORTUGAL AT THE HIGH-PERFORMANCE CLUSTER AND OF GUATEMALA, YEMEN AND MADAGASCAR AT THE LOW-PERFORMANCE CLUSTER REVEAL STRUCTURE OF EACH CLUSTER. BRANCHES WITHIN EACH MAIN CLUSTER ARE INDICATING PARTICULAR SUBGROUPS. THE LONG LINK BETWEEN EQUATORIAL GUINEA AND THAILAND IS THE CONNECTION BETWEEN THE TWO MAIN CLUSTERS. THE LONG LINK BETWEEN LIBYA AND THE REST OF THE COUNTRIES INDICATES THAT THIS COUNTRY FOLLOWED A DYNAMICS THAT IS VERY DIFFERENT FROM THE REST OF THE COUNTRIES AND CANNOT BE GROUPED IN ANY CLUSTER. THE SAME SENTENCE IS VALID FOR IRAQ, YUGOSLAVIA, JORDAN, AND PANAMA BETWEEN OTHERS.

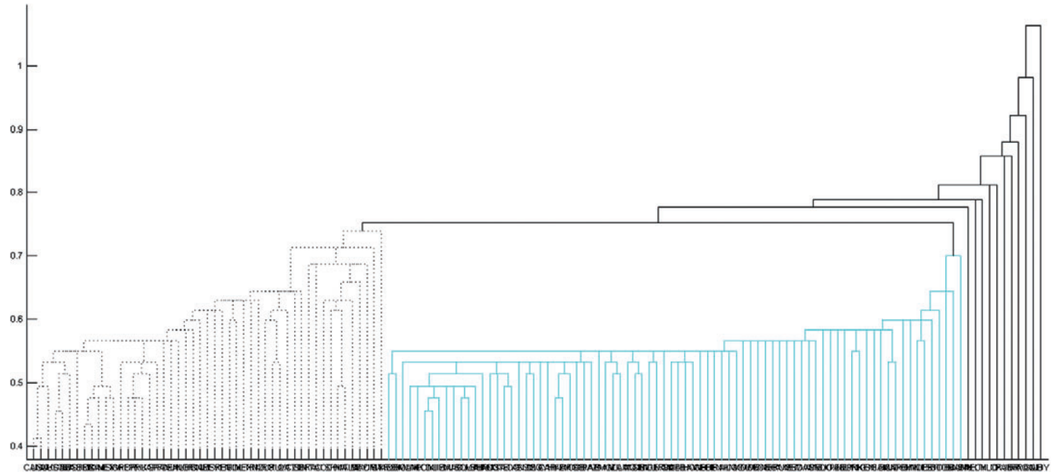

FIGURE 6. HIERARCHICAL TREE OF THE SET OF 140 COUNTRIES. LEFT SIDE GROUP: CAN, U.S., UK, AUSTRI, GER, ITA, AUSTRA, BEL, FRA, SWE, NET, SWI, GRE, POR, PR, HK, JAP, SPA, FIN, DEN, SAUD, NOR, HUN, SAE, IRE, ISR, VEN, BUL, POL, MEX, TRI, NZ, ARG, URU, KUW, QAT, CZE, SIN, BRA, TAI, COL, SK, THA, MAL, TUR, SEY, MAURIT, OMA, SYR MIDDLE GROUP: ALB, ROM, BOL, JAM, NIK, COM, DJI, LIB, ZAI, MAD, SL, SOUTH, MAU, BURU, ANG, COTE, SAO, TOG, TANZ, SOM, SWA, EGY, CAR, HAI, YEM, AFG, CUB, GUA, PAR, ZIM, GAM, GUI, ZAM, LAO, MALI, SEN, ECU, NIGERIA, NAM, SAL, LEB, MALAW, HON, GB, PHI, BEN, PAK, ALG, NIC, MOZ, MOR, MON, CONG, CHA, BRUM, VIE, SUD, RWA, CAME, SRI, INDO, UGA, PER, NEP, BURK, NIG, KEN, GHA, CAM, BAN, CAPE, DOM, CHIN, INDI, LES, ERIT, BOT, TUN, EQU, BANK. RIGHT SIDE GROUP: BAN, REUN, CHI, YUG, CR, PAN, JOR, GAB, LIBY, IRAN, AND IRAQ.

TABLE 2. RICH AND POOR COUNTRIES POSITION (PERIOD 1951–2003).

Year	Poor		Rich		Ratio rich/poor	
	y	*gy* (%)	*y*	*gy* (%)	*y*	*gy*
1951	1,043.41	2.38	5,193.51	4.0	4.98	1.68
2003	2,278.21	2.07	14,862.11	2.1	6.52	1.01

Source: Own calculations based on Maddison Database.

For this, we have to study the evolution of the clusters, answering the following questions: Was the number of clusters always two? Are there any countries that have switched clusters? Is the distance between clusters increasing (or decreasing) with time? Do countries belonging to the same cluster have a similar dynamical behaviour? To answer these types of questions, we introduce time windows of 5, 10, 20, and 30 years and construct the respective MSTs and HTs. To the first question, the answer is yes, there are always two main clusters, but we can also observe some smaller transitory clusters that appear and disappear, sometimes containing countries that at the end switch from the low to the high-performance cluster.

To study the evolution of the heterogeneity among countries, we can define the evolution of the global distance of the corresponding MSTs, as the sum the 139 links in the MST.[4] The global distance is a kind of diameter of the sample measuring its dimension, and the evolution of the global distance reflects expansion or contraction of this diameter. This is useful to detect if the countries of the sample are converging or diverging (in average) to a same type of dynamics. The divergence is understood as the spread of levels of the branches in the MST. Figure 7 shows the evolution of the global distance for different time windows. All these graphs show a maximum level in the 1980s. That is, there exists a first period of expansion reaching a maximum diameter, and then it tends to decrease. We can conjecture that this polarisation has been caused by the transitions undergone by the world economy during the 1980s. This decade showed the first wave of "*neoliberal*" structural adjustments in the U.S. and UK, the incorporation of China to the world market, the straightening of the ties among the European countries, as well as the debt crisis affecting developing countries, particularly in LA. All these changes impacted differently on the economies under analysis. Some of them, such those Southeast Asia saw a boost in their growth rates and GDPs. On the other hand, LA countries suffered what has been called "the lost decade."

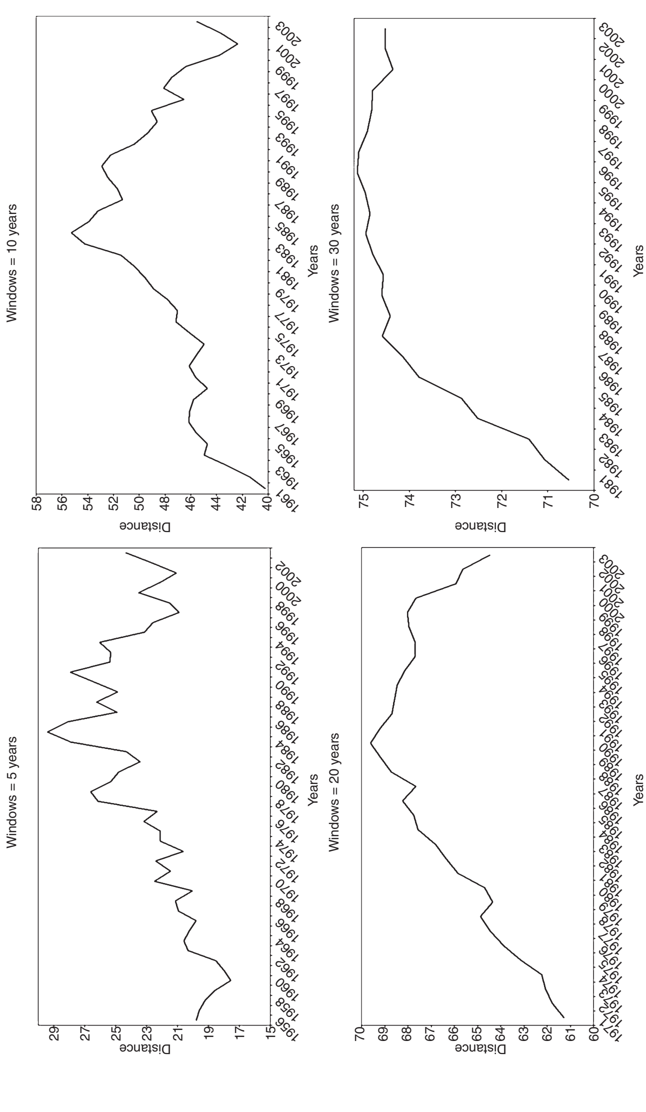

FIGURE 7. EVOLUTION OF THE DIAMETER OF THE MST FOR WINDOWS OF 5, 10, 20, AND 30 YEARS.

TABLE 3. PERCENTAGE OF TIME REMAINING IN A PARTICULAR REGIME (1951–2003).

Regime	Average poor country (%)	Regime	Average rich country (%)
1	54.72	3	71.70
2	45.28	4	28.30

Source: Own calculations.

We can repeat this technique for each one of the main clusters obtained in the previous section. Figures B1 and B2 (see Appendix B) show that whereas rich countries have tended to diverge, the poor countries tend to constitute a more compact cluster. In addition, we study the evolution of the distance between the averages *P* and *R* of poor and rich clusters of countries. To provide a more rigorous analysis, we run Monte Carlo simulations to obtain confidence intervals. Note in Table 3 that an average poor country has been 54.72 percent of the time in regime 1 and 45.28 percent in regime 2; a rich country has been 71.70 percent in regime 3 and the rest, 28.30 percent, in regime 4. Using this information, we generate 53 years of random "poor" and "rich" regimes 10,000 times. Hence, we obtain a simulated distribution of the distance between the poor and the rich countries for 53 years.

Figure 8 shows the evolution of our measure of proximity between groups.

Note that, taking time windows of 5 and 10 years, we cannot reject the hypothesis that the distance between the two clusters has remained stable. However, taking time windows of 20 and 30 years, we see that the distance can be above the upper limit of the confidence intervals. Hence, we cannot reject the hypothesis that poor and rich countries have tended to diverge in some periods.

Cluster Dynamics

In this subsection, we take time windows of 20 years to study the evolution of clusters. Figure 9 refers to the period 1951–1970 and shows three clusters. Inside the first cluster, we find the richest countries: Austria, Italy, Finland, Germany, Belgium, Sweden, Switzerland, The Netherlands, Australia, France, Norway, the United Arab Emirates, UK, Canada, U.S., Denmark, New Zealand, Trinidad and Tobago, and Argentina. A second cluster composed by Uruguay, Kuwait, and Qatar; and finally, a cluster with the lowest economic performance countries. Outside these groups, we find Venezuela, Uganda, Ireland, Czech Republic, and Chile.

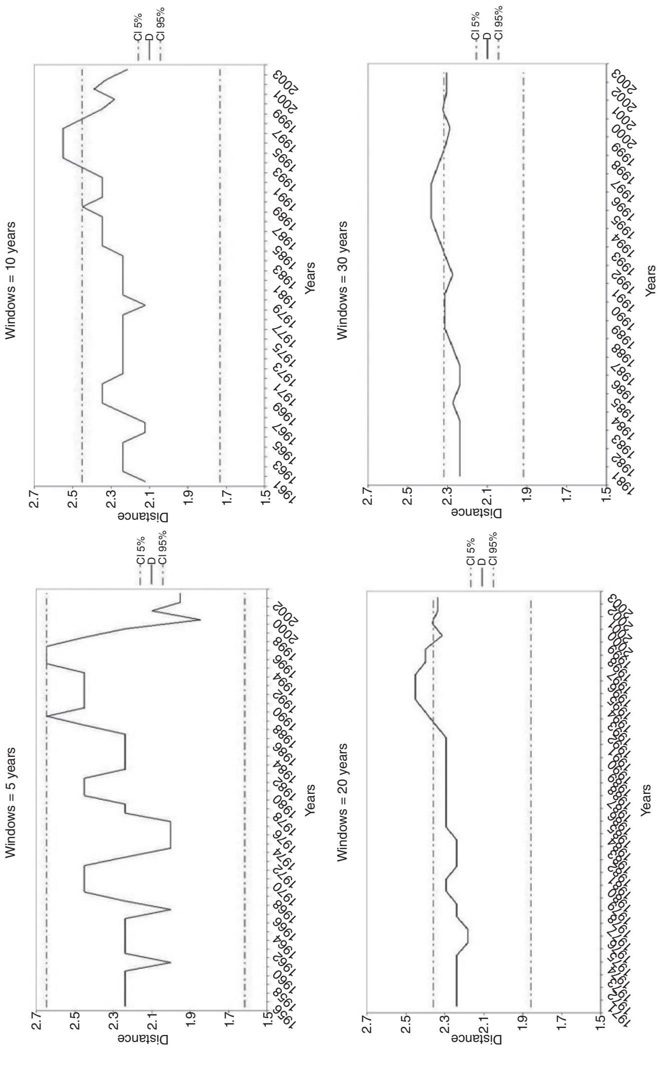

FIGURE 8. DISTANCE BETWEEN CLUSTERS.

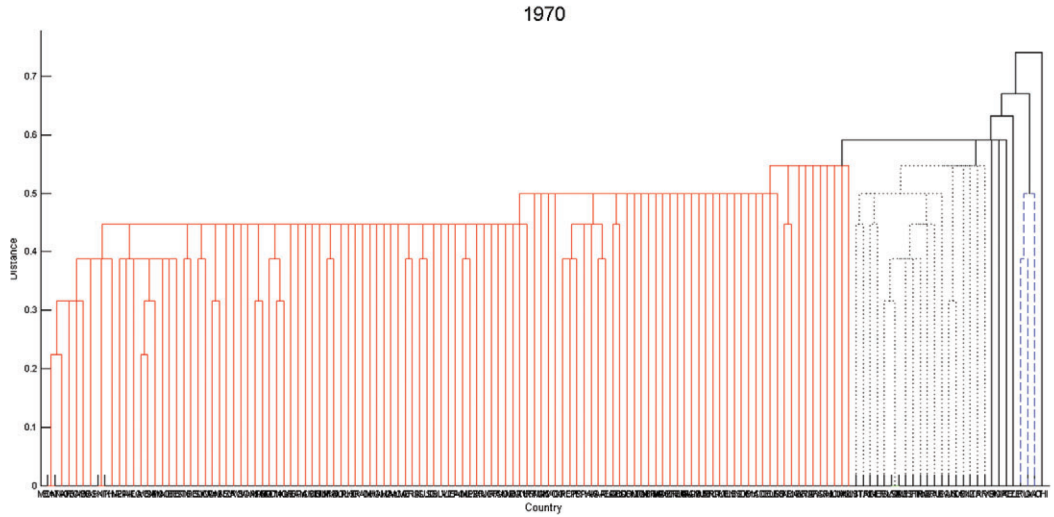

Figure 9. HT for the 20 Years Window from 1951 Ending at 1970. Second Cluster from the Left: Austria, Italy, Finland, Germany, Belgium, Sweden, Switzerland, the Netherlands, France, Norway, Denmark, UK, Canada, U.S., Australia, New Zealand, the United Arab Emirates, Trinidad and Tobago, and Argentina. Green: Uruguay, Qatar, and Kuwait. Second Cluster from the Right: Venezuela, Uganda, Ireland, Czechoslovakia, and Chile. Left Side Group: The Rest of the Countries in the Sample.

In 1975, we found four clusters, and some countries outside those groups. The highest performance cluster is composed by the same countries as before, but the Czech Republic enters to the group while the United Arab Emirates leave the cluster. The second cluster is composed by Greece, Puerto Rico, Portugal, Japan, Saudi Arabia, Hong Kong, Spain, Israel, Hungary, Libya, and Gabon. The third cluster is composed by Bulgaria, Singapore, Poland, Mexico, Iran, and Yugoslavia. Finally, the last group is composed by the lowest performance countries. On the other hand, Uruguay and Kuwait, and Ireland, the United Arab Emirates, Syria, Qatar, Venezuela, and Chile remain outside the clusters (Figure 10).

In 1985, the high-performance group increases embodying Austria, Saudi Arabia, Gabon, Belgium, France, Germany, U.S., Canada, UK, Puerto Rico, Greece, The Netherlands, Switzerland, Italy, the Czech Republic, Ireland, Spain, Austria, Norway, Japan, Portugal, Hungary, Hong Kong, Trinidad and Tobago, Israel, Denmark, Venezuela, New Zealand, Qatar, Uruguay, Sweden, Argentina, Finland, Kuwait, the United Arab Emirates, Bulgaria, Singapore, Poland, Mexico, Yugoslavia and Syria. A second cluster is formed by Brazil, Panama, and Taiwan. The third group is formed by the rest, but Mauritius, Libya, Chile, Costa Rica, Iraq and Iran remain outside the clusters (Figure 11).

In 1995 the high-performance group is composed by Austria, Belgium, Italy, Germany, UK, Canada, U.S., Puerto Rico, France, Portugal, Japan, Greece, Spain, Australia, The Netherlands, Hong Kong, Singapore, Switzerland, Czech Republic, the United Arab Emirates, Mexico, Venezuela, Saudi Arabia, Hungary, Denmark, Bulgaria, Sweden, New Zealand, Trinidad and Tobago, Finland, Israel, Chile, Norway, Argentina, Kuwait, Taiwan, Uruguay, Poland, Ireland, Syria, Qatar, and Brazil. The remaining countries belong to the lowest performance group, while Colombia, Turkey, Oman, Reunion, Yugoslavia, Gabon, Iran, Jordan, Costa Rica, Panama, Iraq, and Libya do not belong to any of the main clusters.

Finally, in 2003, there are two groups. The highest performance group is composed by Austria, Germany, France, The Netherlands, Portugal, Mexico, the United Arab Emirates, Belgium, Finland, UK, Ireland, Australia, South Korea, Mauritius, Taiwan, Chile, U.S., Puerto Rico, Singapore, Poland, Hong Kong, Italy, Japan, Switzerland, Denmark, Brazil, Sweden, Greece, New Zealand, Czech Republic, Bulgaria, Hungary, Trinidad and Tobago, Canada, Spain, Norway, Turkey, Argentina, Uruguay, Kuwait, Venezuela, Saudi Arabia, Israel, Oman, Syria, Qatar, Thailand, Malaysia, Costa Rica, Seychelles, and Colombia, except for Panama, Yugoslavia, Jordan, and Gabon, that do not belong to any cluster, the rest of the countries is in the low-performance group (Figure 12).

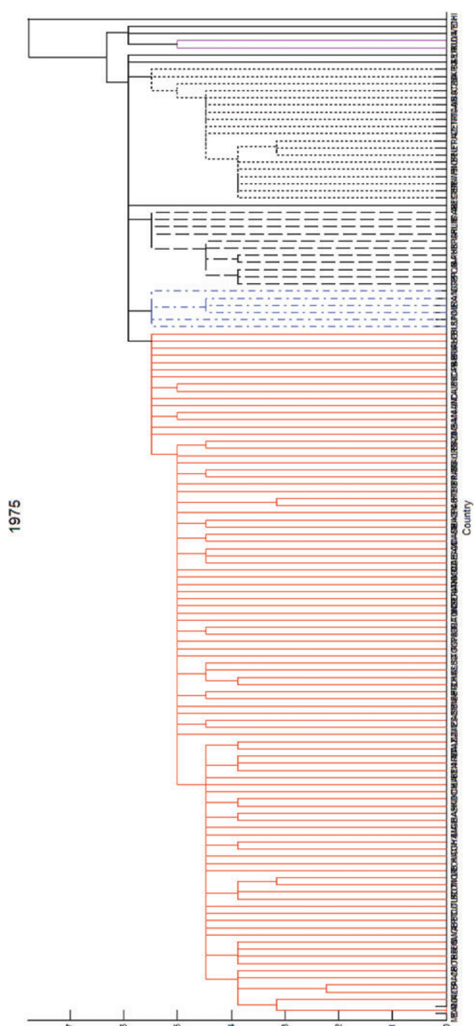

FIGURE 10. HT FOR THE 20 YEARS WINDOW ENDING AT 1975.

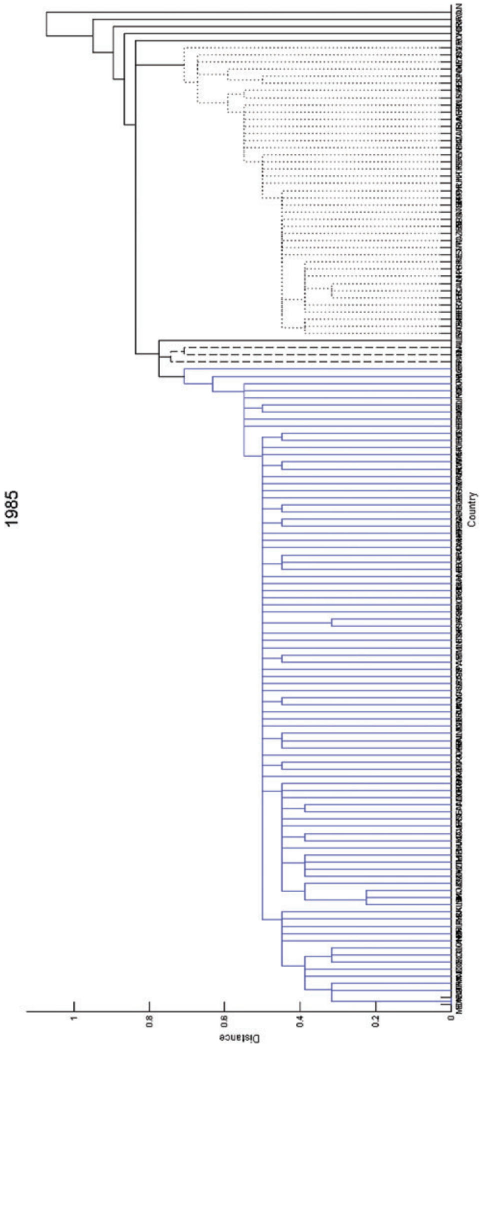

FIGURE 11. HT FOR THE 20 YEARS WINDOW ENDING AT 1985. SECOND CLUSTER FROM THE LEFT: BRA, PAN, AND TAI. RED: AUSTRI, SAUD, GAB, BEL, FRA, GER, U.S., CAN, UK, PR, GRE, NET, SWI, ITA, CZE, IRE, SPA, AUSTRA, NOR, JAP, POR, HUN, HK, TRI, ISR, DEN, VEN, NZ, QAT, URU, SWE, ARG, FIN, KUW, SAE, BUL, SIN, POL, MEX, YUG, AND SYR. OUTSIDE THE GROUPS: MAURI, LIBY, CHI, CR, IRAQ, AND IRAN. LEFT SIDE GROUP: THE REST OF THE COUNTRIES.

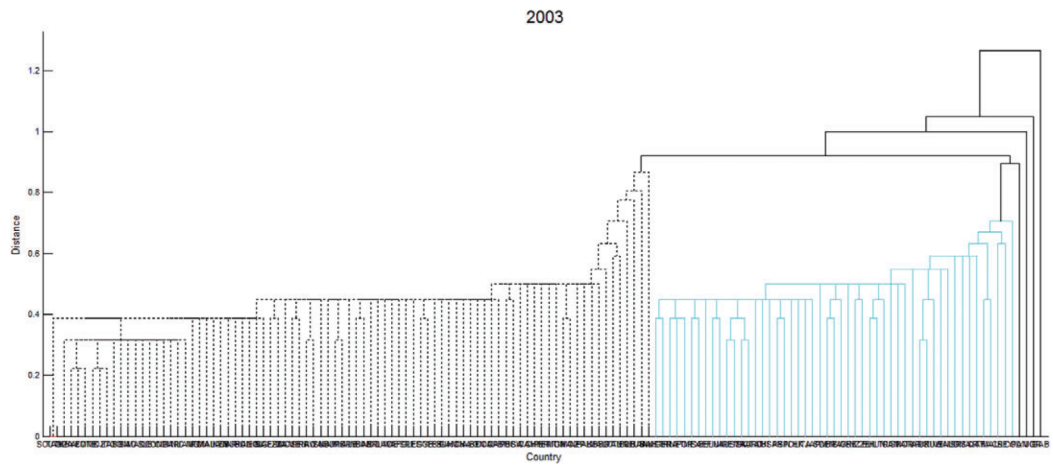

FIGURE 12. HT FOR THE 20 YEARS WINDOW FROM ENDING AT 2003. MIDDLE GROUP: AUSTRI, GER, FRA, NET, POR, MEX, SAE, BEL, FIN, UK, IRE, AUSTRA, SK, MAURIT, TAI, CHI, U.S., PR, SIN, POL, HK, ITA, JAP, SWI, DEN, BRA, SWE, GRE, NZ, CZE, BUL, HUN, TRI, CAN, SPA, NOR, TUR, ARG, URU, KUW, VEN, SAUD, ISR, OMA, SYR, QAT, THA, MAL, CR, SEY, AND COL. OUTSIDE THE GROUPS: PAN, YUG, JOR, AND GAB. LEFT SIDE GROUP: THE REST OF THE COUNTRIES.

Note that the most part of the Latin American and Caribbean Economies failed to reach the richest cluster. Only Argentina belonged to this group for the entire period, while Uruguay, Venezuela, Costa Rica, and more recently, Chile entered in time in this cluster. Chile and Venezuela,[5] before entering in the richest cluster, remained quite isolated form the others. Uruguay and Costa Rica have fluctuated between clusters, until settling into the rich one. This may be related to the variances in the primary production prices.

As Stanley and Kenneth (2006) show, this performance of LA's countries can be interpreted as the result of institutional failures. These authors pointed out that "with the rise of parasite profit opportunities . . . modernization may be halted even when it is privately profitable." The institutional precariousness in the region has been studied thoroughly (Spiller, Stein, and Tommasi 2003).

The other significant observed dynamics comes from the countries referred as new industrial countries. At the beginning of the period, these countries belonged to the poorest cluster. The windows analysis shows that, in time, all these countries end up in the richest group, as a consequence of the steady application export oriented industrialisation policies.

Finally, the initial rich countries remained in the same cluster despite the heterogeneity of the group. It is interesting to see that the initial position is kept in a group of countries whose economic history shows strong institutions and relative economic stability. They started a successful development process that led to continuous growth.

These results show that there are no fundamental traps to development, as countries, particularly at the middle of performance distribution, can change clusters. On the other hand, this does not mean that growth is inevitable as predicted by the neoclassical theory: Countries like Somalia, Haiti, or Paraguay remain always in the low-performance cluster, at a close distance among them. The same happens, for the high-performance cluster, with countries like the U.S. and Canada remaining always in regimes 3 and 4 with keeping the smallest (and quasi constant) distance of the sample. Countries like South Korea, Malaysia, Chile, or Mexico show a richer dynamic, as seen in the evolution of clusters and distances.

Conclusions

In this paper, we have introduced a new method to describe dynamical patterns of multidimensional time series, and we applied it to compare the economic performance of 140 countries during the period 1951–2003. We adopt the concept of regime to describe economic performance in a qualitative way and, following Owen, Videras, and Davis (2009), we study the differential process of growth across countries. Then, we represent the dynamics of each country by levels and growth rates of per capita GDP. Here, dynamics is represented by symbolic time series. Up from a notion of distance between trajectories, we introduce a non-parametric method of clustering to classify countries. With our treatment, the so-called convergence hypothesis can be seen in a different light and seems to call for a complete reformulation.

We detect two main clusters of high and low performance. The evolution of the clusters shows that the low-performance group tends to be more compact while the other group exhibits an increasing dispersion in performances. We also show that same countries change clusters, and that the distance between clusters increases in time. Switching from the low- to the high-performance cluster tends to be more usual than the converse.

The methodology confirms the existence of two clubs of countries that followed different sign patterns. When we investigate inside the groups, we note that whereas rich countries tend to diverge, the poor countries tend to have a more similar dynamical behaviour. Finally, when we study the evolution of the distance between average poor and rich country and take time windows of 30 years, we cannot reject the hypothesis that poor and rich countries have diverged from 1994 to 2002. Most of the findings in this paper have contradicts the traditional analyses of convergence, which predicted inexorable growth toward a steady state. From a more dynamic and multidimensional perspective, this new approach has allowed us to uncover regularities and trends in economic behaviour. We established the existence of clubs of performance, without having to condition the data a priori. All the results found (existence of clusters of countries, divergence/convergence between and intra-groups, etc.) are ex post, eliminating any selection bias. Finally, this methodology allows to incorporate other variables into the analysis (economic, institutional, social, etc.) to compare the influence of such variables in the configuration of clubs up from changes in performance. This is matter of further research.

NOTES

1. The kernel regression was obtained by graphing the growth rate against the log of the per capita GDP. This draw produced a perfect inverted-U. Figure 1 shows the results for the growth rate against the level of per capita GDP, this is the reason why the curve is stretched at the right.
2. The boundaries of the regimes are defined by means of $\geq$ instead of $<$ because the probability of being in two regimes at the same time is 0.
3. Appendix A indicates to which countries corresponds each label.
4. Onnela (2002) propose a measure that indicates the dimension of the tree or of a cluster. This is simple the so-called global distance, obtained by adding all the links in the tree (cluster).

5. These countries have quite different economies between then and with respect to all of the countries. On one hand, Chile has shown a high degree of institutional stability after 1973, applying sustained policies of structural reforms and economic openness. On the other hand, Venezuela has enjoyed the windfall revenues of its oil production except for some periods in which the world prices were low.

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Appendix A Countries of the Sample. Codification

No.	Code	Country	No.	Code	Country	No.	Code	Country	No.	Code	Country
1	AUSTRI	Austria	36	BOL	Bolivia	71	NK	North Korea	106	GAM	Gambia
2	BEL	Belgium	37	CR	Costa Rica	72	VIE	Vietnam	107	GHA	Ghana
3	DEN	Denmark	38	CUB	Cuba	73	BAH	Bahrain	108	GUI	Guinea
4	FIN	Finland	39	DOM	Dominican Republic	74	IRAN	Iran	109	GB	Guinea Bissau
5	FRA	France	40	ECU	Ecuador	75	IRAQ	Iraq	110	KEN	Kenya
6	GER	Germany	41	SAL	El Salvador	76	ISR	Israel	111	LES	Lesotho
7	ITA	Italy	42	GUA	Guatemala	77	JOR	Jordan	112	LIB	Liberia
8	NET	Netherlands	43	HAI	Haiti	78	KUW	Kuwait	113	LIBY	Libya
9	NOR	Norway	44	HON	Honduras	79	LEB	Lebanon	114	MAD	Madagascar
10	SWE	Sweden	45	JAM	Jamaica	80	OMA	Oman	115	MALAW	Malawi
11	SWI	Switzerland	46	NIC	Nicaragua	81	QAT	Qatar	116	MALI	Mali
12	UK	United Kingdom	47	PAN	Panama	82	SAUD	Saudi Arabia	117	MAU	Mauritania
13	IRE	Ireland	48	PAR	Paraguay	83	SYR	Syria	118	MAURIT	Mauritius
14	GRE	Greece	49	PR	Puerto Rico	84	TUR	Turkey	119	MOR	Morocco
15	POR	Portugal	50	TRI	Trinidad and Tobago	85	SAE	United Arab Emirates	120	MOZ	Mozambique
16	SPA	Spain	51	CHIN	China	86	YEM	Yemen	121	NAM	Namibia
17	AUSTRA	Australia	52	INDI	India	87	BANK	West Bank and Gaza	122	NIG	Niger
18	NZ	New Zealand	53	INDO	Indonesia	88	ALG	Algeria	123	NIGERIA	Nigeria
19	CAN	Canada	54	JAP	Japan	89	ANG	Angola	124	REUN	Reunion
20	USA	United States	55	PHI	Philippines	90	BEN	Benin	125	RWA	Rwanda
21	ALB	Albania	56	SK	South Korea	91	BOT	Botswana	126	SAO	São Tomé and Principe
22	BUL	Bulgaria	57	THA	Thailand	92	BURK	Burkina Faso	127	SEN	Senegal
23	CZE	Czechoslovakia	58	TAI	Taiwan	93	BURU	Burundi	128	SEY	Seychelles
24	HUN	Hungary	59	BAN	Bangladesh	94	CAME	Cameroon	129	SL	Sierra Leone
25	POL	Poland	60	BRUM	Burma	95	CAPE	Cape Verde	130	SOM	Somalia
26	ROM	Romania	61	HK	Hong Kong	96	CAR	Central African Republic	131	SOUTH	South Africa
27	YUG	Yugoslavia	62	MAL	Malaysia	97	CHA	Chad	132	SUD	Sudan
28	ARG	Argentina	63	NEP	Nepal	98	COM	Comoro Islands	133	SWA	Swaziland
29	BRA	Brazil	64	PAK	Pakistan	99	CONG	Congo	134	TANZ	Tanzania
30	CHI	Chile	65	SIN	Singapore	100	COTE	Cote d'Ivoire	135	TOG	Togo
31	COL	Colombia	66	SRI	Sri Lanka	101	DJI	Djibouti	136	TUN	Tunisia
32	MEX	Mexico	67	AFG	Afghanistan	102	EGY	Egypt	137	UGA	Uganda
33	PER	Peru	68	CAM	Cambodia	103	EQU	Equatorial Guinea	138	ZAI	Zaire
34	URU	Uruguay	69	LAO	Laos	104	ERIT	Eritrea and Ethiopia	139	ZAM	Zambia
35	VEN	Venezuela	70	MON	Mongolia	105	GAB	Gabon	140	ZIM	Zimbabwe

Appendix B Global Distances

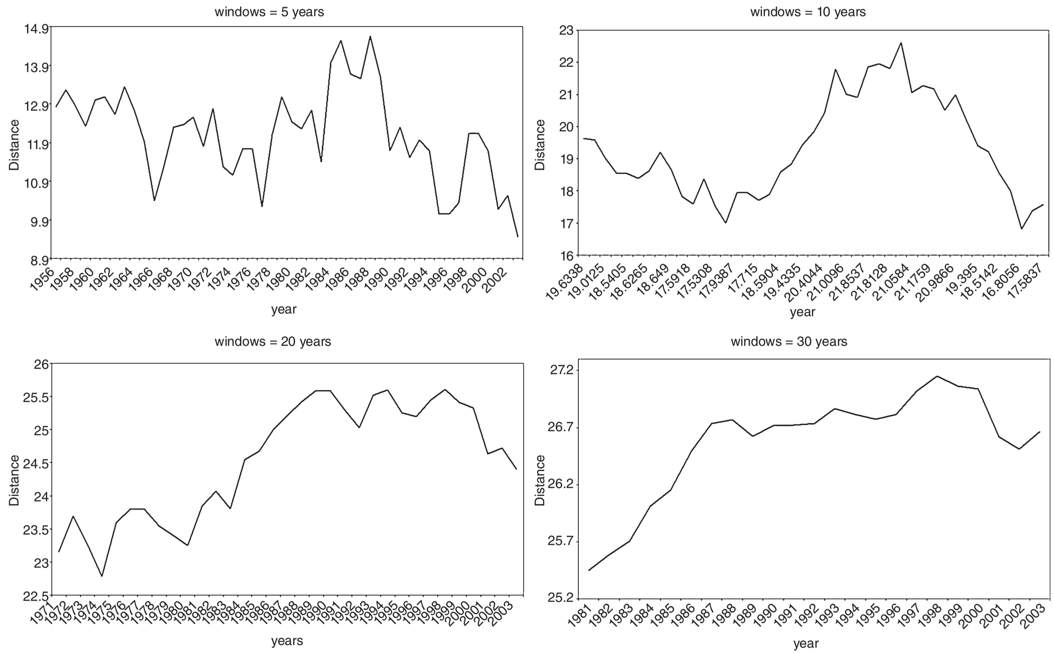

FIGURE 1. EVOLUTION OF THE DIAMETER OF THE MST FOR THE 49 HIGH-PERFORMANCE COUNTRIES DURING THE WHOLE PERIOD, CONSIDERING TIME WINDOWS OF 5, 10, 20, AND 30 YEARS. THE TREND OF THE GLOBAL DISTANCE OF THE MST IS NOT CLEAR FOR TIME WINDOWS OF 5 AND 10 YEARS, BUT IT IS INCREASING WHEN WE CONSIDER 20 AND 30 YEARS. THIS IS AN INDICATOR THAT DYNAMICAL BEHAVIOURS OF THE CLUSTER TENDS TO BE NOT HOMOGENEOUS FOR WINDOWS OF 20 AND 30 YEARS.

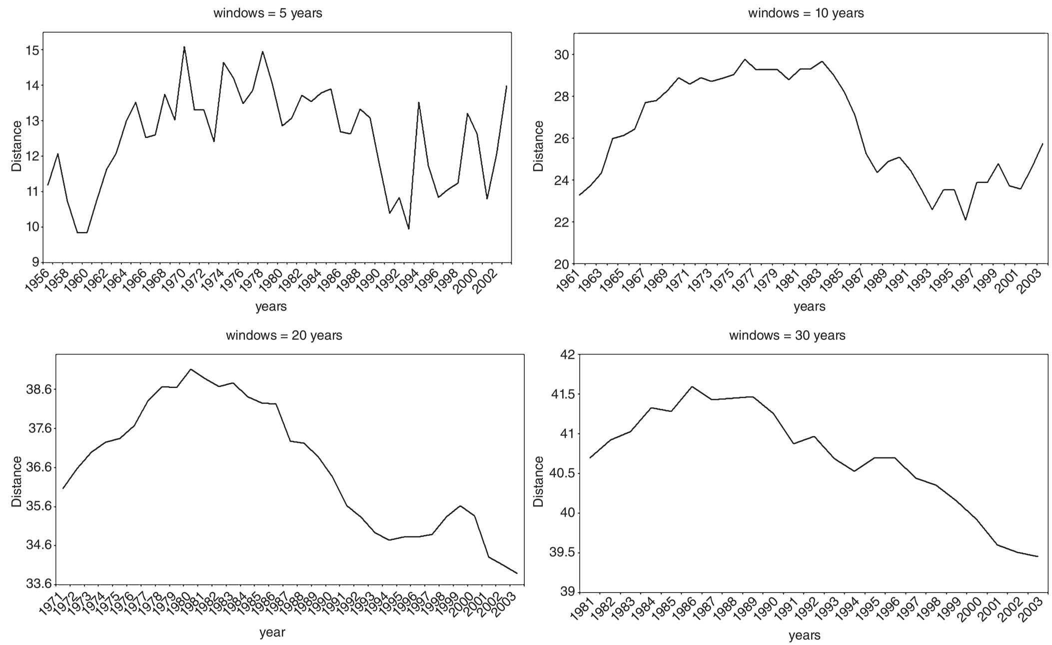

FIGURE 2. EVOLUTION OF THE DIAMETER OF THE MST FOR 80 LOW-PERFORMANCE COUNTRIES, CONSIDERING TIME WINDOWS OF 5, 10, 20, AND 30 YEARS. THE TREND OF THE GLOBAL DISTANCE OF THE MST IS FIRST INCREASING FOR A PERIOD, THEN DECREASING. THIS INDICATES THAT AFTER A PERIOD WHERE DYNAMICAL PATTERNS ARE CHANGING, THE COUNTRIES OF THIS CLUSTER TEND TO HAVE A MORE HOMOGENEOUS DYNAMICAL BEHAVIOUR.