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Kuznets *versus* Kitchin, Juglar & Kondratieff

Renewed Spectral Analysis of Comparative Growth of Per Capita GDP series in the OECD Countries in the Nineteenth and Twentieth Centuries

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Abstract. Spectral analysis is a particularly valuable method for seeking dependences expressed as lags between different magnitudes. Its use in this article was first determined by the search for maximum objectivity in the observation of time series. The possibility of applying it to a large number of series was then examined. This twin requirement resulted from a desire to avoid the criticism generally levelled at statistical studies concerning cyclical movements of the economy. Spectral analysis is based on the theory of stochastic processes. It starts with the core hypothesis that a given time series consists of a large number of sinusoidal components with different frequencies (univariate spectral analysis). It makes it possible to divide a particular category of records into a set of oscillations of different frequencies and then to show the links between the components with the same frequency in the various series examined (cross-spectral or bivariate spectral analysis). It has had limited applications in cliometrics to date. It is used here to determine the frequency of GDP series of several OECD countries. A reminder of the method (I) is followed by successive examination of the various series chosen, the treatment of these series and the results of spectral analysis (II). It is then possible as a conclusion to show the prospects of this type of approach and to synthesise a completely new major result for understanding economic dynamics in the nineteenth and twentieth centuries, that is to say the existence of a single intermediate cycle with 15 to 20-year frequency that calls into question or even partially contradicts previous work on economic cycles.

Introduction

Spectral analysis is a particularly valuable method for seeking dependences expressed as lags between different magnitudes. Its use in this article was first determined by the search for maximum objectivity in the observation of time series. The possibility of applying it to a large number of series was then examined. This twin requirement resulted from a desire to avoid the criticism generally levelled at statistical studies concerning cyclical movements of the economy. Spectral analysis is based on the theory of stochastic processes. It starts with the core hypothesis that a given time series consists of a large number of sinusoidal components with different frequencies (univariate spectral analysis). It makes it possible to divide a particular category of records into a set of oscillations of different frequencies and then to show the links between the components with the same frequency in the various

series examined (cross-spectral or bivariate spectral analysis). It has had limited applications in cliometrics to date[1]. It is used here to determine the frequency of GDP series of several OECD countries. A reminder of the method (I) is followed by successive examination of the various series chosen, the treatment of these series and the results of spectral analysis (II). It is then possible as a conclusion to show the prospects of this type of approach and to synthesise a completely new major result for understanding economic dynamics in the nineteenth and twentieth centuries, that is to say the existence of a single intermediate cycle with 15 to 20-year frequency that calls into question or even partially contradicts previous work on economic cycles.

1. Methodology

Spectral analysis, which is applied essentially to determinable[2] stationary[3] series, makes it possible to divide a particular categories of long-term data sets into a set of oscillations with different periods (breaking down any time series into a sum of periodic functions) and then to show the links between the components with the same frequency in the various data sets examined (Priestley [5]). Each of these stages has obvious cliometric interest. The first, by showing all the frequency components of a data set and by isolating—if it exists—the most important frequency component (and its harmonics) reveals the cyclical behaviour of a time series and shows the frequency and amplitude characteristics of this cyclical movement. The second stage makes it possible to compare the periodic movements of two series and to establish a correlation between them. The latter stage therefore seems particularly suited to the aim of this article.

1.1 Estimation of Spectra

The amplitudes of the different oscillations (from the breakdown of stationary series) are random variables that can be defined by the scale of the values that they might have. A variance corresponds to each given period oscillation and this defines what is called the spectrum of the process envisaged. The differences between the various sinusoids are insignificant.

More precisely, the spectrum of a stochastic process $[X_t]$ is the function $f(\omega)$ defining to within a multiplicative constant the expected value of the square of the amplitude of frequency ω in the Fourier decomposition of the relations of the process. The spectrum thus describes the importance of the various frequencies in the process in question.

The calculations are as follows. For stationary processes, a bias-free estimator can be calculated from a single realisation of the process, that is to say from a particular time series X_t in which (t = 1, 2, …, T). This estimator is the periodogram and can be defined as:

$$I(\omega) = \frac{1}{2\pi} \sum_{\theta=-T+1}^{T-1} \upsilon_\theta \cos \omega\theta$$

υ_θ being approximately the empirical autocovariance, and more precisely with $\bar{x}$ the empirical mean of the series:

$$\upsilon_\theta = \frac{1}{T} \sum_{t=1}^{T-\theta} (x_t - \bar{x})(x_{t+\theta} - \bar{x})$$

Although it has no bias, the periodogram is not a good estimator of the spectrum because it is not convergent. This is why the erratic function $I(\omega)$ is replaced by a more regular function representing the mean trend of variations of $I(\omega)$ with ω. This is referred to as the smoothing of the periodogram.

The smoothed function is then:

$$f'(\omega) = \frac{1}{2\pi} \sum_{\theta=-m}^{m} \left(1 + \cos\frac{\theta\pi}{m}\right) \upsilon_\theta \cos\omega\theta$$

This formula is Tuckey–Hanning's estimation function (or spectral window). There are other estimation formulas, especially Parzen's, that causes less leakage in non-adjacent frequency bands but leads to higher correlation between the successive estimated values of the spectrum.

Finally, to improve spectrum estimation, the X_t series is generally filtered beforehand by subjecting it to a transformation in such a way that it is possible a priori to consider that the spectrum of the filtered series is more representative. In many of these practices, filtering thus eliminates the trend of the series in such a way that the hypothesis of the stationarity of the generating process seems less coarsely imprecise (especially for economic data series). The filter chosen here is that proposed by Hodrick and Prescott [6], for several reasons. Firstly, it is easy to apply. Secondly, abundant literature shows that its statistical properties are satisfactory. Finally, it is commonly used in the literature and in the empirical analyses performed by national bodies and international organisations (Bouthevillain [7]).

1.2 Estimation of Cross-Spectra

Cross-spectra examine the existing relations between the spectral components taken in pairs for two given time series. Generalising the case to a single variable, (X_t, Y_t) are stationary if their first and second moments are both independent of time. In this case, one of the results of the theory of stationary processes is that the component centred at ω_j is independent not only of the other components of the variable, but also of the components of any other variable whether or not it is centred on ω_j. A full description of the system of relation between two stationary processes just requires knowledge of the extent to which the frequency component ω of the process [X_t] is correlated with the frequency component ω of the process [Y_t] and knowledge of their phase difference.

This correlation between two frequency components in two processes is given by:

$$C^2(\omega) = \frac{c^2(\omega) + q^2(\omega)}{f_x(\omega) f_y(\omega)}$$

$0 \leq C^2(\omega) \leq 1$, $c(\omega)$ is called the cospectrum and $q(\omega)$ is the quadrature. $C^2(\omega)$ is the square of coherence at ω (equal to the square of the coefficient of correlation). The measurement of the phase difference between the frequency components of the two processes is given by:

$$\Phi^{(\omega)} = \arctan\left(\frac{q(\omega)}{c(\omega)}\right)$$

It can therefore be said that the amplitude cross-spectrum of two processes [X_t] and [Y_t] defines the expected values of the product of the amplitudes with which each frequency ω affects [X_t] and [Y_t] and that the phase cross-spectrum defines the expected phase difference with which each frequency is involved in the two processes.

Spectral analysis, whose theoretical basis has thus been described briefly, is a logical extension of our work on outliers and that on long memory time series[4]. It is a particularly suitable mathematical tool for the development of our research programme and should give good results on condition that the statistical data series used are suitable for it. These series are now examined.

2. Cliometric Results

The aim of our research is the comparison of the behaviour of the per capita GDP (log transformed) in 15 OECD countries, with on the one hand a study of the national cyclical features of the 15 OECD countries and on the other a search for common factors in these cycles. For this we use the now well-known database drawn up by Maddison [8], expressed in 1990 US dollars for the period 1870-1994, and extended (until 2000) by EUROSTAT indicators.

2.1 Analysis of Spectra

The characteristics of the national cycles are first analysed individually. The aim is to find out whether all the countries display the same propensity for cyclical fluctuations and the same regularity in these fluctuations. It must be possible to determine whether a country typology can be shown according to the cyclical properties as the impetus and propagation of fluctuations at the international scale can only be fully understood if this national heterogeneity is taken into account (Fayolle and Micolet [11]).

Graphic analysis of the fluctuations establishes in a general manner that the different countries are characterised by relative cyclical regularity but that the features of this cyclicity are unevenly distributed at the international level. However, these results should viewed in relative terms and subjected to spectral analysis as the cycle typology shows that duration and amplitude characteristics vary from one cycle to another and above all that cycles are similar to sets of Russian dolls and their influences can strengthen or oppose each other depending on whether the swings coincide or not or are in phase or not. Whence the advantage of spectral analysis for separating and analysing the different cycles integrated by per capita GDP and then putting forward a more perspicacious country typology in the relations of impetus and propagation of fluctuations at the international scale.

Application of the spectral density methodology described above showed an interaction between two types of cycle in each of the 15 countries analysed. Indeed, the spectral density functions (Figure 1) show that the cyclical movement can be decomposed into two distinct cyclical components. One is short and of the Kitchin type with a frequency of 3-5 years (Kitchin [12]) and relatively moderate amplitude and the other an intermediate phenomenon between the Juglar business cycle (Juglar [13]) and a long Kondratieff type of cycle (Kondratieff [14]). The latter, a Kuznets type cycle (Kuznets [15]) with a frequency of 15-20 years and comparatively large amplitude, underlies GDP conjuncture. *More widely accepted in recent years is the 15- to 25-year swing in economic growth rates uncovered by Nobel laureate S. Kuznets. The cycle is more evident in the United States than elsewhere. M. Abramovitz recognises the Kuznets cycle as associated with population growth and immigration. Most economists hold that this cycle was material only for the period from 1840 to 1914* (Diebolt [16], see also Abramovitz [17], Goldstein [18], Schumpeter [19] and Solomou [20]). It should be noted that although the swing of short cycle is smaller than that of the intermediate cycle, it nevertheless has sufficient amplitude and volatility to inflect the overall movement of the cycle that may account for the differences observed in the graphic analyses at cycle aggregate level and thus invalidate the statistical characteristics generally used in the analysis of cycles. This justifies the use of spectral analysis and hence the analysis of cyclical international relations between fluctuations in the same categories.

With this double cyclical movement of per capita GDP combining short oscillations and slow intermediate movements, we consider that national economic fluctuations are first of all governed by storage behaviour. Here, the minor cycles reflect essentially storage and

release phenomena by businesses and above all large investments involving large amounts of capital such as those for the construction industry or for transport and seen as a response to population factors as Kuznets type intermediate cycles basically govern conjuncture. The economic situation is therefore governed essentially by a 15-20-year frequency and not by short cycles of the Kitchin or Juglar type or by long movements of the Kondratieff type. We consider that the driving force underlying this frequency can be compared to the mechanisms proposed by Kuznets, that is to say an economic reaction to demographic mechanisms, for example via the movement of large investments or the labour market. Indeed, the links between the functioning of the labour market and demographic movements may be an explanation, in particular through three essential mechanisms linked to demographic factors. These are first of all a cycle linking work and employment (the productivity cycle), then an effect linking unemployment and wages (the Phillips effect) and finally a link between demand and income (the consumption function). These three mechanisms also play greater or lesser roles according to the period and the country; they can increase or reduce the cycles and hence account for the international disparities observed.

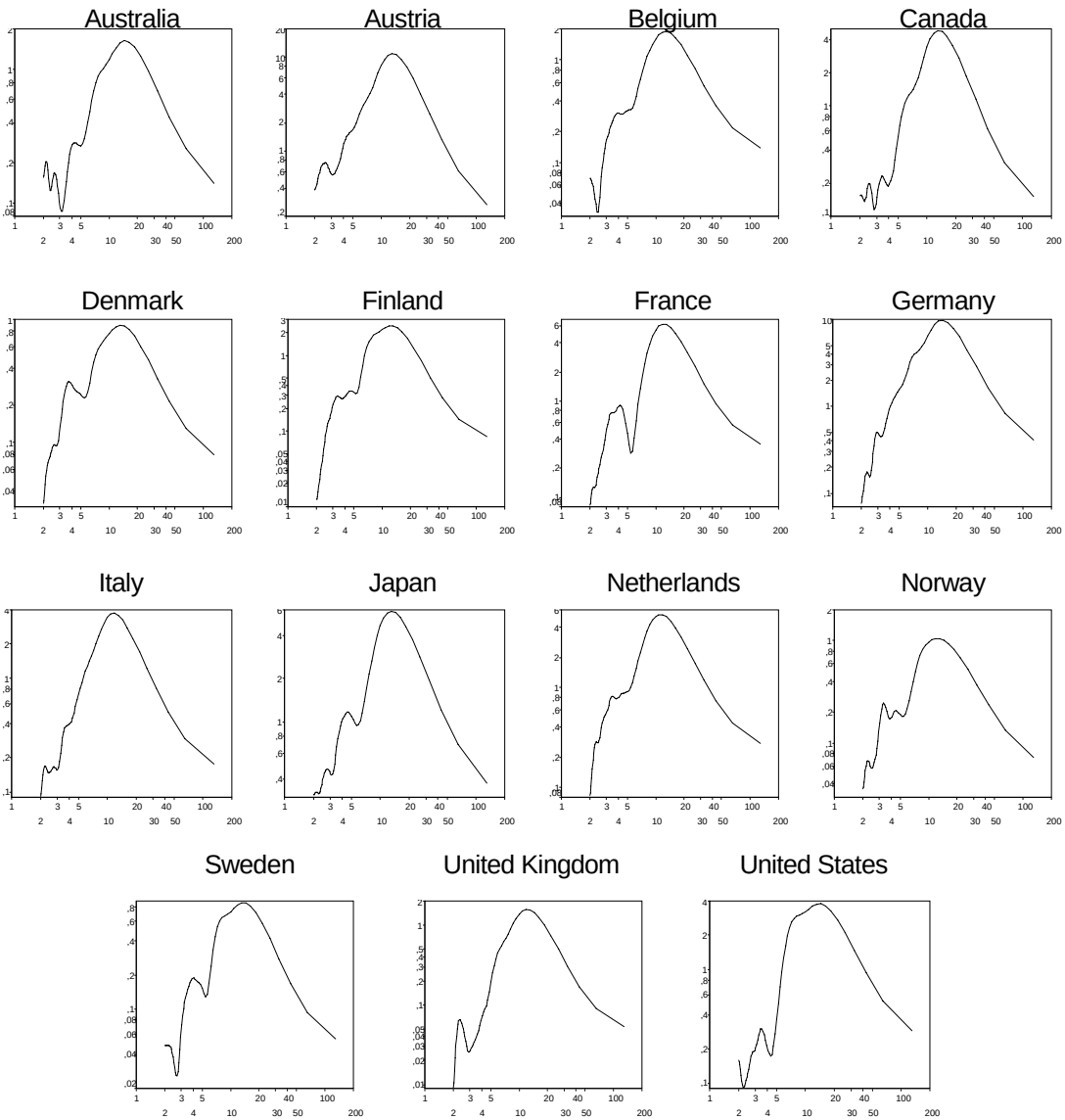

Figure 1. Spectral Density of Per Capita GDP

This preliminary study of the characteristics of national cycles that shows agreement between the cycle characterising the different countries is followed by a study of the impetus and propagation relations at the international scale through cross-spectral analysis.

2.2 Analysis of Cross-Spectra

The search for international relations between the main economic cycles is the other fundamental component of this analysis. We therefore incorporate the cycle approach in addressing the entire international economy through the multivariate spectral approach (i.e. cross-spectral analysis). This makes it possible to examine the similarities and synchronisation of the different national cycles. Here, we first analyse the coherence[5] between the different cycles using coherence of 0.7 or more as the criterion of significance. This is followed by study of the phases[6] of the cyclical processes whose coherence is significant. The results of the two methods can be represented schematically to make it easier to examine and interpret the results.

Coherence is represented by lines (dotted, unbroken or double unbroken) indicating their degree of importance (0.7, 0.8 and 0.9 respectively), while the phases are shown by the direction of the coherence relation with the beginning of an arrow showing the process that is ahead with regard to the process at its extremity (a double arrow means that there is no lag between the processes—they are synchronous). Thus, it is seen in a general manner that the impetus and forces governing national intermediate cycles are not independent between countries and there is thus strong interconnection between national cyclicity. This can be shown in more detail by a grouping in three geographic zones and linked to notions of similar, common cycles[7].

Using this (Figure 2), a first parallel can be made between the English-speaking countries (United States, Canada and the United Kingdom) that are linked in a joint cycle through their common historical, political and geographic context. A second, much wider parallel can be set between the European countries in the broad sense (the countries of continental Europe and Scandinavia) where the characteristic of the cycle is that it is largely similar in all the countries of this zone and sometimes common with certain neighbouring countries (e.g. Belgium and the Netherlands and Germany and Austria), explained in particular by a flexibility of the labour market and geographic mobility of labour are made easier by geographical proximity. However, the cycle in the United Kingdom displays greater similarity with that of the United States and Canada than with the European countries. Finally, Japan seems to form a zone all by itself with a cycle similar to that of all the European countries but more advanced.

In a general manner, a regime of growth and international fluctuations is defined by a combination of properties characterising the international area. The cyclicity of the economy at the international level is not independent of the hinging and compatibility of growth trends which, as has been seen above, indicates a phenomenon of catching up over a long period. This catching up is only possible through the efficiency and profitability of productive resources, whence conditioning with regard to constraints of external equilibrium and the cyclical interdependence found in all the countries studied (Fayolle and Micolet [11]).

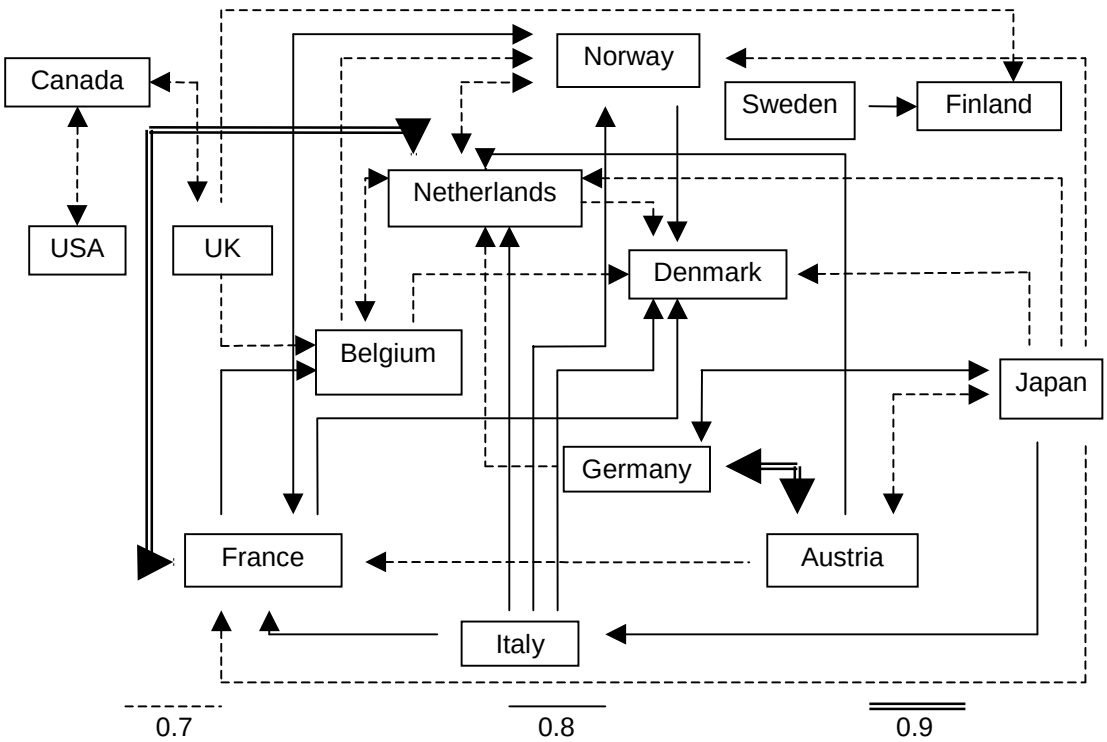

Figure 2. Relation between Intermediate Cycles of the Kuznets Type

Conclusion

This analysis of national fluctuations and cyclical interconnections makes it possible to enrich our understanding of the cyclical mechanisms between nations. It gives a major, entirely new result for the understanding of economic dynamics in the nineteenth and twentieth centuries, that is to say the existence of a single intermediate cycle with a frequency of 15 to 20 years that calls into question or even contradicts (at least partially) previous work on economic cycles. This understanding of cyclical mechanisms is all the more essential today as it will make it possible to put forward more concerted and more cooperative economic policies aimed at parallel development of activities. Indeed, although growth cycles leave real but comparatively small room for manœuvre for intervention by the authorities on the determinants of growth, macroeconomic policies can nevertheless slow, shift, accelerate or dampen cyclical phenomena, whence the advantages of better understanding national cyclical features and their interaction at the international level.

Endnotes

[1]Interested readers should see, in particular, Ewijk [1], Gerster [2], Reijnders [3] and Metz [4].

[2]An important theorem developed by Cramer ensures that stationary series can be broken down into a set of separate sinusoidal oscillations whose characteristics, amplitudes and relative differences are random. There will generally be a very large number or even an infinity of such oscillations, each of which is very small and the process is then said to be indeterminable. This contrasts with determinable processes consisting of a finite number of sinusoidal oscillations, each of which will have a finite non null amplitude.

[3]A very important class of series is that given by processes whose first moments are not functions of time. Such series are referred to as being stationary of the second order.

[4]See especially Darné and Diebolt [9] and Diebolt and Guiraud [10].

[5]Coherence makes it possible to measure the degree of linear correlation between components of the same frequency in two processes. The closer it is to 1 for a given frequency, the more the two processes move in a similar manner for this frequency or periodicity.

[6]The phase makes it possible to measure the time shift of a process in relation to another. A positive phase shows that the second series is ahead of the first and the opposite if it is negative. Interpretation of the phase is then strongly linked with coherence as the analysis of a lag between two processes is only meaningful if the processes are related, that is to say if their coherence is high.
[7]Indeed, a distinction should be drawn between a similar cycle and a common cycle. A cycle is referred to as being similar when the cyclical component that drives the movement of each series is founded on the same propagation mechanism but engendered by a specific impulse series so that the cyclical components can be markedly different and desynchronised. This similar cycle can be called common when the impulse series applied to it are perfectly correlated, that is to say the cyclical components are perfectly synchronised and differ only in their amplitude (Bentoglio, Fayolle and Lemoine [21]).

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