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 the theories of long waves. The long wave tradition asserts that deep recessions, such as the present one or similarly the ones that occurred in 1930's and 1970's, are the result of an amplified long-lasting downturn, reoccurring every 40-60 years over the history of capitalism's development. Although the long lasting cyclical evolution of capitalistic development is obvious to many researchers, even with a simple visual observation of the history of the data, there are also doubts of its existence that are expressed both by a variety of different theoretical and empirical approaches. However, the increasing number of statistical methods for long wave examination depicts exactly that the confirmation of a long-wave, as well as its exact periodization, depends both on theoretical fixations and / or the use of different empirical methodologies and data. The present paper uses the modern and helpful methodology of Spectral Analysis in order to investigate the importance of the long lasting cycles relative to cycles of other duration such as the business cycles in the periodicity of European Countries' economic evolution. Motivated by the current persistent crisis we provide a theoretical discussion and empirical evidence in order to answer question: Do these long cycles exist? And if they do, how different is the periodicity of the economic evolution among European Countries? To answer the second question, we take one step further from the relevant empirical literature. We apply Cross-Spectral analysis in order to investigate whether the long cycles of different countries interact or have the same timing and periodicity. In this manner our empirical comparisons reveal the cross-country differences over the historical cyclical evolution of capitalism.

Key words: Business Cycles, Long Waves, Spectral analysis, Cross-Spectral Analysis

JEL codes: C22, E32

1. INTRODUCTION

The financial crisis of 2008 led to one of the longest and most persistent Post War recessions of global economic activity. Similarly to corresponding periods in economic history, it generated already 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 section of economic literature. Traditionally, the theories of long waves come in the foreground 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 1930's and 1970's, are the result of an amplified long-lasting downturn, reoccurring every 40-60 years over the history of capitalism's development.

The initial empirical evidences for long-lasting cyclical economic development lead us back to the first contributions at the end of 19th century by Jevons (1884), Parvus (1901), Van Gelderen (1913), De Wolff (1924) and the following, statistically more advanced, analysis of Kondratieff (1928). [158] Aside to 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.

Literature on theoretical justification of long waves is quite extensive. Contributions can be divided in three different schools: Marxists (Mandel 1981, 1975 1980) 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 downward and move the economy back to a new phase of expansion.

Closely 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 they are propitious for the continuity of capital accumulation, reassure the transition to the next upswing. (Gordon 1980, 1991; Gordon et al. 1994; Gordon, Weisskopf & Bowles 1983)

Different than 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 1987, 1986; Mensch 1975; Schumpeter 1939).[159].

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[158] Although, the literature uses the term "Kondratieff cycles", there are many authors who believe that the credits 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).

[159] 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: Perez 1985, 1983, 2010, 2002, 2004;Tylecote 1992), 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.

Despite the different significance given to the parameter of technological progress, its influence on economy's long term evolution is undoubtedly accepted. Long fluctuations of economic activity were empirically and timely 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 of the 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). 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, also this cycle was 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 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 a fifth long wave began, associated with the revolution in electronics, telecommunications and informatics (Freeman & Lou 2001; Korotayev & Tsirel 2010; Perez 2010). Some believe that we are still in the longer-lasting downswing of the fourth long wave (Zarotiadis 2012; Wallerstein 1984), while others assume that now begins 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 1986; Kleinknecht & Bieshaar 1983; Korotayev & Tsirel 2010; Reijnders 1992, 2009; Van Duijn 1977, 1983; Metz 1992), as well as many contributions that question the existence of long waves (Garvy 1943; Van der Zwan 1980; Van Ewijk 1981, 1982; Solomou 1998, 1990) . As Van Duijn (1983, p. 18)(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 to 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 in answering the following questions:

1) Do economies present cyclical movements that last longer than a common business cycle?
2) Could these movements be considered as periodical?
3) Are their movements related?
4) Is their development synchronised as an international economic phenomenon?

ANSWERING QUESTIONS WITH NEW METHODOLOGY.

Until present the most widespread methodologies for detecting long cycles are decomposition approaches and the most recent spectral analysis. With decomposition approach (Kondratieff's method, 1928), time series are decomposed between trend and cycles (cyclical components) of different duration. This approach was used by Kondratieff,

who estimated a second degree time polynomial trend and after its elimination, smoothed the residuals by using a 9-year moving average (eliminating the common business cycle component). The recent techniques however, such as spectral analysis allow for simultaneous estimation of the importance of cycles of different duration, avoiding in such manner, bias estimations over a specific size of cycle.

Thus, *Spectral Analysis* or analysis in the *frequency domain* is a helpful methodology in order 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[160]. 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.

Answering the first question.

Despite the skepticism of some researchers long waves do exist and this is obvious even to a naked eye. The graphs below depict, though not so clearly, long waves occurring from 1850 until present. Despite the reasoned (due to technological progress upward trend), we can see an expansion phase lasting approximately until approximately 1870 in almost all countries (except Italy and Holland 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. Since then, all economies move closely together upwards, until 1990, where the previously observed convergence starts perishing[161]. These movements in all 6 countries' GDP become more obvious by smoothing the series with the help of Hodrick Prescott Filter.

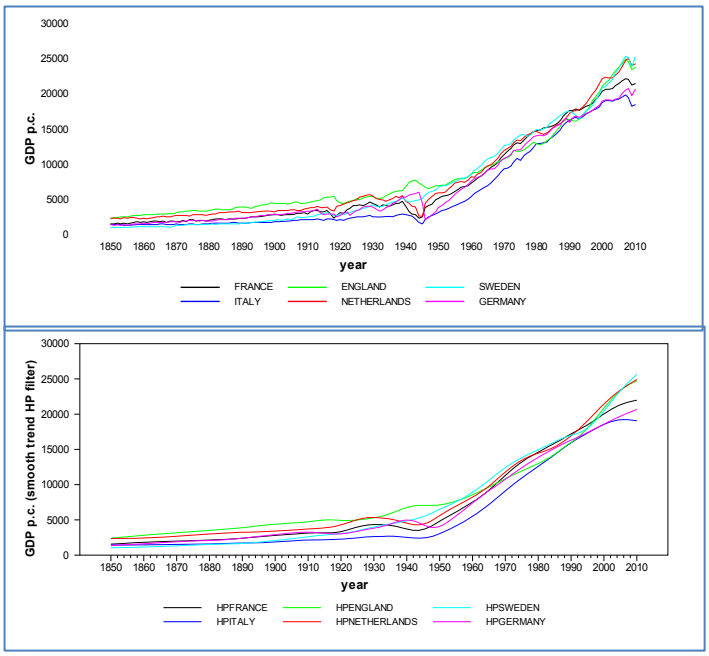


Fig 1: Long Waves of GDP from 1850-2010.

[160] 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

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. Linear trend elimination favours the presence of longer economic cycles, while, on the contrary, de-trending by the use of filtering techniques does the opposite. This gives us a great opportunity to repeat something that has been widely notified in the relevant literature: to confirm the existence and the duration of a long-wave depends to a great extent on the pre-existing theoretical fixations

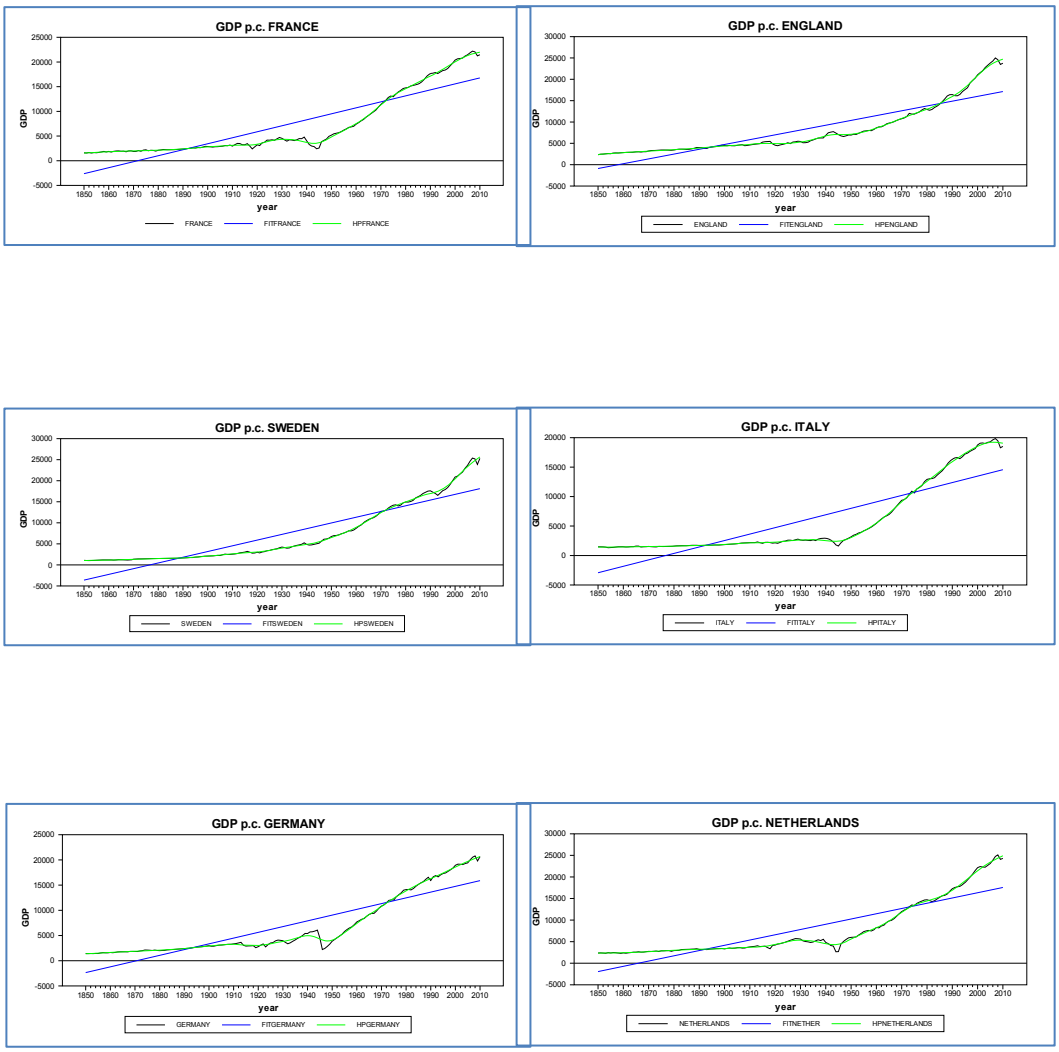


Fig 2: Real series (FRANCE, SWEDEN etc), linear trend estimation (FITFRANCE, FITSWEDEN etc) and smoothing HP trend (HPFRANCE, HPSWEDEN etc.) of each country's GDP.

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. 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). That is the reason why, the presence of long lasting cycles depends on

a great degree upon the theoretical assumptions of each researcher about the trend curve that fits better to the series. *"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).* On the other hand, de-trending the series with HP trend estimation, poses the danger of excluding long wave movements. Truly, if we take the residuals that remain after estimating a more 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.

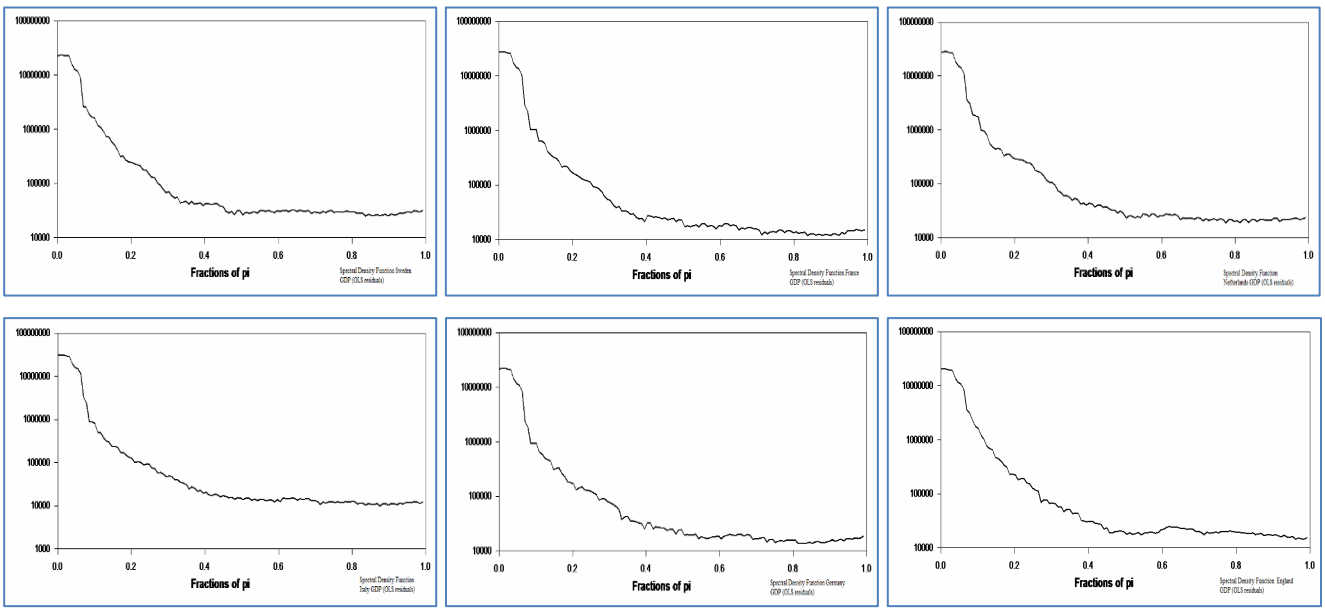
Answering the second question with Spectral Analysis:

Each time series can be expressed as a sum of cosines and sines in case 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 depicts 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 one can find at Granger and Hatanaka (1994) and Hamilton (1994) and for a comprehensive interpretation should also look in Engle (1976).

Below, we present the results of the spectral density function estimations of 6 countries, France, England, Sweden, Italy, Netherlands and Germany for the period 1850-2010. We start with an analysis of GDP per capita annual series and next, we proceed with an analysis of GDP growth rates.

Period (in years)	Frequency Fractions of pi,)	Frequency (Fractions of pi,)	pi
NONE	0	0	0
32	0,06	π/16	0,1964
16	0,13	π/8	0,3927
10	0,19	3π/16	0,5891
8	0,25	1π/4	0,7854
6	0,31	5π/16	0,9818
5	0,38	3π/8	1,1781
45.714	0,44	7π/16	1,3744
4	0,5	1π/2	1,5708
35.556	0,56	9π/16	1,7671
3.2	0,63	5π/8	1,9635
29.091	0,69	11π/16	2,1598
26.667	0,75	3π/4	2,3562
24.615	0,81	13π/16	2,5525
22.857	0,88	7π/8	2,7489
21.333	0,94	15π/16	2,9452
2	1	π	3,1416

Fig 3: Spectral Density Functions of GDP de-trend time series

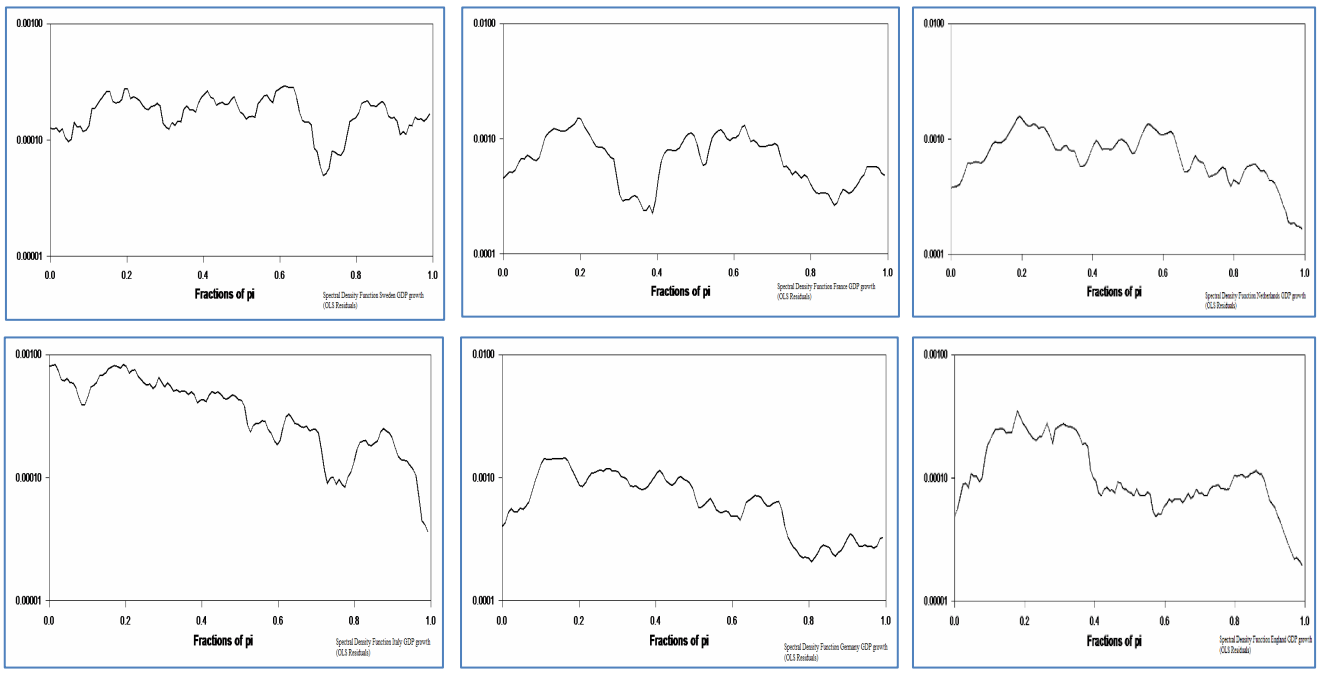


As expected from the above, the spectral density estimations after the elimination of a linear trend depict clearly the presence of long cycles or differently cycles of low frequencies' periodicity. In the horizontal axes we see the frequencies - fractions of π. As we mentioned above at π (3,14) the 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.). On the table you can see how the proportions of pi correspond to a frequency of a cycle. The function gets higher estimated values at cycles that have a duration of more than 32 in each country, thus our series depict high possibility to be periodical every 32 (and more) years.

Additionally, we estimated the spectral density functions for annual growth rates, using again the same de-trending procedure. As obvious, now the functions get flatter supporting apart from long waves, the presence of Juglars, Kuznets and Kitzin cycles in most of the countries.

Period (in years)	Fre-quency Fractions of pi,)	Fre-quency (Frac-tions of pi,)	pi
NONE	0	0	0
32	0,06	π/16	0,1964
16	0,13	π/8	0,3927
10	0,19	3π/16	0,5891
8	0,25	1π/4	0,7854
6	0,31	5π/16	0,9818
5	0,38	3π/8	1,1781
4,5714	0,44	7π/16	1,3744
4	0,5	1π/2	1,5708
3,5556	0,56	9π/16	1,7671
3,2	0,63	5π/8	1,9635
2,9091	0,69	11π/16	2,1598
2,6667	0,75	3π/4	2,3562
2,4615	0,81	13π/16	2,5525
2,2857	0,88	7π/8	2,7489
2,1333	0,94	15π/16	2,9452
2	1	π	3,1416

Fig 4: Spectral Density Functions of GDP growth de-trend time series



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

Using almost the same methodology, one can examine the periodicity of two variables inter-related. 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. 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 does which one of the two leads the other. Thus the two functions were estimated for pairs of countries. 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).

As it can be seen in the first figure, all countries appear to have a strong synchronization in all frequencies and thus in all periodicities. Moreover, all countries' GDP p.c. series appear to have strong linear dependence. Exceptions to the above, relatively to coherence, appear to be England and Germany. England's GDP p.c. series do not present strong linear correlation to the other countries' GDP p.c. series and especially at low frequencies (at longer lasting periodical movements). Similar behavior present the series of Germany, which as depicted in the figures below, they do not depict high linear correlation with the rest countries' series and this is particularly obvious at low frequencies.

The results of cross-spectral analysis of the growth rates are a little different to that of GDP p.c. levels. High linear correlation is presented in most of pairs of the six countries, apart from those that include England and Sweden. Sweden's growth rate presents small coherence with almost all countries and its long cycles appear to be leading relatively to those of other countries apart from Netherland. Similarly with the analysis of GDP p.c. levels, England also here presents the lowest coherence (under 0, 75) with all countries. Moreover, it appears to lag in longer cycles and leading in shorter ones. Finally, Germany's growth rate presents low correlation with that of England's and Sweden's relatively to the other 3 countries. Moreover, Germany's longer lasting cycles lag to almost all long cycles of other countries (apart from England's).

Fig 5: Cross-Spectrum of GDP p.c. de-trend time series

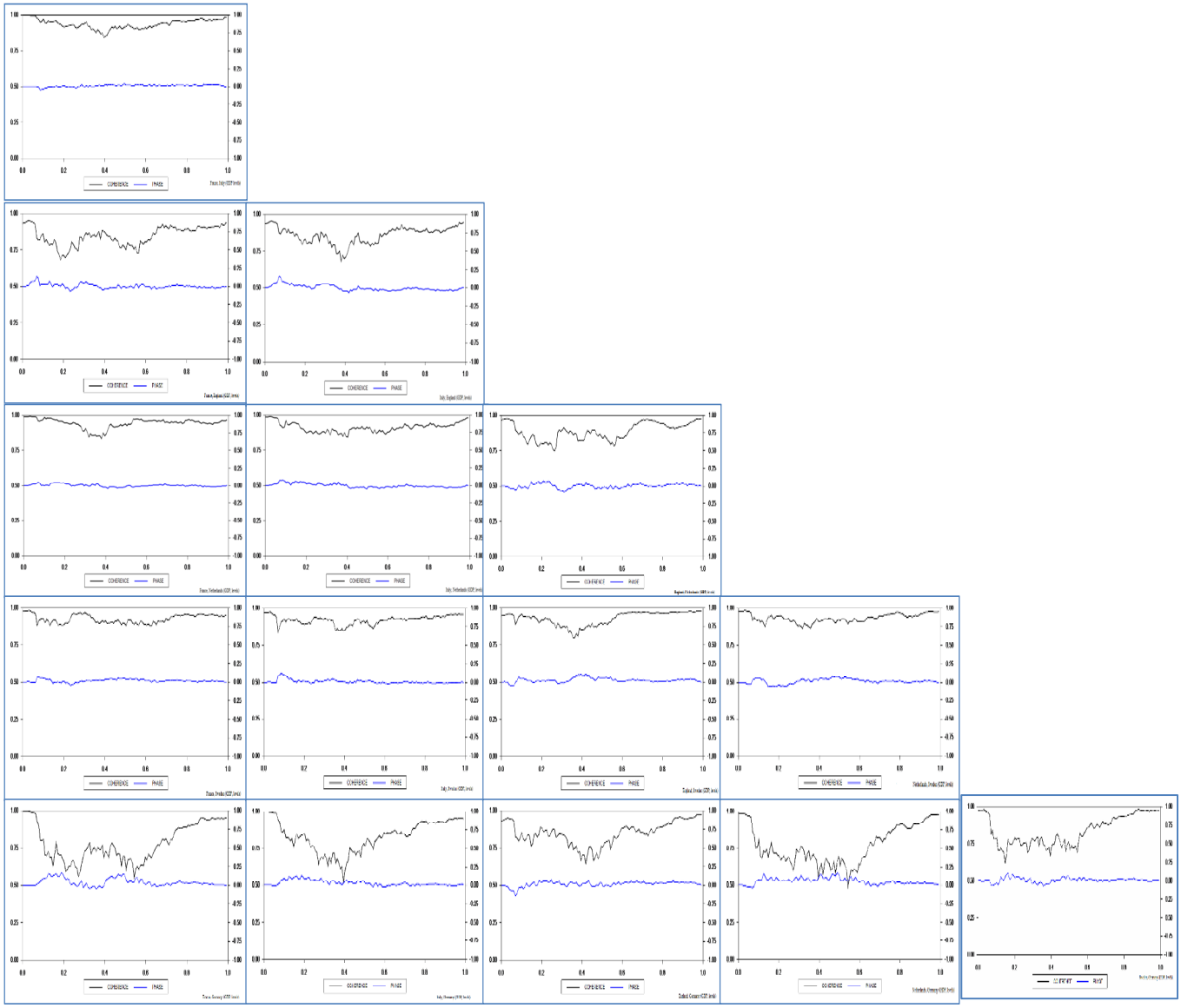


Fig 6: Cross-Spectrum of GDP p.c. growth de-trend time series

CONCLUSIONS:

Our empirical estimations confirm 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 case of the GDP p.c. growth rates the results support, apart from long waves, the presence of Juglars, Kuznets and Kitzin 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, exceptions do exist. England, in both two analyses (levels - growth rates), depicts clearly a different character from all

other European countries examined. Additionally, Germany appears to be always a follower especially in lower frequencies. This maybe could be explained due to the fact its economy was mostly influenced in long economic periods such as the one after the Second World War

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