Instability constraints and development traps: an empirical analysis of growth cycles and economic volatility in Latin America

Danilo Spinola

Abstract

Latin America and the Caribbean is a region characterized by a repetitive pattern of volatility that thwarts its development process. This article conducts an empirical investigation into its volatility, comparing it with other regions. First, an asymmetrical band-pass filter is used to decompose GDP growth time series into cycles of different types for 136 countries, employing data from the Maddison Project Database for 1950–2018. Next, *k*-means clustering methods are used to classify volatility patterns into groups to understand their characteristics. In most countries in the region, overall volatility is explained by the relative dominance of long-run economic cycles linked to heavy dependence on commodity exports, with changes in specialization resulting from technology-driven changes in the inputs used by the countries they export to. Despite claims to the contrary in the literature, the region is not the world's most volatile, but its countries have many particular, common characteristics.

Keywords

Economic conditions, economic growth, economic structure, macroeconomics, gross domestic product, business cycles, economic analysis, Latin America and the Caribbean

JEL classification

C21, C32, 047

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I. Introduction

Historically, sustaining growth has been a central problem for many developing countries seeking to implement a virtuous development strategy (Foster-McGregor, Kaba and Szirmai, 2015). Short-term growth spurts and high volatility in macroeconomic prices are constantly observed in developing countries, reducing their average period of stable growth. This results in an endogenous pattern of instability, reproduction of inequality, net outflows of financial capital and sharp fall-offs in investment. Macroeconomic volatility places major constraints on the economic development process, affecting long-term decision-making and creating periodic crises (Stiglitz, 2000). It impacts the economic structure, undermining long-run economic growth (Ocampo, Rada and Taylor, 2009).

Macroeconomic volatility is not a new issue, but it is currently a central problem for developing countries. Despite its importance, little effort has been made to understand the consequences of the type of volatility that emerges from the production structure, affecting the potential growth rates of economic systems. Volatility is usually treated as being related to stock market fluctuations and government debt (Eichengreen and Hausmann, 2010) rather than to structural fragility and the production structure, which leaves a gap in the literature.

Drawing on structuralist theory (Ocampo, 2002; Taylor, 1991), we plan to treat the periodic phenomenon of volatility as something driven by structural fragility (defined as the inability of an economy to absorb external economic shocks). We focus on aspects associated with volatility in GDP growth and empirically demonstrate different patterns of volatility in a variety of countries and regions.

Many structuralist authors have argued that the structural causes of volatility in Latin America and the Caribbean are related to its peripheral position in the international division of labour (Ffrench-Davis, 2005; Ocampo, Rada and Taylor, 2009; Prebisch, 1950). This position is characterized by external fragilities associated with these countries' specialized production structure and resulting in low resilience to external shocks, which is a major source of volatility. Accordingly, authors working in the structuralist tradition argue that the historical development of the Latin American and Caribbean economies has given these an idiosyncratic aspect that makes them more fragile (Furtado, 1965). However, there is a lack of empirical research to prove (or disprove) this claim. Do Latin American and Caribbean economies' volatility patterns actually differ from those of developed countries and other developing regions?

To answer this question, we shall (i) present some stylized facts about GDP growth volatility for the countries in our dataset, (ii) apply filtering techniques to decompose economic growth time series into different types of cycle and analyse the patterns that emerge from the data and (iii) use cluster analysis to build a typology that groups countries by their patterns of volatility. This methodological strategy will allow us to analyse the type of expansion cycle processes followed by each country.

Section II provides a brief review of the literature covering (i) the main theories behind the idea of economic cycles, (ii) the structuralist perspective and (iii) the empirical evidence for the existence of cycles. Section III presents the data used in this research. Section IV focuses on the methodologies employed, namely the Christiano-Fitzgerald band-pass filter and the *k*-means method of cluster analysis. Section V presents evidence from the original data before application of the filtering method. Section VI shows the results of applying the filters to the data and discusses them for the different types of cycle. Lastly, section VII summarizes the main results and concludes.

II. Literature review

This section consists of a literature review that presents the classical and current discussion of economic cycles and volatility, covering three main aspects: the relevance of cycles to economic theory, the approach taken to volatility in structuralist theory, and some methodological and empirical evidence for cycles in growth theory.

1. Cycle theory

The study and development of cycle theories has helped many analysts to understand economic dynamics. Different theories have approached the observation of economic cycles with their own explanations of the phenomenon (Korotayev and Tsirel, 2010). The relevance of studying these cycles is that when they arise in certain key economic variables, they affect countries' short- and long-run economic behaviour and development strategies. The existence and causes of cyclical behaviour have been extensively addressed by a whole tradition in cliometrics and cliodynamics.

Economists have long claimed to identify cyclical patterns in economic prices and growth. In the early days of the discipline, Juglar (1863) showed that cycles were related to business activity. They ranged from 8 to 11 years and were caused by investments maturing. This insight was later developed into business cycle theory, now a staple of economics. As regards long-run cycles, Kondratiev (1935) discussed the existence of periods of volatility in the world economy every 45 to 60 years (Korotayev and Tsirel, 2010). The identification and causes of long cycles are still the subject of debate, as will be discussed. Another type of cyclical behaviour, in the medium run this time, was discovered by Kuznets (1940), who related it to infrastructure investment. This type of cycle was discussed by Abramovitz (1961 and 1969), who empirically analysed the recurrence of periods of crisis in economic growth for a broad range of countries at similar intervals. Very short-run cycles (Kitchin cycles) are usually related to changes in inventories (Korotayev and Tsirel, 2010) and to international portfolio flows that create short-run oscillations.

In his classic book on business cycles, Schumpeter (1939) described how technological aspects tied in with the cyclical behaviour of an economy and proposed a typology for them in accordance with their periodicity. An updated version of his typology (Jadevicius and Huston, 2014) allows us to identify four types of cycles: the Kitchin cycle (3 to 5 years), the Juglar cycle (8 to 11 years), the Kuznets cycle (15 to 25 years) and the Kondratiev wave (45 to 60 years). The present study is based on this typology. It takes an expanded range for each cycle in order to have full time frame coverage in the band-pass filter calibration, which ranges from 2 to 60 years. The fluctuations of economic cycles are not only related to particular aspects of a specific economy, but are present in every economy, each with its special nature.

The reasons for the existence of cycles are a topic of great debate in economic theory, with different authors seeking to understand their causes. Those posited include (i) the build-up of inventories (Kitchin, 1923), (ii) credit behaviour, (iii) the maturing of investments (Besomi, 2014; Fukuda, 2009), (iv) infrastructure investments (Abramovitz, 1969; Kuznets, 1940), (v) technological development (Perez, 2010; Schumpeter, 1939) and (vi) international financial flows. Note should also be taken of Fischer's debt deflation theory (Palley, 2008) and of the financial instability hypothesis (Minsky, 2016).

The structuralist tradition is composed of theories that seek to explain the behaviour of cycles in developing countries, looking at both supply- and demand-side aspects of the macroeconomic system. The special feature of these theories is that they treat cycles as endogenous to the behaviour of the system, thereby differing from the traditional real business cycle framework, which treats the main sources of cycles as exogenous (Kydland and Prescott, 1990). From the real business cycle perspective, well-functioning markets result in a stable equilibrium, meaning that fluctuations are the result of real (e.g., technological) shocks leading to efficient responses from the market, not a structural characteristic of particular economic systems.

2. Structuralism and volatility: why are developing countries so volatile, and what is the international position of Latin America and the Caribbean?

The centre-periphery concept is at the core of the research conducted by the Economic Commission for Latin America and the Caribbean (ECLAC), historically linked as it is to the Latin American structuralist tradition. Latin America and the Caribbean has been seen as a region with a specific economic dynamic compared to other regions ever since the studies conducted by Prebisch (1950), Sunkel (1972), Furtado (1959) and Fajnzylber (1990), and more recently by Ocampo (2002), Botta (2010), Pérez Caldentey and Vernengo (2010) and Cimoli, Porcile and Rovira (2010). Latin America and the Caribbean is a region with a peculiar economic dynamic resulting from its peripheral position in the international division of labour. Taylor (1991) models and summarizes the effects of the centre-periphery dynamic in the establishment of a cyclical dynamic. His argument is that pronounced cycles have resulted from the idiosyncratic economic and institutional development of the region over history, a specificity that impacts the short- and long-run growth dynamic.

Prebisch (1950) developed a theory explaining the emergence of a centre-periphery (or core-periphery) dynamic in the international system. The position of each country in the system depends on the types of goods it produces (their technological intensity), which determines how the country participates in the international division of labour. The centre (the North, containing the central or core countries of the system) is the locus of technological change, producing new advanced, high-technology products with a high income elasticity of demand. On the other hand, the periphery (the South) participates in the international dynamic by producing and exporting raw materials and low-technology products. This theory marked the beginning of the Latin American structuralist tradition. Bielschowsky and Torres (2018) track all the improvements in structuralist theory over the 70 years of ECLAC economic thought.

The result has been the emergence of an uneven distribution of productive and technological capabilities that are reproduced endogenously over time, leading to institutional differences in which the periphery has a distinct economic dynamic in its long-run development as compared to the centre. In the centre-periphery framework, the underdevelopment of the production structure is seen as the main contributor to increasing fragility in developing countries (the periphery). Taking a long-run perspective, the theory posits a long-term decline in the terms of trade (the Prebisch-Singer hypothesis) that creates barriers to economic development.

Moving on to the post-Keynesian tradition, Thirlwall (1979 and 2012) developed the balance-of-payments-constrained growth model. In this theory, countries are constrained in the long run by the income elasticity of demand for imports and exports of the products they trade. An increase in the growth rate should be compatible with external sector stability, which depends on the production structure and defines the pattern of fragility. More recently, Cimoli and Porcile (2014) linked external constraints to the technological capabilities of peripheral countries, merging the post-Keynesian, structuralist and evolutionary perspectives.

The lack of dynamism in the production structure of developing countries and the aforementioned fragility have resulted in a specific pattern of international trade specialization. Developing countries' activities are concentrated in low-technology products and highly standardized goods (commodities). This creates a disadvantage and worsens terms of trade: specialization in commodities results in higher volatility. Significant studies such as Ziesemer (2010) have evaluated terms of trade by observing commodity price trends: commodity prices in international markets are more volatile than those of high-technology manufactured goods. This volatility affects the balance-of-payments conditions of developing countries not only in the long run, as discussed by Thirlwall (2012), but also in the short run, constraining economic development. The source of high volatility in developing countries may be the increased fragility created

by a specialized and undynamic production structure (Hausmann and Gavin, 1996), itself resulting from a specific type of peripheral participation in the international division of labour.

This can be explained by certain specific mechanisms. Higher volatility in international prices generates a mismatch in the balance of payments (exports, imports and capital flows) which affects economic growth through the following channels:

- From a Keynesian perspective, it increases uncertainty, affecting economic agents' decisions in the short and long run, with investment projects that tie up large amounts of capital being perceived as less profitable. Marginal capital efficiency is reduced, as described by Keynes (1936). The result is fewer long-run projects, with smaller investments and less aggregate demand, leading to lower economic growth.
- Instability in the external account reduces the scope for importing capital goods. This is particularly serious for developing countries, where a virtuous catching-up strategy requires access to capital goods (machinery) in the technology vanguard (Stiglitz, 2000).
- Volatility in external prices affects a country's real exchange rate. Larger swings in the exchange rate increase uncertainty, which may generate greater opportunities for arbitration and speculation but does not improve the potential for development (Andrade and Prates, 2013).
- Uncertainty affects not only investment but also consumption. Real wages are very sensitive to changes in the exchange rate. In an uncertain environment, the price channel reduces consumption and aggregate demand (Gabriel, Jayme and Oreiro, 2016).
- Increased uncertainty regarding investment and the exchange rate affects agents' behaviour through higher price volatility. Agents defend themselves by increasing prices to protect their mark-up (Steindl, 1979). Thus, volatility can also be seen as an inflationary mechanism.
- Lower investment, especially in the manufacturing sector, is also linked to lower productivity. Following the classical Kaldor-Verdoorn discussion (Kaldor, 1975), debated by McCombie and Spreafico (2016), investment and growth boost not only the stock of capital but also its quality, generating economies of scale and greater learning opportunities. This, then, is another mechanism that reinforces underdevelopment through specialization in low-technology activities.

In mainstream economics, leading economists have argued that fragility is correlated with lower resilience to shocks, especially in the case of external shocks resulting from abrupt price changes (Blanchard and Gali, 2007) and also from institutional issues (Acemoglu and Robinson, 2012). Countries with less diversified exports suffer most from external price volatility. Volatility has historically been much higher for low-technology goods than for high-technology manufactured goods, and this exacerbates fragility in developing countries.

Most of the literature usually focuses on the short- and medium-term aspects of development. We would also like to focus on the long-run element, which our empirical analysis indicates may be crucial in explaining many of the oscillatory mechanisms operating in Latin America and the Caribbean.

Building on the traditional analysis used to explain cycles, we argue that another important explanation for the dynamics of volatility, especially in developing economies, lies in changes to the composition of inputs in a new emerging technology paradigm (Bollen and Appold, 1993; Bunker, 1985; Brady, Kaya and Gereffi, 2011). This relates the idea of long waves to that of natural resource dependence. An interesting piece of evidence comes from the long historical analysis of Latin America conducted by Bertola and Ocampo (2012). The authors observe the central role that international dynamics have historically had in the composition of development and the crucial part that the reorganization of (natural resource-related) economic activities has played in determining development patterns, volatility and

crises. Bulmer-Thomas (2003) associates dependence on input integration with the colonial legacy of the Latin American countries, following the same line of argument as Furtado (1959) in discussing the economic formation of Brazil. These contributions focus on the structural reasons why developing countries, especially in Latin America and the Caribbean, evince a strong and permanent pattern of boom and bust.

The import-export pattern is a central element in this discussion, whether in relation to short-run fluctuations or to long-run waves. As discussed above, a whole tradition in the literature has sought to identify the sources of both short-run and long-run volatility, but very few studies have set out to measure and explain them. The purpose of the present study is to use economic cycle theory to measure different aspects of volatility.

3. Cycle analysis methodologies and empirical evidence for economic cycles

Different methodologies have been developed in the field of time series to extract cycles from the original GDP growth time series data. There is a whole tradition in disciplines such as physics (oscillatory dynamics) in which frequencies are viewed as essential for understanding the behaviour of certain volatile phenomena. Much the same is true in economics, where we can empirically observe the existence of cyclical behaviour in many economic variables.

Mention may be made of three main methodologies used to empirically observe the existence of cycles: spectral analysis (Bossier and Huge, 1981; Korotayev and Tsirel, 2010; Van Ewijk, 1981), the filter design approach (Kriegel, Kröger and Zimek, 2009; Metz and Stier, 1992) and wavelet analysis (Gallegati and others, 2017). These methodologies focus on analysing the different frequencies that emerge from real time series.

Spectral analysis applies Fourier transforms to time series and observes their spectrum in different frequencies. Using power spectral densities, it is then possible to identify the existence of periodic oscillations in the time series. This method starts by removing the trend from the series as a requirement of stationarity. Fourier transformations use combinations of sines and cosines to represent a non-local function, so that changes affect the whole function. This restriction allows windowed transformation (bands) to be used. Wavelet analysis is analogous to spectral analysis but uses a finite domain.

It is important to mention the literature on structural breaks, which follows Pritchett (2000) and Bluhm, Crombrugghe and Szirmai (2016) in seeking to capture shifts in growth regimes. In this literature, a time series is not understood as a cyclical component around one stable trend, since the breaks change the slope of the trend over time, as seen in the trend-cycle decomposition of Perron and Wada (2016). This approach may help us understand ongoing changes in development strategies. Because of our focus on historical cyclical components and the need for a large number of observations, we have opted to study the filter decomposition with structural breaks at a later stage of the research. The large number of breaks reduces the number of observations available for observing the overall cycles, which potentially reduces the accuracy of the cyclical results. Accordingly, we have not used structural breaks in this analysis, but left it for the future to compare its results with those of an analysis using breaks.

This paper uses a filter design approach, a development of spectral analysis that involves identifying a specific band filter. There are various possible filters, as described and enumerated by Pollock (2013). One commonly employed is the low pass filter, also known as the Hodrick-Prescott filter (Hodrick and Prescott, 1997). Despite being one of the most widely used, this methodology was heavily criticized by Hamilton (2017) for its strong bias. Another important methodology is the band-pass filter, in its symmetrical (Baxter-King) and asymmetrical (Christiano-Fitzgerald) versions. The latter is used to observe long waves and growth cycles. The procedure entails filtering coefficients to isolate specific frequencies with a view to identifying the ideal filter band. We use the asymmetric

band-pass filter of Christiano and Fitzgerald (2003), which was also used by Erten and Ocampo (2013) to identify commodity cycles.

We find some empirical evidence for regular patterns of volatility (cycles) in GDP growth. There are many studies which test the existence of cycles at the global level. Korotayev and Tsirel (2010), using spectral analysis, argue that it is highly likely that Kitchin, Juglar and Kondratiev cycles exist at a global level. Kuznets cycles are the third harmonic of the Kondratiev cycle, detected as occurring every 17 years at the world level. In another important study, Diebolt and Doliger (2008) identified Kuznets swings for GDP growth.

Although these studies pointed to the existence of cyclical behaviour in economic systems, it is important to note that the findings of the literature are still open to debate, with contradictory results that are sensitive to the methodology applied. There is still disagreement about the empirical existence of short and long waves (Bosserelle, 2015). This debate is not a focus of the present study, which does not set out to question the results of the research cited, but it is worth mentioning that the existence of regular GDP growth cycles remains a controversial topic.

III. Data

This paper uses the Maddison Project Database, updated with data from the World Bank World Development Indicators. The database builds on the work of Maddison (2001 and 2003) and was most recently updated by Bolt and Van Zanden (2014), who calculated long-run historical per capita GDP data for a large number of countries and regions. The database has data from antiquity until 2010. We selected the period 1950–2010 and used per capita GDP growth rates from the World Bank Database to update the information from 2010 to 2018. The updating procedure involved removing population growth from the database in order to ascertain GDP growth (not per capita growth). The former Soviet republics and the former Yugoslavia were excluded from the database because of problems with their data.

The treated database consists of GDP growth data for 136 countries from 1951 to 2018. Christiano and Fitzgerald's (2003) band-pass filter was applied to each country's time series and the original data were decomposed into different cycles. With the cycle data extended, these cycles cover the very short run of 2 to 8 years (Kitchin cycle), the short run of 8 to 15 years (Juglar cycle), the medium run of 15 to 30 years (Kuznets cycle) and the long run of 30 to 60 years (Kondratiev cycle). The *k*-means methodology was used to cluster the results, dividing instability patterns into different groups.

GDP growth data were used in the research for two main reasons: (i) to remove the problem of non-stationarity of the time series, since stationarity is a fundamental requirement of the filtering decomposition analysis; and (ii) because GDP growth focuses only on the dynamic aspect of volatility. The aim is not to observe how the stock of wealth (GDP level) affects volatility, but how the flow (growth) is related to an oscillatory pattern.

IV. Methodology

1. The band-pass filter

Erten and Ocampo (2013) use the asymmetric band-pass filter to identify commodity price cycles. The same method is used here to filter the GDP growth time series. The asymmetric band-pass filter allows a time series to be decomposed into different frequency components, which are then used to identify the cycles in the different time series. This approach is combined with the identification of medium-run

cycles, following Comin and Gertler (2003) and Drehmann, Borio and Tsatsaronis (2012). The method adopted splits per capita GDP growth (y) into five components: (i) a long-run cycle (y^{LR}) with periodicities of 30 to 60 years (Kondratiev cycle), (ii) a medium-run component (y^{MR}) with periodicities of 15 to 30 years (Kuznets cycle), (iii) a short-run cycle (y^{SR}) with periodicities of 8 to 15 years (Juglar cycle), (iv) a very short-run cyclical component (y^{SSR}) with periodicities of less than 8 years (Kitchin cycle) and (v) a residual component e, which will be discussed later as the structural component.

$$y_t \equiv y^{LR}{}_t + y^{MR}{}_t + y^{SR}{}_t + y^{SSR} + e \tag{1}$$

The average length of a supercycle, as reported by Erten and Ocampo (2013) in their analysis, is 35.7 years, with a minimum of 24 years and just 3 (out of 18) supercycles being more than 40 years long. The Kuznets cycle is considered to have a periodicity of between 15 and 30 years. The long-run trend therefore has a periodicity of more than 30 years and up to 60 years, following the Kondratiev waves. A medium-run Juglar wave is then defined as having a periodicity of between 8 and 15 years, with the short-term Kitchin cycle having a periodicity of less than 8 years.

The idea behind this procedure is to identify different types of cycle from the original time series and apply the methodology to all the countries for which data are available. We then group countries with similar cyclical characteristics (e.g., larger oscillations in short-run cycles) into clusters. Lastly, we study the characteristics of each group. The asymmetric band-pass filter is helpful here, as it serves to identify bands for the periods in which we would like to extract the cycles. With the categories determined, we can then ascertain whether the Latin American and Caribbean countries evince any similarities, and what explains these.

We initially use the band-pass filter to extract the high-frequency Kitchin cycle from the original time series (see table 1). Then we adjust the band to extract the Juglar cycle from the residuals of the Kitchin cycle. From the residuals of the Juglar cycle, we extract the Kuznets cycle. The same procedure is used to extract the Kondratiev cycle from the residuals of the Kuznets cycle. The resulting data form a residual, which is linked to long-run economic growth. The sum of the five components yields the original time series. Cluster analysis can be used to group the different patterns of cyclicality extracted for different countries.

Table 1
Cycles in economic theory and their respective time periods

Cycle name	Main origin	Period *(Years)*	Possible cause as per the theory
Kitchin	Market/financial flows	0–8	Inventories (consumption)/portfolio decisions
Juglar	Business investment cycle	8–15	Medium-run investments
Kuznets	Structural investment cycle	15–30	Long-run investments (infrastructure)
Kondratiev	Technological cycle	30–60	Technological paradigm shift
Residual	Trend	-	Structural element, human capital

Source: Prepared by the author.

2. Cluster analysis

Cluster analysis consists of organizing elements into similar groups by selected attributes. There is no standard way of clustering, but many different methodologies are used to group elements with similar aspects. In this paper, the *k*-means methodology, a method of vector quantization that groups observations in clusters by partitioning the data space into regions, is used to divide the selected countries into separate groups on the basis of their cycle standard deviations.

The *k*-means method minimizes distance in a graph in order to group elements with similar (selected) characteristics. We have to determine the number of groups (clusters) we wish to find. The method determines which observations are similar by the distance between them. The *k*-means method can use many variables. For example, we might choose eight relevant characteristics to group people with similar interests from a selected population.

Technically, *k*-means is a randomized method that divides data into k distinct clusters. The n objects are grouped into clusters by the nearest mean. The optimal number of clusters is not known and must be exogenously determined (however, there are tests available to help with this). The objective of this methodology is to minimize intracluster variance (the squared error function). This is done by identifying an objective function j that is used to calculate a distance function which must be then minimized. The objective function can be written as:

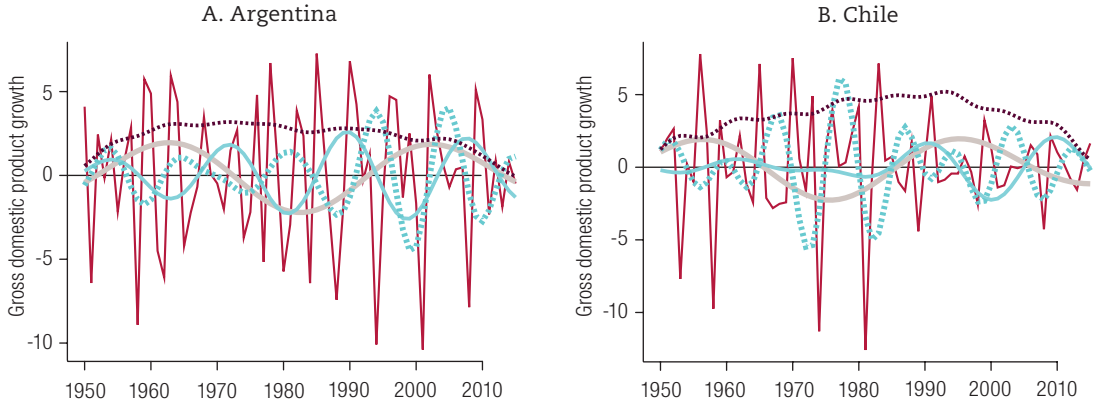
$$j = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2 \tag{2}$$

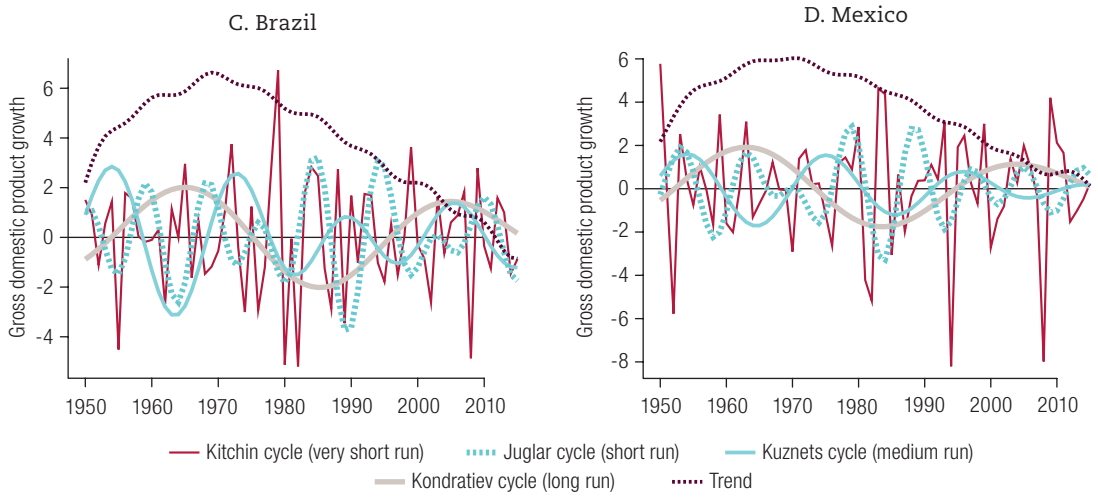
where x_i represents case i and c_j the centroid for cluster j. The method first computes k exogenously given clusters. Then it randomly selects cluster centres and assigns observations to them, following the distance function, and calculates the mean of each object. This method is repeated until the distances are minimized, yielding clusters in which similar countries are divided from those that are dissimilar in respect of the selected variables.

V. Analysis by cycle type

In order to illustrate the methodology and the results obtained, we present the filtering method as applied to some selected Latin American and Caribbean country data below. Figure 1 shows the four types of cycle filtered from the original GDP growth time series for the selected countries. Each cycle has a detailed aspect and can be used to identify historical turning points in these countries' economies. This extraction procedure reveals the different degrees of stable volatility. An interesting aspect is the residual non-cyclical component. This reveals long-run features that could be related to the countries' economic structures.

Figure 1
Latin America and the Caribbean (selected countries): volatility, cycles and residual
(Percentages)





Source: Prepared by the author, on the basis of Maddison Project Database.

Figure 1 shows the decomposition of growth time series into cycles and trend for Argentina, Brazil, Chile and Mexico. The scales are different in each graph because of the differences in the volatility patterns of each country. The short-run Kitchin cycles, in red, have the highest frequency and variance. This cycle is characterized by high amplitude and small duration. The presence of major economic crises can easily be seen in the strongly marked Kitchin cycle. This is the case with many Latin American countries in the 1980s, an example being the Mexican peso crisis of 1982.

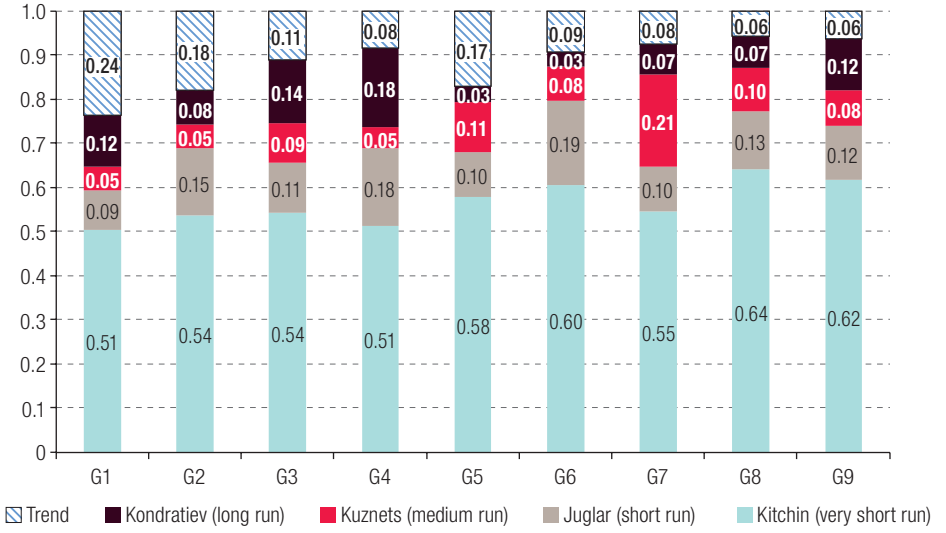
Following the literature, each cycle can be linked to a major element. The short-run Juglar cycle follows the investment cycle in each economy, while the Kuznets cycle is associated with longer infrastructure-related investment cycles. The Kondratiev cycle is best approached by the theory of technological change (Perez, 2010). We can also observe the presence of a residual component which follows not a cyclical pattern, but a trend. This residual can be used to explain changes in the production structure, such as the decline in the share of the industrial sector as part of a specialization pattern that began in Latin America and the Caribbean in the late 1970s, which is a topic for a future study.

VI. Results of the cluster analysis as applied to cycles

The cluster analysis was applied to the different cycle components of the time series, with countries being grouped by their volatility patterns. The clustering algorithm was run 1,000 times because of the randomized aspect of the *k*-mean, yielding Monte Carlo frequencies that served to identify the groups. The cluster analysis took the short-, medium- and long-run cycles as inputs. The decision to isolate very short-run cycles was taken on the basis that cycles of this type captured all the noise from aspects (mostly political) not directly related to the economy. Cluster optimization criteria were employed to select the number of clusters, yielding nine groups.

Group 1 represents the least volatile countries, which include the majority of developed countries. This group is marked by low variance and a relatively large trend component (see figure 2), with overall volatility being explained mainly by long-run cycles, while very short- and short-run volatility play less of a role. Group 2 has similar characteristics to group 1, but greater variance and a larger role for very short- and short-run volatility. It still includes some developed countries, with certain emerging economies in Africa that show a similar volatility pattern making up the rest of the mix.

Figure 2
Variance of each cycle as a share of total variance (average per cluster group)



Source: Prepared by the author, on the basis of the Maddison Project Database.

As table 2 shows, overall variance is practically the same in groups 3 to 6. The differences lie in the relative contribution of each cycle to volatility. In group 3, the Kondratiev cycle is more important, while the trend, short-run and very short-run cycles explain a lower than average share of volatility. In group 4, both the Juglar and the Kondratiev cycles play more of a role, while group 5 shows a pattern in which the trend, medium-run and very short-run cycles are more prominent. In group 6, lastly, the Kitchin and Juglar cycles are very important (short-run oscillations explain a larger share of overall volatility).

Table 2
Average variance in gross domestic product growth, by cluster group

Group 1	7.90	Group 4	28.76	Group 7	33.09
Group 2	15.93	Group 5	22.17	Group 8	69.97
Group 3	21.84	Group 6	26.65	Group 9	181.13

Source: Prepared by the author, on the basis of the Maddison Project Database.

Group 7 has slightly higher average variance than the first six groups and is characterized by a larger role for the medium-run cycles. In groups 8 and 9, lastly, overall volatility has much greater variance, with the very short-run cycles playing a much larger role and the long-run cycle and long-run trend much smaller ones.

Table 3 compares the different groups by their cycle characteristics. Each group's shares are compared with the averages, showing which cycle is the most important in explaining the differences between the clusters. Each group evinces different behaviour that poses some questions. Why is a particular country more affected by the long-run cycle? What determines this? Is it related to the structural conditions of economies? Is it a matter of fragility?

Table 3
Summary of the relative contributions of each cycle, by cluster group

	Kitchin (very short run)	Juglar (short run)	Kuznets (medium run)	Kondratiev (long run)	Trend
Group 1	--	--	-	+	++
Group 2	-	+	-	-	+
Group 3	-	-	0	++	-
Group 4	--	++	-	++	-
Group 5	+	-	+	--	+
Group 6	+	++	-	--	-
Group 7	-	-	++	-	-
Group 8	++	0	+	-	-
Group 9	++	-	-	+	-

-	-1SD < *X* < 0
--	*X* < -1SD
+	0 < *X* < 1SD
++	*X* > 1SD

Source: Prepared by the author, on the basis of the Maddison Project Database.
Note: *X* represents the difference in the volatility of each cycle component relative to the average, by group, using the same data as in figure 2. ++ = greater by more than 1 standard deviation; + = greater by up to 1 standard deviation; -- = smaller by more than 1 standard deviation; (-) = smaller by up to 1 standard deviation.

Table 4 shows which countries are grouped in each of the clusters identified by the *k*-means methodology. Some regional features can be observed in this table. All developed countries are in groups 1 and 2. These first two groups also contain many low- and middle-income countries in Africa and Asia such as Bahrain, Bangladesh, Benin, Burkina Faso, India and Lao People's Democratic Republic. Most central Asian countries are in groups 8 and 9. Latin American and Caribbean countries fall between groups 2 and 7, with most in group 3.

What is measured is growth volatility, so a catch-up process immediately after the Second World War followed by a long period of stagnation, as in Japan, is measured in a specific way (heteroskedasticity). On the other hand, countries in a state of profound stagnation are not volatile, and this is the case with some of the developing countries in groups 1 and 2.

In Table 4, Latin American and Caribbean countries are highlighted in grey. It can be seen that half are in group 3 (11 countries out of 23), although the continent is represented in every group except the two most volatile (8 and 9). Puerto Rico follows a pattern similar to that of the developed countries. Colombia, Honduras and Mexico also have a volatility pattern close to that of group 2 developed countries. Chile and Uruguay differ from most Latin American and Caribbean countries, not in overall volatility, but in the very large role played in this by the very short- and short-run cycles. Cuba, Nicaragua and Peru are in group 4, Ecuador is in group 5 and the Bolivarian Republic of Venezuela and Trinidad and Tobago are in a more volatile group (7). In general, however, the Latin American and Caribbean countries fall into two main groups, those where the short-run (Juglar) cycle is more dominant (groups 2, 4 and 6) and the majority where the long-run (Kondratiev) cycle is more dominant (groups 3 and 4). These two groups will be termed Juglar-dominated and Kondratiev-dominated, respectively.

We expect countries in group 1, the least volatile group, to be most advantageously placed, followed by those in group 2. Groups 8 and 9 contain the countries that suffer most from volatility. From groups 3 to 7, however, no value judgement can be made about which countries are best placed. These groups simply identify countries whose situations differ in many respects, such as their integration into the international economy, institutions and economic structures, among other possible explanations.

Table 4
Cluster analysis applied to the standard deviations of the Juglar, Kuznets and Kondratiev cycles

Group 1		Group 2	Group 3		Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Australia	Lao People's Democratic Republic	Burkina Faso	Algeria	Mongolia	Afghanistan	Burundi	Central African Republic	Cameroon	Cambodia	Angola
Austria	Morocco	Colombia	Argentina	Myanmar	Albania	Ecuador	Chile	Comoros	Chad	Equatorial Guinea
Belgium	Nepal	Finland	Bolivia (Plurinational State of)	Namibia	Cuba	Egypt	China	Cyprus	Democratic People's Republic of Korea	Iraq
Benin	Netherlands	Guinea-Bissau	Brazil	Panama	Djibouti	Hong Kong (China)	Democratic Republic of the Congo	Jordan	Gabon	Kuwait
Bangladesh	Norway	Honduras	Botswana	Paraguay	Eswatini	India	Lesotho	Republic of the Congo	Iran	Libya
Bahrain	Pakistan	Ireland	Bulgaria	Philippines	Ethiopia	Liberia	Mauritius	Sudan	Lebanon	Oman
Canada	Puerto Rico	Japan	Costa Rica	Sao Tome and Principe	Mozambique	Malawi	Niger	Trinidad and Tobago	Nigeria	Qatar
Germany	Senegal	Kenya	Côte d'Ivoire	Slovenia	Nicaragua	Malaysia	Seychelles	Venezuela (Bolivarian Republic of)	Rwanda	
Denmark	South Africa	Madagascar	Dominican Republic	Uganda	Peru	Republic of Korea	Thailand	Yemen	Sierra Leone	
France	Sri Lanka	Mali	Gambia	United Republic of Tanzania	Poland	Singapore	Uruguay		Somalia	
Guinea	Sweden	Mexico	Ghana	Zambia	Romania	Türkiye	Zimbabwe		Syrian Arab Republic	
Indonesia	United Kingdom	New Zealand	Greece		Saudi Arabia				United Arab Emirates	
Italy	United States	Portugal	Guatemala		Togo					
		Spain	Haiti							
		Switzerland	Hungary							
		Taiwan Province of China	Israel							
		Tunisia	Jamaica							
		Viet Nam	Mauritania							

Source: Prepared by the author, on the basis of the Maddison Project Database.
Note: Latin American and Caribbean countries are highlighted.

Results for the behaviour of economic cycles in Latin America and the Caribbean include the following (see table 5):

- Half the Latin American and Caribbean countries are in group 3, which is characterized by a middling standard deviation (neither small nor large compared to the world average). In group 3 (and 4), the long-run (Kondratiev) cycle is relatively dominant despite the long-run trend being relatively unimportant.
- Latin American and Caribbean countries are not altogether homogeneous as a group in their volatility patterns. This poses a challenge when it comes to generalizing results to the whole continent. Thus, anyone seeking a general theory for the causes of overall volatility in the Latin American and Caribbean countries must take these specificities into account and discuss the reasons for them. It is worth highlighting again that most Latin American and Caribbean countries are in one group (3).
- On one hand, the volatility pattern in the Latin American and Caribbean countries differs clearly from that observed in developed countries. On the other, it resembles that in some other developing regions, especially central Asia and parts of sub-Saharan Africa.
- Considering only the large countries in the region, Colombia and Mexico have a different pattern from Argentina and Brazil, while Chile is different again.

Table 5
Countries of Latin America and the Caribbean: cycle dominance

Juglar-dominated	Kondratiev-dominated		Juglar- and Kondratiev-dominated	Other
Chile	Argentina	Haiti	Cuba	Ecuador
Colombia	Bolivia (Plurinational State of)	Jamaica	Nicaragua	Puerto Rico
Honduras	Brazil	Panama	Peru	Trinidad and Tobago
Mexico	Costa Rica	Paraguay		Venezuela (Bolivarian Republic of)
Uruguay	Dominican Republic			
	Guatemala			

Source: Prepared by the author, on the basis of the Maddison Project Database.

It is important to discuss the meaning of Kondratiev dominance. What does it mean when the long-run cycle contributes so much to growth volatility compared to the others?

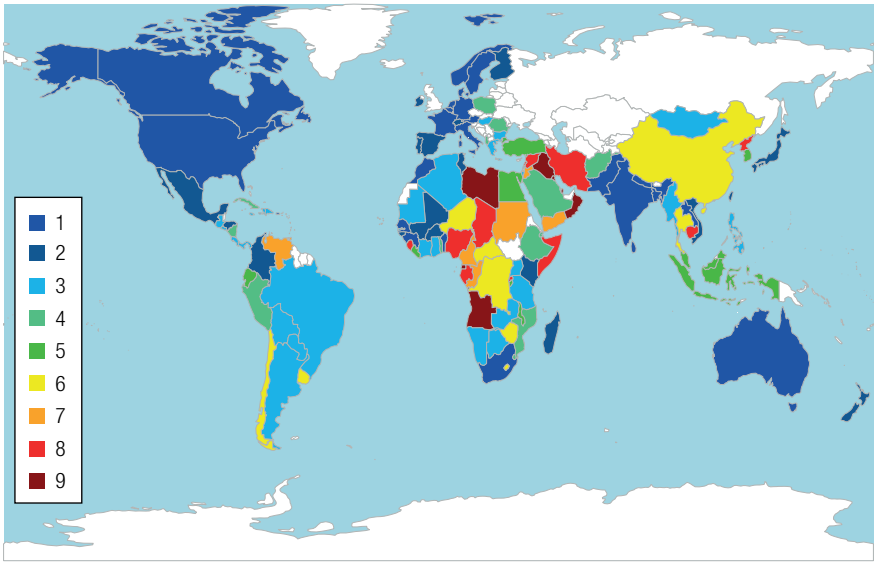
Before the relationship between volatility and development is investigated, which is the goal of the research agenda this paper is associated with, it is useful to observe the aspects producing similar patterns at the world level. This can be done for groups of countries with many different volatility patterns. The cluster analysis yields the following results (see map 1 and map 2):

- Developed countries are the least volatile, as all of them are in groups 1 and 2. Oil-rich countries are the most volatile, being situated in groups 8 and 9.
- In addition to the more developed countries, there are many low- and middle-income countries in groups 1 and 2. This needs to be investigated further, as their low volatility may not be related to their structural conditions.
- Developing countries with similar overall volatility are found to have very different patterns when the sources of this volatility are examined. For some countries, volatility comes from shorter-run cycles, while for others it comes from longer-run cycles and the trend.

Map 1
Latin America and the Caribbean: volatility levels by cluster group

Source: Prepared by the author, on the basis of the Maddison Project Database.
Note: 1 indicates the lowest level of volatility and 9 the highest.

Map 2
World: volatility levels by cluster



Source: Prepared by the author, on the basis of the Maddison Project Database.
Note: 1 indicates the lowest level of volatility and 9 the highest.

1. Kondratiev dominance: the importance of the long-run cycle

The evidence in this research shows that most Latin American and Caribbean countries are in a situation where the Kondratiev long-run cycle is more dominant than in the other groups identified in the previous section. As already mentioned, Kondratiev long-run growth may be associated with technological changes in international trade patterns (Perez, 2010).

Latin America and the Caribbean depends heavily on commodity exports. A possible explanation for the dominance of the long-run cycle is that changes in the technological paradigm result in long-run volatility in commodity prices. This may be caused by a reduction in dependence on the inputs used in the previous industrial paradigm, with effects on the exchange rate. The emergence of a new paradigm requires new inputs, leading Latin American and Caribbean economies to adjust to the cycle and change the products they specialize in if they can. In Brazil, for example, there have historically been different commodity cycles: the rubber cycle, the sugar cane cycle, the gold cycle and the oil cycle. Each cycle was directly related to the industrial paradigm of the period.

The input volatility explanation has resonated strongly with the idea of dependence and world systems (Brady, Kaya and Gereffi, 2011). Schwartzman (1995) and Bollen and Appold (1993) pioneered the idea that trade dependence hurt diversification. This can be related to the concept of the natural resource curse (Collier, 2007), also mentioned by the new developmentalist school (Bresser-Pereira, 2008 and 2013). As Brady, Kaya and Gereffi (2011) suggest: "In an argument anticipated by Bunker (1985), the dependence on raw material exports fails to produce economic linkages into manufacturing, leads to cycles that hinder diversification, forcing government subsidization of distant outposts of extraction disconnected from urban populations and economic centres" (p. 188).

The pattern of increasing specialization worsens structural fragility, as it creates a strong dependency, in terms of external sector dynamics, on the price of a few commodities. When the demand for those commodities declines for some reason, such as a reduction in world demand caused by changes in production patterns, there is a large decline in their price, with a direct impact on the domestic economy of the exporting country. This is amplified even further by financial dynamics reacting procyclically to the economic crisis (De Paula, Fritz and Prates, 2020). This problem of external constraints has received a great deal of attention as regards short- and medium-run dynamics. However, we want to argue that there is also a long-run dynamic associated with this behaviour (Marañon and Kumral, 2019), as waves of industrial and technological development at the world level change input requirements, with a very strong historical effect on developing economies. This provides another factor in the explanation of long-run dynamics, one that is empirically and historically discussed by Bertola and Ocampo (2012).

Most developing countries, those of Latin America and the Caribbean included, are highly dependent on commodity production and exports. The region, though, seems to be integrated into the world economy in a special way. If we observe cycle synchronization (from the data used in this research), we see that Latin America and the Caribbean is actually closely coordinated with the international pattern. This coordination is not as strong in Africa and Asia. The economic space of Latin America and the Caribbean seems to be strongly linked to that of the developed countries, especially with regard to long-run changes. Short-run volatility is not as great as expected, but there is an element of dependency that generates high volatility in the long run.

Peripheral (but strong) integration is the key to the specificity of Latin America and the Caribbean, which has a low capacity for absorbing and generating technology and a structure that favours specialization in low-technology sectors. Lastly, economic history (Ffrench-Davis and Griffith-Jones, 1995) suggests that the debt crisis of the 1980s, changes in the openness of the capital account in the 1990s and the rise of China in the 2000s (Stiglitz and others, 2006) had a very strong impact on the volatility of growth

and exports in Latin America and the Caribbean that almost immediately affected short-run volatility and the medium-run pattern. For the long run, longer-term data are still needed to see the impacts of these changes on Kondratiev waves. However, we can argue that changes with the new industrial paradigm (Industry 4.0 and the green revolution) and the reallocation of production to new areas constitute a tipping point that will lead to the emergence of a new production system, with new input requirements. Erten and Ocampo (2013) identified these changes by analysing the long-run commodity cycle with an empirical strategy much like the one applied in this paper, finding that commodity prices were close to a tipping point in their long-run dynamics. Some major commodity prices have declined since 2014 (before the COVID pandemic), perhaps indicating the ebbing of the last wave and the beginning of a new one, with major implications for Latin America and the Caribbean.

2. Juglar dominance: the importance of the short-run cycle

We argue, on the basis of Korotayev and Tsirel (2010), that the Juglar cycle is related in the literature to investment cycles. High volatility in this cycle is associated with the fact that investment is carried out in blocks, tying up a great deal of capital. The uncertainty intrinsic to economic systems is greater in developing countries and results in investments being carried out during periods when economic conditions are positive, commonly the upturn of commodity cycles. These cycles start to mature, and economic conditions in the system change. There is a period of falling investment that coincides with a worsening of the economic environment, which increases uncertainty and raises the (opportunity) cost of new investments. This drop in investment leads to a downswing in the cycle.

This cyclical component is then associated with commodity cycles in developing countries. The dependence of the production structure on imports and exports of a few low-technology commodities is a major source of uncertainty. The balance-of-payments-constrained model (Thirlwall, 2012) states that investment in these economies tends to be endogenous to the situation in the external sector, which is also related to structural economic conditions (Cimoli, Porcile and Rovira, 2010). The destabilizing effects of export and import prices, together with the price and income elasticity of traded goods imports and exports, result in the oscillation captured by the Juglar cycle.

This is seen in countries such as Chile, Colombia and Mexico, where mining activities have traditionally been the main economic activity in respect of exports. Investments are responsive to changes in the prices of the mining products these countries export, being made when prices are sustained at a high level for a certain period of time (Bertola and Ocampo, 2012).

VII. Conclusions

Macroeconomic volatility is a thermometer that measures resilience when countries experience economic, political and institutional shocks. This paper set out to empirically study volatility at the country level. Its specificity lies in its effort to identify different types of regularities in GDP growth time series. Filter analysis was used to extract these regularities from the original series and identify different components (cycles). A cluster analysis applied to the cycle components allowed countries with similar volatility patterns to be identified.

The above procedure made it possible to constitute country groups that provided a basis for answering the question posed at the outset of this study: do the Latin American and Caribbean economies differ in their volatility patterns from developed countries and other developing regions? The answer to this question is not simple and needs to take account of the following.

Latin America and the Caribbean is generally characterized by a middling GDP growth standard deviation (relative to the entirety of the 136 countries examined in the analysis). The long-run cycle plays a particularly important role in half its countries, even though the long-run trend (and the short-run cycle) are relatively unimportant. Latin American and Caribbean countries are not homogeneous in their volatility patterns, although they do have a common characteristic, namely the relative importance of the short-run Juglar cycle. Their differences make it difficult to generalize results to the whole continent. Thus, any general theory for the causes of overall volatility in the Latin American and Caribbean countries must take these specificities into account and consider the reasons for them.

Latin America and the Caribbean depends heavily on commodity exports. Changes in the technological paradigm result in long-run volatility in commodity prices. This may be caused by a reduction in dependence on the inputs used in the previous industrial paradigm, which affects the exchange rate (Guzman, Ocampo and Stiglitz, 2017). The emergence of a new paradigm requires new inputs, which would lead Latin American and Caribbean economies to adjust to the cycle and change the products they specialize in if they can, generating large, long-run Kondratiev cycle oscillations.

High volatility in the Juglar short-run type of cycle is related to the fact that investment is carried out in blocks. The uncertainty intrinsic to economic systems is greater in developing countries and results in investments being carried out during periods when economic conditions are positive, commonly during commodity cycle upturns. These cycles start to mature, and economic conditions in the system change. There is a period in which no new investments are made, coinciding with a worsening of the economic environment that increases uncertainty and raises the costs of new investment.

On one hand, volatility patterns in Latin America and the Caribbean clearly differ from the pattern observed in developed countries. On the other, the region's pattern is similar to that of many other developing regions, especially central Asia and parts of sub-Saharan Africa. We see some evidence that Latin America and the Caribbean behaves differently from developed countries, but no evidence to further differentiate it from other developing regions.

In summary, the evidence from the Maddison data shows that countries in Latin America and the Caribbean are more volatile on average than developed countries. However, countries in the region cannot necessarily be said to be more volatile than other developing countries. This is a common misconception in the structuralist literature, mainly because it tends to compare Latin America and the Caribbean with developed countries and not with other developing regions, which leads to sometimes misleading strong statements of this kind. At the same time, Latin America and the Caribbean is a continent with a common idiosyncratic cyclical pattern of its own that the filtering methodology brings to light, at least where most of its countries are concerned.

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