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INVESTIGATING THE LONG CYCLES OF CAPITALISM WITH SPECTRAL AND CROSS-SPECTRAL ANALYSIS

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Abstract
The persistent current phase of negative growth has already triggered the awakening of long wave theories. Although long waves are obvious, even with a simple visual observation of the history of the data, doubts as to their existence are expressed by a variety of different theoretical and empirical approaches. However, the increasing number of statistical methods for long wave examination illustrates very clearly that their confirmation, as well as their periodization, depends both on theoretical fixations and / or the use of different empirical methodologies. The present paper uses Spectral Analysis in order to investigate the importance of the long lasting cycles in the periodicity of European Countries' economic evolution. The correlation and timing differences among them are identified with the help of Cross-Spectral analysis.

JEL: C22, E32
Key words: Business Cycles, Long Waves, Spectral analysis, Cross-Spectral Analysis.

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1. Introduction

The financial crisis of 2008 led to one of the longest and most persistent post-war recessions in global economic activity. Similarly to corresponding periods in economic history, it has already generated vigorous debates. Neoclassical growth theory considers this crisis as the stochastic downturn of a common business cycle. On the other hand, the persistent current phase of negative growth triggers the awakening of theories that belong to a different area of economic literature. Traditionally, the theories of long waves come to the fore with the occurrence of persistent long-lasting economic recessions. The long wave tradition asserts that deep recessions, such as the present one or similarly the ones that occurred in the 1930's and 1970's, are the result of an amplified long-lasting downturn, recurring every 40-60 years over the history of capitalism's development.

The initial empirical evidence for long-lasting cyclical economic development leads us back to the first contributions at the end of the 19th century by Jevons (1884), Parvus (1901), Van Gelderen (1913), De Wolff (1924) and the following, statistically more advanced, analysis of Kondratieff (1928).[1] Apart from the familiar business cycles, they emphasized the continuing long waves lasting approximately half a century. Since that time, interesting questions have been raised, concentrating mostly upon the true existence of such economic movements and their theoretical explanation.

The literature on theoretical justification of long waves is quite extensive. Contributions can be divided into three different schools: Marxists (Mandel 1975, 1980, 1981) interpret long waves by the falling course of the rate of profit, which is indisputably a driving force of the system. At the same time, they incorporate various exogenous factors – wars, geographical / sectoral market expansion and technological progress – which avert the systemic downturn and move the economy back to a new phase of expansion.

Close to the Marxian approach, the Social Structure of Accumulation (SSA) School provides an additional argument, offering a framework of continual cyclical movements: the social institutional arrangements such as labour relations, the banking system, the political environment etc., when propitious for the continuity of

1. Although the literature uses the term "Kondratieff cycles", there are many authors who believe that the credit should be given to earlier works: "*It would, in fact be more appropriate to speak about van Gelderen – De Wolff long waves*" (Kleinknecht, A, 1992, p1).

capital accumulation, assist the transition to the next upswing (Gordon 1980, 1991; Gordon *et al*. 1994; Gordon, Weisskopf & Bowles 1983).

In contrast to the above, the Schumpeterian/Innovation School focuses on a similar cyclical movement of technological progress. Based on appropriate micro-oriented arguments like entrepreneurial motivations for adapting new ideas, theorists consider the fluctuations of economic activity as the result of innovation clusters (Kleinknecht 1986, 1987; Mensch 1975; Schumpeter 1939).[2]

Despite the different significance attached to the parameter of technological progress, its influence on an economy's long term evolution is undoubtedly accepted. Long fluctuations of economic activity were empirically and chronologically closely related to the occurrence of great technological revolutions. More specifically, the first long wave appears at the end of the 18th century with the beginning of the Industrial Revolution. The second started in the mid- 19th century and was related to the mechanically produced steam engines that became the driving mechanism of production process in many industries and transportation (mechanization, first technological revolution). The direct outcome was the geographical expansion of capitalism. The opening of new markets for the mass produced industrial products occurred within the expanding period of the next, third long wave, which lasted until the end of the Second World War. Nevertheless, this cycle was also related to another (third) technological revolution: electrification, that was accompanied by the expanded use of iron and heavy engineering. The fourth long wave starts after 1940 (in 1945 for Europe), relates to the revolution in natural sciences and is known as the era of atomic energy, oil, automobiles and steel technologies connected with highly structured technology research.

The end of the fourth long wave divides scholars' opinions. Some say that since the 1970's a fifth long wave has begun, associated with the revolution in electronics, telecommunications and informatics (Freeman & Louca 2001; Korotayev & Tsirel 2010; Perez 2010). Some believe that we are still in the longer-lasting downswing of

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2. In the course of time, various theoretical contributions combined the arguments of the mentioned schools, in order to avoid a mono-causal interpretation of long waves. Kleincknecht (1992) encourages this mixture; neo-Schumpeterians include also SSA-arguments in their discussion (Clark *et al*. 1981; Freeman 1982; Tylecote 1992; Perez 1983, 1985, 2002, 2004, 2010), while other theorist combine the scarcity of natural resources with the emergence of new technologies (Rostow 1975; Volland 1987). Also Van Duijn (1977, 1983) incorporates Schumpeter's theory of innovation and the dynamic system of Forrester (1976) and Sterman (1985, 1986) in his product life cycle approach.

the fourth long wave (Zarotiadis 2012; Wallerstein 1984), while others assume that we are now seeing the beginning of the sixth wave, associated with new developments in nano-bio technologies (Lynch 2004). Part of this disparity results not only from using different empirical techniques but also different theoretical arguments.

Truly, the existence of long waves is primarily an empirical exercise. There are both a number of empirical confirmations (Kleinknecht & Bieshaar 1983; Kleinknecht 1986; Korotayev & Tsirel 2010; Van Duijn 1977, 1983; Metz 1992; Reijnders 1992, 2009), as well as many contributions that question the existence of long waves (Garvy 1943; Van der Zwan 1980; Van Ewijk 1981, 1982; Solomou 1990, 1998). As Van Duijn (1983, p. 18) pointed out "*the longer a cycle, the harder it is to prove its existence*". Yet, the confirmation of a long-wave, as well as the exact periodization, depends both on theoretical fixations and/or the use of different empirical methodologies and data. This is what the present paper tries to do. Motivated by the current persistent crisis, it combines alternative methodologies in different countries in order to contribute to answering the following questions:

a. Do economies present cyclical movements that last longer than a common business cycle?
b. Could these movements be considered as periodical?
c. Are their movements related?
d. Is their development synchronised as an international economic phenomenon?

2. Answering questions with new methodology

Until the present the most widespread methodologies for detecting long cycles have been decomposition approaches, with spectral analysis more recently. In the decomposition approach (Kondratieff and Oparin 1928), time series are decomposed between trend and cycles (cyclical components) of different duration. These studies, although useful in revealing long wave patterns, are unable to estimate at the same time the significance of cyclical components of different duration. The recent techniques however, such as spectral analysis, allow for simultaneous estimation of the importance of cycles of different duration, thereby avoiding bias estimations over a specific size of cycle.

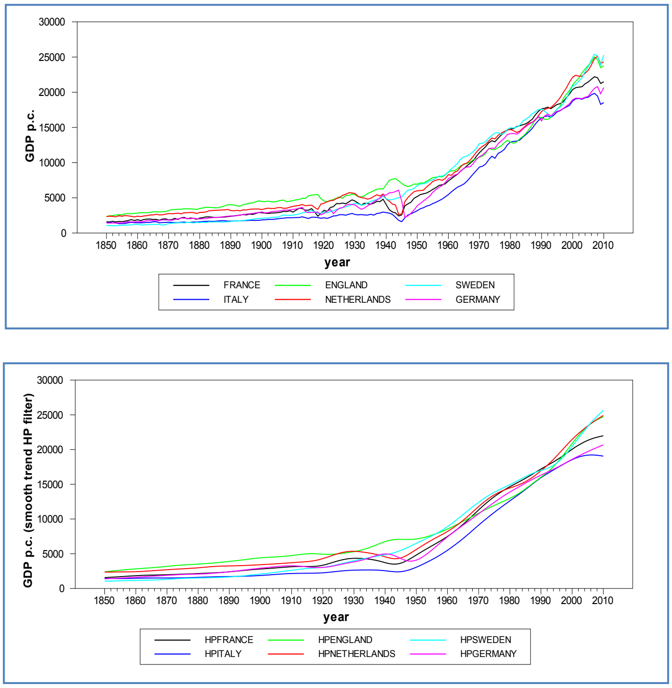
Thus, *Spectral Analysis* or analysis in the *frequency domain* is a helpful methodology for a researcher to see how important are the long lasting cycles relative to cycles of other duration in the periodicity of the series/variable chosen to express economic activity. In this paper, we use spectral analysis to investigate the different periodical movements of 6 economies, France, England, Sweden, Italy, Netherlands and Germany for the period 1850-2010 using the most recent Maddison Project datasets.[3] In order to investigate whether the cycles of the different countries interact or have the same timing and periodicity we take one step further and apply cross-spectral analysis.

2.1 Answering the first question

Despite the skepticism of some researchers long waves do exist and this is obvious even to the naked eye. The graphs below depict, though not so clearly, long waves occurring from 1850 until the present. Despite the explicable (due to technological progress) upward trend, we can see an expansion phase lasting approximately until approximately 1870 in almost all countries (except Italy and the Netherlands where it is not that obvious). Then, there is a downward movement until approximately 1890 where another expansion phase begins. After 1925, we have a downward movement until 1945. From then, all economies moved closely together upwards, until 1990, where the previously observed convergence starts to vanish. These movements in all 6 countries' GDP become more obvious by smoothing the series with the help of the Hodrick Prescott Filter.

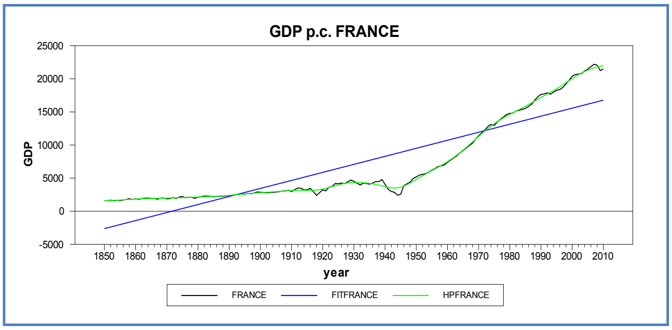
3. Bolt, J. and J. L. van Zanden (2013). The First Update of the Maddison Project; Re-Estimating Growth Before 1820. Maddison Project Working Paper 4. http://www.ggdc.net/maddison/maddison-project/data.htm

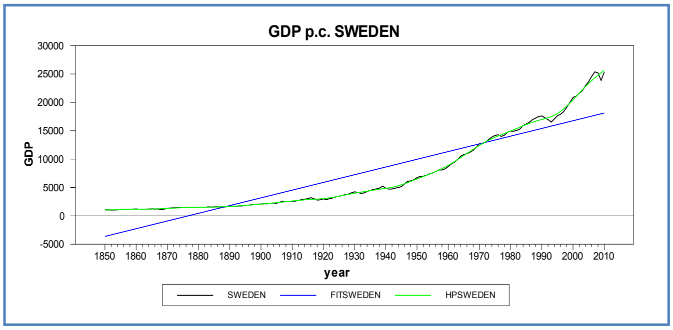
Figure 1. Long Waves of GDP from 1850-2010

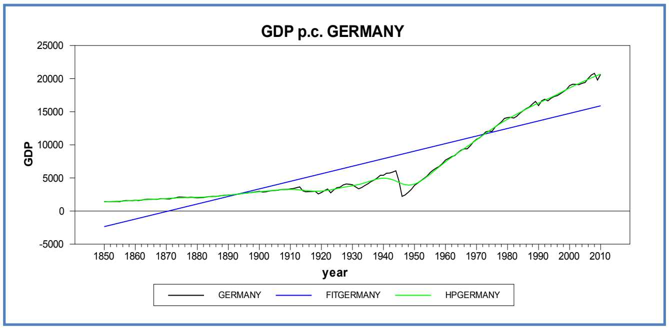


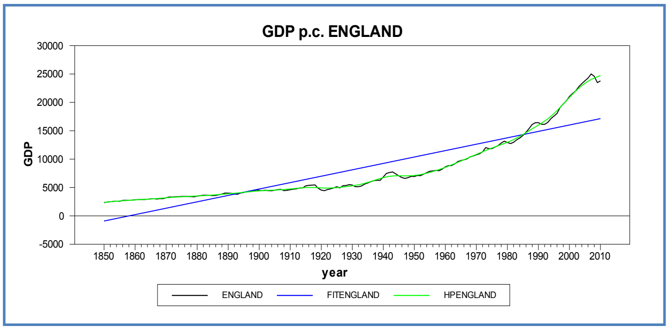
Before discussing the results of spectral analysis, we should mention that there is an obvious difference in the importance of periodicities according to the de-trending technique. Series can become stationary, either by having monotone or polynomial de-trending. Nevertheless, if we choose a polynomial de-trending, fitting on the actual data may be better, but we lose cyclical information, starting from the longer lasting cycles. Generally, monotone trend eliminations maintain longer lasting fluctuations, while, in contrast, polynomial trends, either being of constant or of adjustable degree e.g. Hodrick-Prescott (1997), preserve only shorter cycles. This gives us a great opportunity to repeat something that has been widely noted in the relevant literature: confirming the existence and the duration of a long-wave depends to a great extent on the pre-existing theoretical fixations *"as there are obviously no statistical criteria for choosing the ''true'' trend curve, the existence of long waves depends solely on subjective criteria related to the trend."(Metz 2011, p. 211).*

Figure 2. Real series (FRANCE, SWEDEN etc), linear trend estimation (FITFRANCE, FITSWEDEN etc) and smoothing HP trend (HPFRANCE, HPSWEDEN etc.) of each country's GDP








GDP p.c. ENGLAND
GDP
30000
25000
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1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
year
ENGLAND
FITENGLAND
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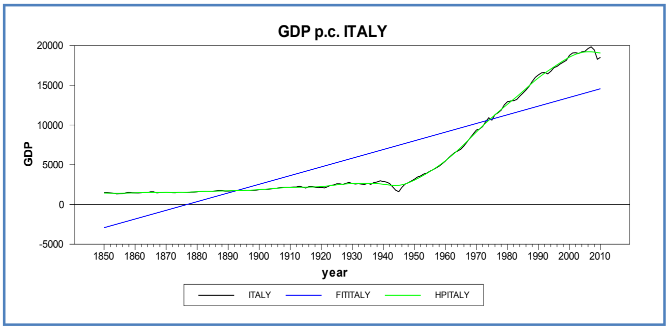
GDP p.c. ITALY
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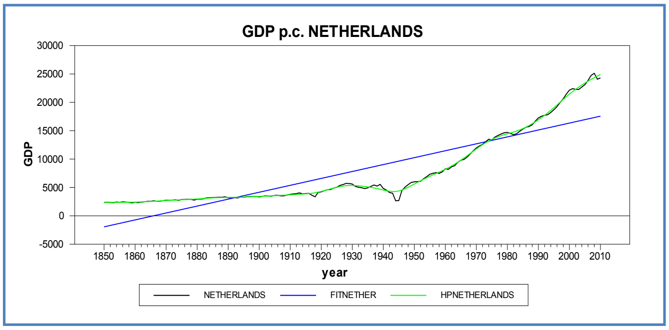
GDP p.c. NETHERLANDS
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Above, we depict the course of GDP of each country. As we can see there is an upward movement which is depicted more clearly by estimating a linear trend.[4] However, by taking out of the series the linear trend it is quite obvious that there will remain cyclical components of long duration (in the above graphs we can clearly see three waves up and down the trend line). On the other hand, de-trending the series with HP trend estimation involves the risk of excluding long wave movements. Indeed, if we take the residuals that remain after estimating amore sensitive, flexible trend – for instance by the use of HP – waves of more than 40 years disappear. Does this mean that they do not exist, or that the sensitive trend itself reproduces actually the deeper regularity of longer lasting periodicity? We believe that the second argument is true; that is why we use only de-trending techniques to GDP per capita levels and then to growth rates.

2.2 Answering the second question with Spectral Analysis

Each time series can be expressed as a sum of cosines and sines in case, provided it is stationary. Thus, each time series can be expressed as periodic function that depicts a periodicity at π. This is achieved with Fourier Transformation of the series' auto covariance function. In this manner the series are presented as a function of frequencies ($\theta \in (0,\pi)$) (the number of cycles per period). This means that the series can be plotted upon the points at which the series present a proportion/number of periodical movements (cycles). For example at π we have 0,5 cycle, at 2π one cycle etc. This function is named as power spectral densities function or power spectrum and illustrates the importance of periodic components in the total variance of the series. This is because if we integrate the function for all possible frequencies (from 0 to π), the area under the function is equal to the total variance of the series. For a more detailed analysis of the spectral methodology, see Granger and Hatanaka (1994) and Hamilton (1994), and, for a comprehensive interpretation, Engle (1976). Below, we present the results of the spectral density function estimations of 6 countries, France, England, Sweden, Italy, Netherlandsand Germany for the period 1850-2010. We start with an analysis of GDP per capita annual series, and then proceed with an analysis of GDP growth rates.

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4. In all countries GDP p.c. follows a clear exponential path. Therefore, future discussions of the same issue should proceed with exponential de-trending as well in order to capture any possible biases.

Figure 3. Spectral Density Functions of GDP de-trend time series

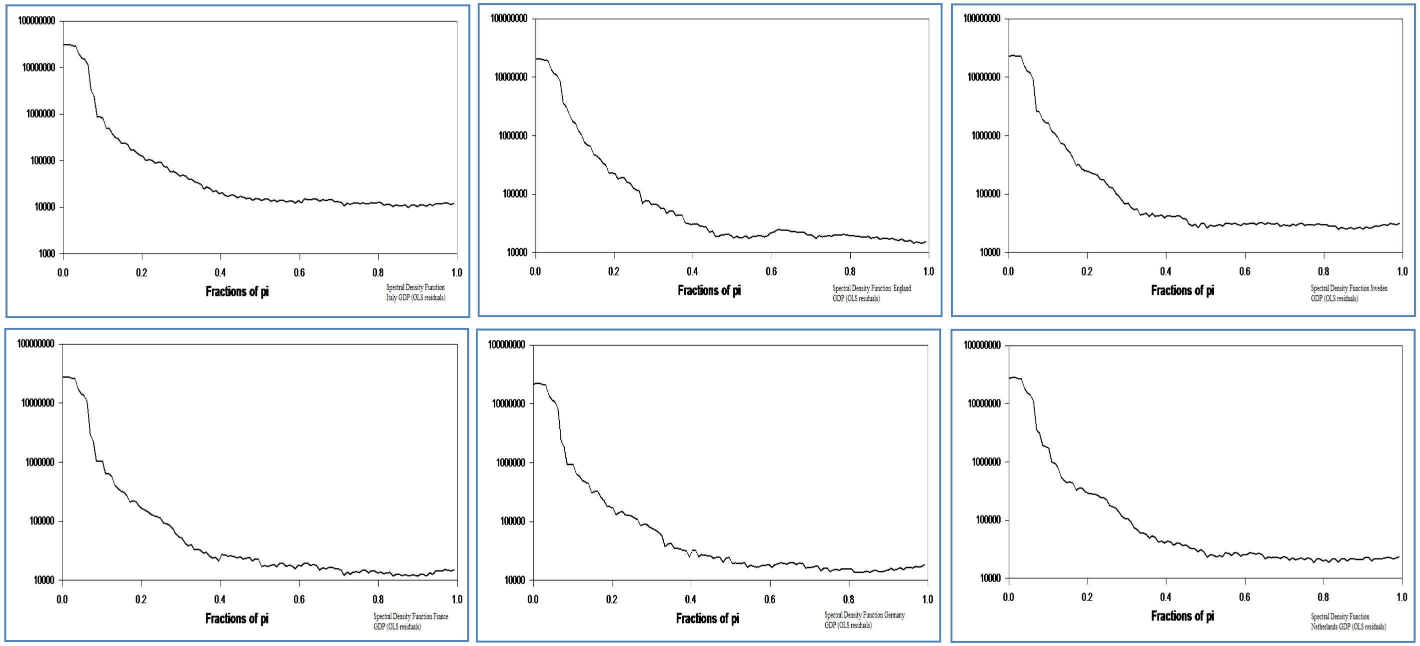


Table1: Spectral Density Estimations, level series.

Frequencies/Fractions of pi		0,02 - 0,065	0,065-0,178	0,178 - 1
Cycle Duration		29- 86 years	11-29 years	2-11 years
Explanation of GDP p.c. series' residual variance (%)	SWEDEN	51%	9%	3%
	NETHERLANDS	51%	8%	3%
	ITALY	53%	5%	1%
	GERMANY	52%	7%	3%
	FRANCE	52%	6%	2%
	ENGLAND	50%	11%	3%

As expected from the above, the spectral density estimations after the elimination of a linear trend depict clearly the presence of long cycles or, otherwise cycles of low frequencies' periodicity. In the horizontal axes we see the frequencies – fractions of π.[5] In the table below our estimations we present how each interval of frequencies of the horizontal axis corresponds to each different length of cycle. Additionally we present the percentages of explanation of the total variance of the series by each type of cycle[6]. As we can see, Kondratieff cycles in the level series of all countries' GDP p.c. explain almost half of the series' total variance. Additionally, we estimated the spectral density functions for annual growth rates, using again the same de-trending procedure. What someone needs to consider when viewing the specific figures is that spectral density functions of the growth rates become more flat than those of the levels for all series. This was expected. Generally, by using stationarity methods such as implementing the first differences in logarithmic series, a danger of excluding long wave movements always exists (Ewijk 1982). By definition in growth rates, every cycle in the series' levels is divided into two sub-cycles. Thus, the small percentages for Kondratieff cycles, in the second table, must not be interpreted to mean that these series don't present long cycles, since when we investigate growth rates, all cycles are being transformed to shorter ones. That is the only reason why, in that case, the business cycles explain almost all the variance of the series.

5. As we mentioned above at π (3,14) the Fourier transformed series depict half periodical movement meaning a half cycle in 1 periods of time (example if we use years as periods' measure units, 1 year) and one full cycle in 2 periods of time, thus 2 years. Thus, π in the horizontal axis corresponds to a full cycle with a periodicity of 2 years. As we move towards the beginning of the axis, the frequencies of the cycles are lower and correspond to cycles of larger duration (ex. π/2 (1,5) corresponds to a cycle of 4 years duration etc.).
6. Note that the sum of total variance for all category of cycles is less than 100%. This is because there is an additional category of cycles covering 100 years (Hegemonic cycles) that we do not present in our table because: 1) we are interested in the Kondratieff cycles and 2) because Hegemonic cycles lack a theoretical background that could give them partly economic meaning

Figure 4. Spectral Density Functions of GDP growth de-trend time series

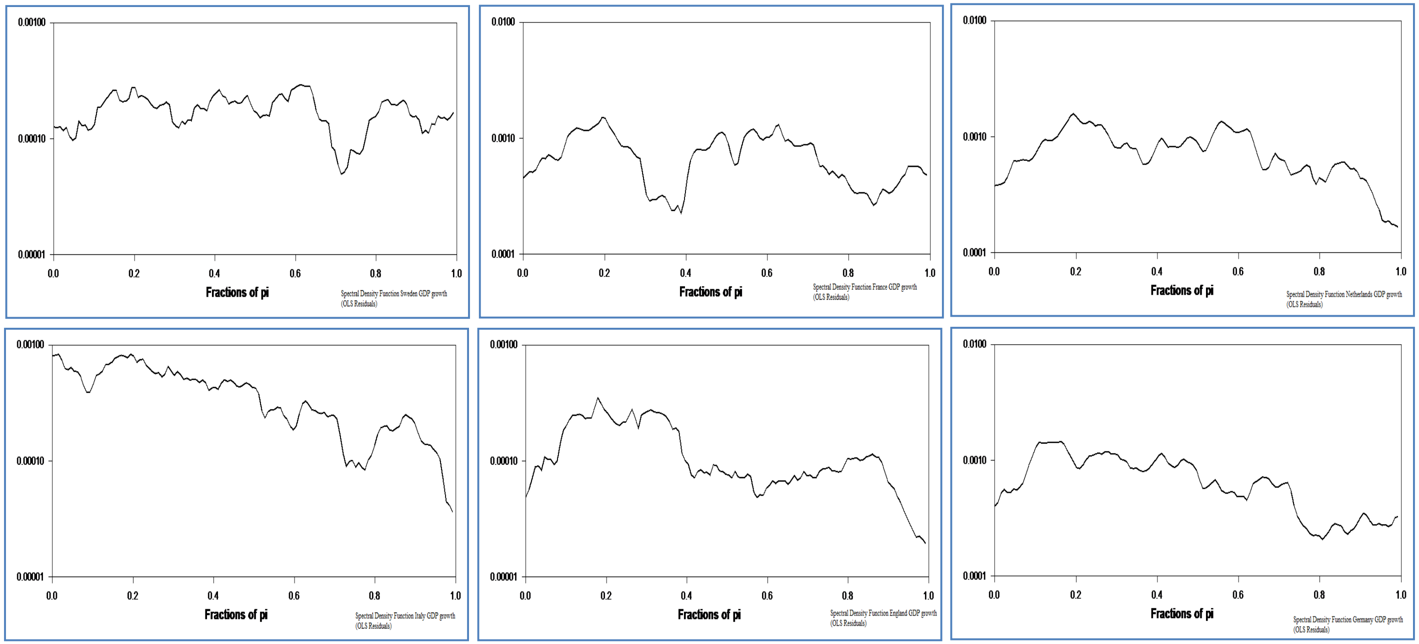


Table 2. Spectral Density Estimations, growth series

Frequencies/Fractions of pi		0,02 - 0,065	0,065-0,178	0,178 - 1
Cycle Duration		29- 86 years	11-29 years	2-11 years
Explanation of GDP p.c. series' residual variance (%)	SWEDEN	3%	13%	83%
	NETHERLANDS	3%	14%	82%
	ITALY	8%	18%	69%
	GERMANY	4%	21%	74%
	FRANCE	4%	17%	78%
	ENGLAND	4%	20%	75%

2.3 Answering the third and the fourth question with Cross-spectral Analysis

Using almost the same methodology, one can examine the periodicity of two variables as they inter-relate. More specifically, it is possible for a researcher to examine how two variables interact or how they are related in the frequency domain. This is achieved with the use of cross-spectral analysis and by estimating the Fourier Transformation of the series' cross-covariance function. However, the presentation of the results of cross-spectral analysis is different than the above. With cross-spectral analysis, we examine mainly two statistics: the coherence (squared) and phase:

The coherence is like a correlation coefficient and takes values between 0, 1. It depicts the correlation between two series in the frequency domain.

The phase depicts whether one variable leads the other. It is measured in fractions of a cycle, hence, as we described before, in fractions of pi.

In the present paper we applied cross-spectral analysis on the same data using GDP p.c. series levels and annual growth rates of GDP p.c. and we present the results in the two figures below (figures 5, 6). For both kinds of series we have estimated the coherence and phase function in all frequencies. The two functions were estimated for pairs of countries. In this manner we can see whether one economy is related to another under the same low frequency, hence, a long cycle. And if it is, which one of the two leads the other. The coherence values are presented in the left-hand axis whereas the phase values are depicted in the right-hand axis. The minimum phase lag is -1π (a half cycle lag) and the maximum phase lead is $+1\pi$ (a half cycle lead). Of course, if we do not have strong coherence (< 0.5), phase estimations are of no importance.

As can be seen in figure 5, all countries' GDP p.c. series appear to have strong linear dependence in all frequencies and thus in all periodicities. In the table below (Table 3) we eliminated only the results of our estimations for cycles lasting between 32-52 years. The same procedure was implemented for the growth series (Table 4). The coherence value is in all cases above 0,5 and extremely close to 1. Moreover, the cycles appear to be almost synchronized since the proportions of cycle lags, especially for the level series, are very limited. However by using only the signs of the phase's values we could reach some conclusion about which country is leading the other during a long cycle of its economic activity. A positive sign of the phase value means that the long cyclical activity of the county on the left vertical axis is ahead of the corresponding cyclical activity of the country on the horizontal axis.

Figure 5: Cross-Spectrum of level series

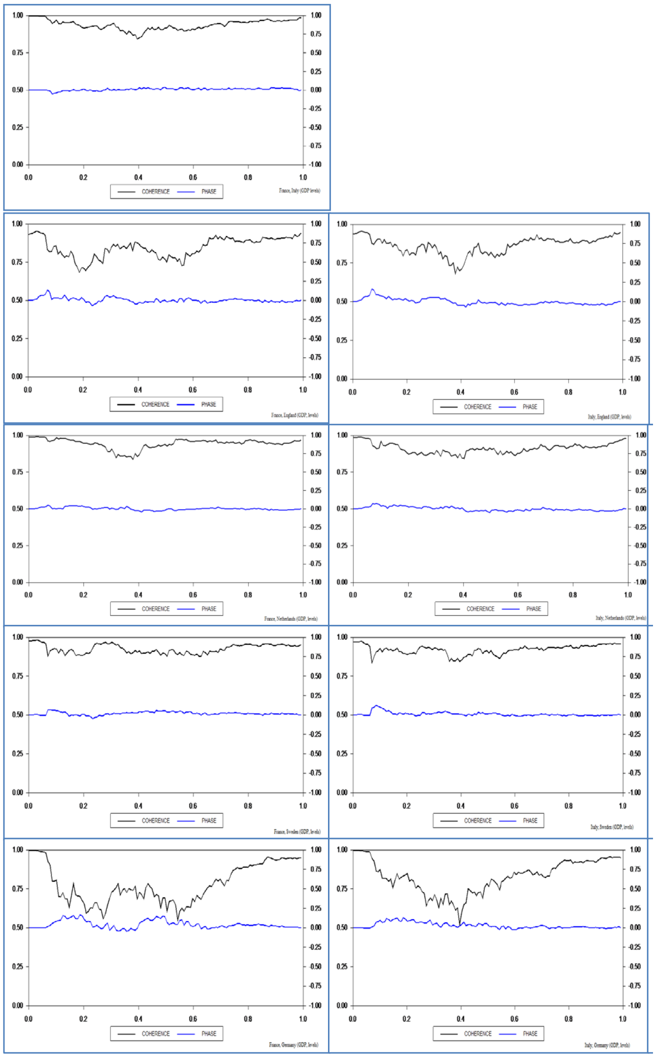


Figure 5: Cross-Spectrum of level series (continued)

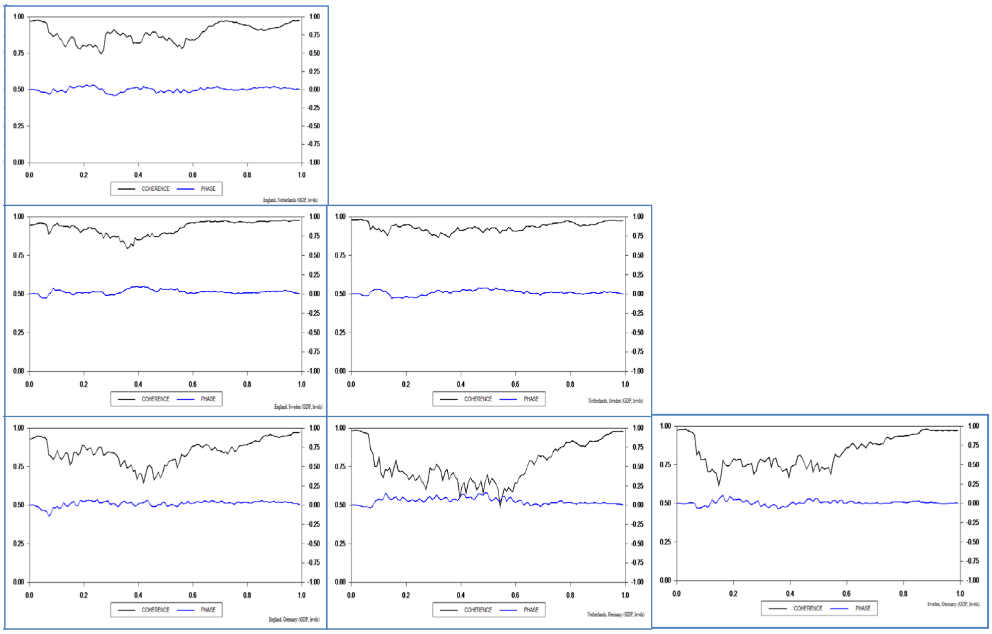


Table 3: Results of cross-spectral analysis on levels

Leader, Follower

Leader(+), Follower (-)

2	1	France				Itally				England				Netherlands				Sweden				Germany			
	Cycle Years	52	43	37	32	52	43	37	32	52	43	37	32	52	43	37	32	52	43	37	32	52	43	37	32
France	Coherence																								
	Phase Values																								
Itally	Coherence	>0,5	>0,5	>0,5	>0,5																				
	Phase Values	+	+	+	+																				
England	Coherence	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5																
	Phase Values	+	+	+	+	+	+	+	+																
Netherlands	Coherence	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5												
	Phase Values	+	+	+	+	+	+	+	+	-	-	-	-												
Sweden	Coherence	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5								
	Phase Values	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-								
Germany	Coherence	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5				
	Phase Values	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+				

Table 4: Results of cross-spectral analysis on growth

Leader, Follower

Leader(+), Follower (-)	2	1	France				Itally				England				Netherlands				Sweden				Germany			
		Cycle Years	52	43	37	32	52	43	37	32	52	43	37	32	52	43	37	32	52	43	37	32	52	43	37	32
	France	Coherence																								
		Phase Values																								
	Itally	Coherence	>0,5	>0,5	>0,5	>0,5																				
		Phase Values	+	+	+	+																				
	England	Coherence	>0,5	>0,5	>0,5	>0,5	>=0,5	>0,5	>0,5	>0,5																
		Phase Values	+	+	+	+	+	+	+	+																
	Netherlands	Coherence	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5												
		Phase Values	-	-	-	-	-	-	-	-	-	-	-	-												
	Sweden	Coherence	>0,5	>=0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5								
		Phase Values	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-								
	Germany	Coherence	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>0,5	>=0,5	>0,5				
		Phase Values	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	+	+	+	+				

Figure 6. Cross-Spectrum of growth series

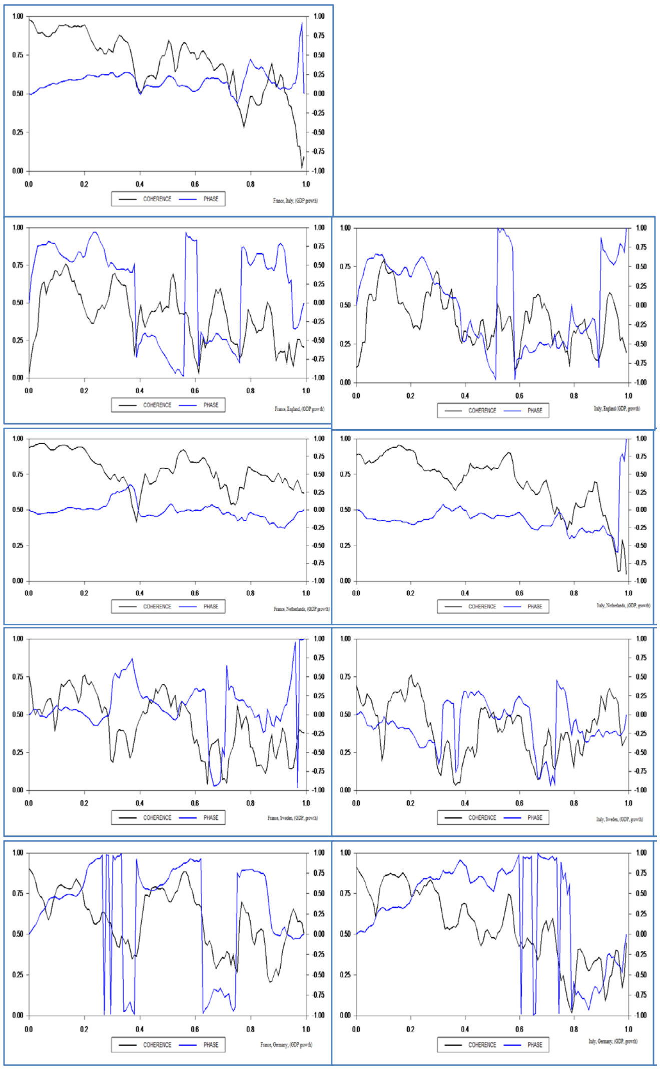
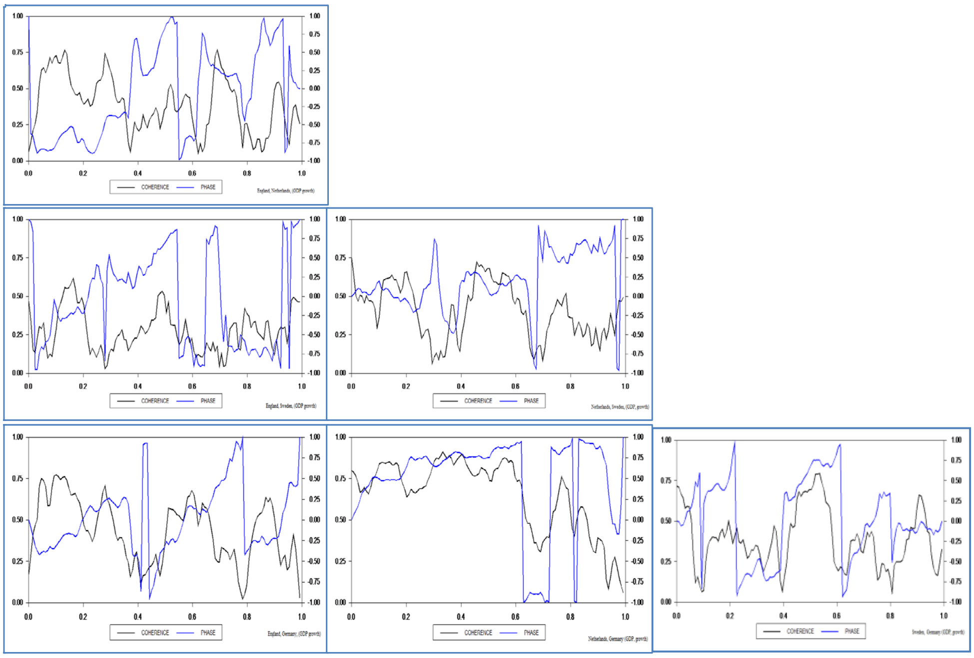


Figure 6. Cross-Spectrum of growth (continued)



Conclusions

Our empirical estimations confirm the long wave's significant contribution in GDP p.c. series. The spectral density estimations after the elimination of a linear trend depicted clearly the presence of long cycles in the series. However, in the case of the GDP p.c. growth rates the results support, apart from long waves, the presence of Juglars, Kuznets and Kitchin cycles in most of the countries. Trying to answer whether these long movements are related with the use of cross-spectral analysis, we found that they have a strong synchronization and a strong linear dependence especially in the GDP p.c. levels. However, the English economy's long cyclical movements are always ahead relatively to other European Countries. This was to be expected, since after the Industrial Revolution, the evolution of capitalism primary influenced England's economy, driving all other countries in the same direction.

Additionally, Germany appears to be a follower especially in three out of the other five countries. This might be due to the fact that its economy was mostly influenced in long economic periods, such as that after the Second World War.

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