# Connections between the Dry Bulk Freight Index and the Cyclical Economic Activity of the G7 Countries

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The article analyses the connections between the dry bulk freight market and the economic activity of certain countries. The objective was to confirm the existence of a similar cyclical nature for the Baltic Dry Index and main indicators of the business cycle of the G7 countries. The applied macroeconomic variables were: the real GDP and the industrial production index. In examination a spectral analysis was used. The discovered identical periodicities were analyzed in terms of time relations. It was demonstrated, that the cyclical part of the BDI (periodicity of 13.1 and 15.3 quarters) either leads or is coincident with the indicators of the business cycle.
The global financial crisis in 2008-2009 showed that the behaviour of freight indices was similar to stock exchange indices and macroeconomic variables in advanced economies. It is worth to observe shipping market because higher values of freight indices could anticipate increasing demand for sea trade and economic growth.

**Keywords:** shipping market, business cycle, Baltic Dry Index, freight index, spectral analysis.

**JEL Codes:** E32, R41.

## 1. INTRODUCTION

Economic fluctuations are described in various ways. The traditional approach distinguishes several kinds of economic cycles according to different lengths of time and the various causes which lead to their occurrence. The criterion of division is the duration of the cycle. This approach consists the following cycles: the Kitchin cycle (3-4 years), the Juglar cycle (7-11 years), the Kuznets cycle (15-20 years), the Kondratiev cycle (about 50-60 years) and the Wageman cycle (about 150 years) ( Zarnowitz, 1992).

At the same time we can observe that modern macroeconomics more and more often dispenses with the precise distinction of the aforementioned economic cycles and searches instead for a periodicity which can be equated with contemporary business cycles of a duration from one to ten years. Another frequent time bracket is a period of 2 - 8 years or 6 quarters - 8 years (Baxter & King, 1995).

Both approaches can be applied simultaneously. In this case, the first step is to establish the periodicity of variables. Studies of this type are intended to provide an answer to the question of the time bracket, which comprises the period of contemporary business cycles. We can therefore talk about a search of a bracket of possible solutions. The established periodicity with a time bracket of up to 8 years constitutes a regularity which confirms the hypothesis of the existence of a business cycle. Only the second step then consists in the comparison of the observed periodicity with the different cycles which we know from the classical approach. The obtained results can be juxtaposed with the traditional division.

An important decision is the choice of a variable to be equated with the periodicity of the general level of economic activity. The first choice is in most cases the real GDP. This indicator is a natural candidate for the empirical assessment of the fluctuations of economic activity. It is even described as the „quintessence" of the economic condition, wherefore its fluctuations are a reflection of its cyclical changes (IMF, 2002). In an economic analysis this value therefore plays the role of the best reference variable and its fluctuations represent the reference cycle.

It is, however, not the only indicator used in analyses, whose fluctuations are identified with a business cycle. Apart from the GDP, there are other reference variables which are applied in analyses, such as the industrial production index (PI). In this article the inclusion of the PI into the group of variables identified with the economic activity of countries depended on several factors. First of all, from the point of view of the conducted analyses, it would be interesting to obtain results, in which the economic activity would be limited only to that area of activity, which is closely connected with transport. The industrial production fulfils this condition due to the importance of mineral raw materials for industrial processes. Raw materials are the dominating group among dry bulk cargos in maritime transport. Another reason to use it for research are often technical issues connected with the frequency of data collection. Furthermore, in the developed countries, the industrial production index is characterized by a greater variability, which is why it is often easier to read the signs of a coming change of the cycle phase.

The analysis of not only one, but several variables constitutes a reference to the definition of a cycle formulated by A. Burns and W. Mitchell (1946). This definition can be treated as the starting point for one of the most frequently applied methods of economic analysis and forecast – the indicators analysis. This method is based on finding and appropriately classifying the temporal relations between the course of many different economic variables and the assumed reference variable representing the model business cycle. The choice of the applied variable does not imply the necessity to refer to any theory of the business cycle, but uses the formal statistical characteristics of specific time series. This method is based on identifying an external image of periodicity. The observed behaviour of the time series of different economic phenomena in relation to the course of the reference variable can be a criterion for the classification of these values. The behaviour in time in relation to the reference variable allows to distinguish three classes of indicators: leading, coincident and lagging. The leading and coincident indicators have the greatest practical value. This article analyzes to which of the three groups belongs the freight index of the dry bulk cargo market and examines its relation to the GDP and the PI of certain countries.

Another decision which had to be taken in this article, concerned the question, whether to base the analysis on macroeconomic variables of individual countries or of larger groups of countries. This decision is connected with the problem of synchronizing the business cycles. The synchronization of business cycles can be defined as the concurrence of the turning point of the reference cycle in the relevant countries (Bordo & Helbling 2003). The confirmation of the existence of a synchronization should indicate that the analyzed economies are in the same cycle phase. Minor time shifts between the cycles which are considered as synchronized, are permissible. This reservation has an influence on the formulation of the conclusions of analyses including this issue. As the objective is not to search for proof in order to confirm or reject the thesis of the identity of the course of the cycles, in the end – on the basis of the obtained results - the forming of categorical divisions and classifications of the analyzed countries based on such a criterion can also be avoided. The literature does mostly not contain any sharp division into countries with synchronized or unsynchronized cycles, but distinguishes countries with more or less synchronized cycles.

Is there, then, a global synchronization of cycles, or at least between the main centres of economic development? The clear majority of the empirical analyses show that there is no global business cycle understood as the synchronized simultaneous, identical fluctuation of the GDP in all the countries. This is established among others by the analyses of Stock and Watson (2003). What is more, these authors come to the conclusion, that there is no synchronization even between the greatest economies worldwide, which form the group G7. It was also not shown that there was any essential change in this respect during the 40 years included in the analysis. They prove thereby, that the progressive openness of the economies does not seem to influence the unifying processes of the course of the business cycles. At the same time, they establish the fact, that there are groups of countries between which the synchronization is greater. A greater convergence was noted for the euro-zone countries as well as between the English-speaking countries. The confirmation or denial of the existence of a synchronization of the business cycles between countries depends among other things on the length of the analyzed period and the adopted method of analysis. Bordo and Helbling (2010) write about evidence for an increased synchronization in the 20th century. Aruoba et. al. (2010) search for aspects shaping national economic activity and changing the degree of synchronization between the G7 countries. The

quoted studies analyze the degree of synchronization rather than confirming its occurrence. Even analyses which prove an increased synchronization (e.g. in the euro-zone or in G7 countries) do not establish an identical course of the national business cycles, but only a greater co-movement (Furceri & Karras 2008; Antonakakis & Scharler 2012). Literature very often do not concentrate on confirming ideal comovement of cycles but is looking for factors that make business cycles better synchronized in recent years, for example being in EMU-area or intensive FDI links (Jansen & Stokman 2014).

The article recognizes that the comparative analyses cannot be based on an aggregated business cycle for a group of several countries and even less for the whole world. According to current knowledge it must be admitted, that the concept of a theoretical global cycle calculated on the basis of the worldwide GDP would be too far from the reality. Such a model would be characterized by a too high degree of generality. Therefore, it was considered as the suitable approach to base the analysis on national cycles and to apply macroeconomic variables representing individual countries.

It was decided to choose those countries for the analysis, whose economy is characterized by a developed market system, who belong to the worldwide leaders with regard to their GDP and who participate in a significant degree in the international business exchange. The chosen countries are the countries of the group G7. Apart from the group of countries G7, which have occupied top positions in the global GDP ranking for years, another high-ranking country is also the dynamically developing China. China, however, is not included in the empirical analyses conducted in this article. The main reason for this is the fact that in the analyses it was necessary to consider time series going as far back as the 90s. The countries to be considered therefore had to be countries which for the entire period belonged to the group of developed countries with a stable socioeconomic system and a solid position within the international economic relations. Simultaneously, the condition concerning the acquisition of the required data had to be fulfilled. It was necessary to select countries for which reliable data over many years concerning the GDP and the industrial production in quarterly sections could be obtained.

In the analysis, the indicators of economic periodicity were compared with time series of the dry bulk freight index. Freight indices are indicators, which provide the best basis on which to assess the situation on a given partial freight market and to set its current state in relation with past levels. From the point of view of the realization of the informative function, they are better qualified than individual freight rates, because they reflect the condition of the entire partial freight market for which they are drawn up. As a collective indicator they therefore provide a much more transparent picture of the situation on a given market, and not only with regard to individual relations. Thanks to this, their analysis is often the basis for developing forecasts including sometimes the entire maritime industry and their values are important evidence in the decision-making process of companies representing the different segments of the industry, such as ship owners, charterers, financial institutions or insurance companies.

One of the most recognized indices for the dry bulk cargo market is the Baltic Dry Index – BDI. The name BDI may be misleading. It can suggest the connection between the index and trade at the Baltic Sea. In fact the name comes from The Baltic Exchange – the institution which has been publishing the index since 1985 r. The BDI contains key time charters from all over the world for four main ship classes: Capesize, Panamax, Supramax and Handysize. The significance of this index results from its characteristic features, above all the precisely selected scope of shipping relations, the transparent structural rules and the broad applicability (Stopford, 2006). Moreover, the essential role of the BDI on the maritime shipping market is connected with the recognisability and reliability of the institution by which it is issued.

## 2. METHOD

The connections between freight indices and macroeconomic variables are complex and multi-dimensional. Therefore, the quantitative assessment of the co-movement of the cyclical fluctuation of these variables can be complicated. The aim of the present empirical analyses is to find an answer to the question concerning the price variations on the freight markets from the perspective of business cycles. The first step was to confirm the occurrence of a statistically significant periodicity in an appropriately prepared BDI time series. Then, the attempt was made to determine the morphological characteristics of this periodicity with the focus on the length of the cycles. The third question concerns the quantitative

search for common periodicities of the BDI and the economic activity indicators of the G7 countries.

The assumed typical feature of economic time series is that in their course it is possible to distinguish changes in form of: long-term tendencies, business cycles, seasonal or random fluctuations. In order to more closely analyze only one of the components, the others must be excluded from its course, because their presence in the series could have such an influence on the obtained results, that they would impede the analysis of the relevant component. The analyses were based on quarterly data, so it was necessary to eliminate trends and seasonal fluctuations (by means of the method Census II). As a result, the analyses concerned only cyclical components rid of fluctuations shorter than one year as well as of long-term development tendencies.

The designation of a deterministic trend defined by the function of time was dispensed with. In accordance with V. Zarnowitz (1992) it was assumed as improbable that over several decades the GDP changed always subject to one mathematical function, in spite of different kinds of political tensions, historical turning points, changing technologies or wars. A similar opinion is held by F. Kydland and E. Prescott (1992) who stress that the permanent changes in work output and the capital productivity make it impossible to determine one trend function covering several decades. The search of the function best adapted to the empirical data would implicate the additional risk that, depending on the length of the sample subject to analysis, this best function could take on different forms. The occurrence of a stochastic trend was assumed as most probable. The article equates economic fluctuations with deviations from the trend determined by means of the technique proposed by R. Hodrick and E. Prescott (1997). In accordance with Ravn and Uhlig (2001) a lambda parameter of 1600 was assumed.

The next stage of the research was to apply a spectral analysis to the suitably prepared time series. This method is ideal for the purposes of this article, as it makes it possible to examine variables with regard to the identification of significant cyclical fluctuations during their course. It also allows for the discovery and quantitative assessment of regularities often not directly visible on the progression chart of the given variable. No other means would provide the possibility to establish the lengths of periods and at the same time to determine the importance of a given periodicity for the analyzed variable.

Spectral analysis is applied in order to establish characteristic features in sequences of macroeconomic variables, including the identification of morphological features of economic cycles. It can be applied in order to describe the cyclical behaviour of prices for shipping services in maritime transport and to compare them with business cycles. The phenomenon of fluctuating freight rates is observed by the companies functioning on the market, and the description of the behaviour of indices in the consecutive time units can be found in the specialised literature. However, only by presenting the analyzed variables in terms of frequency is it possible to discover regularities which could not be determined by any other means.

The application of spectral analysis[1] is based on the assumption that a time sequence can be presented in terms of frequency and not as a progress over time. It relies on the fact that each sequence is the sum of sine and cosine functions with different frequencies.

The high value of the spectral density function for a given frequency bears witness to the significant part of this harmonica among the other components. Therefore, by assessing spectral densities one can select those frequencies which have the greatest influence on the variability of the sequence. The internal structure of the series is reflected in the shape of the spectral density chart. The importance of the individual harmonics can be assessed by means of the spectral density function chart drawn up with regard to frequency. The harmonics which appear in the chart as the dominating apexes play the most important role in the variance of the given series. The statistical significance of the harmonics was analyzed by means of the F-test.

A spectral analysis can be conducted for an individual series, but can also be enlarged and comprehend two variables at the same time. With an analysis of two time series it is possible to examine, if they are characterized by a similar periodicity or if they have a similar harmonic structure. A cross-spectral analysis reveals, if there

[1] Details of the spectral analysis and the models used in the article are presented for example in: J. Hamilton, *Time Series Analysis*, Princeton University Press, Princeton 1994, p. 152-180; For more information on the application for macroeconomic data, see A. Iacobucci, *Spectral Analysis for Economic Time Series*, „Documents de travail", OFCE, 2003.

is a correlation between the periodicity of the analyzed variables, i.e. if their fluctuations are similar. By comparing the reference series with the BDI, the squared coherency and the time shift between the essential harmonics were calculated. The time scope of the analysis includes the years 1990-2012. Quarterly data were used. The macroeconomic data were taken from the International Financial Statistics data base of the IMF, whereas the BDI values were taken from issues of the Shipping Statistics and Market Review.

## 3. RESULTS OF THE ANALYSES

### *3.1. ANALYSIS OF THE PERIODICITY OF THE BDI*

The first stage consisted in the analysis of the internal structure of the BDI. Before the actual analysis, the series was adequately prepared. The variable was rid of seasonal features and trend.

The purpose of these procedures was to prepare the series for the fundamental analysis, based on an analysis of the internal structure of its cyclical component. For a proper analysis the series had to be stationary. Therefore, the cyclical component obtained from the previous transformations was subjected to a test in order to verify its stationarity. This was done by means of the Augmented Dickey-Fuller test (ADF) in two versions of the tested regression model: without a constant and with a constant. All the analyzed series rid of trend and seasonal features are stationary at a statistical significance level of 0.05. The establishment of the stationarity of each of the analyzed series was the condition in order to proceed to the next steps of the analysis.

The determined spectral density of the BDI is presented in figure 1 and table 1 provides a precise characteristic of the statistically significant harmonics.

The peak visible in the chart indicates the frequency which plays the most important role in the variability of the BDI. This apex corresponds to a period of 13.1 quarters, i.e. of over 3 years. The period of 15.3 quarters has a slightly lesser density. The proximity of the two harmonics, which practically form one apex, may be caused by the change of the cyclical nature in this frequency bracket.

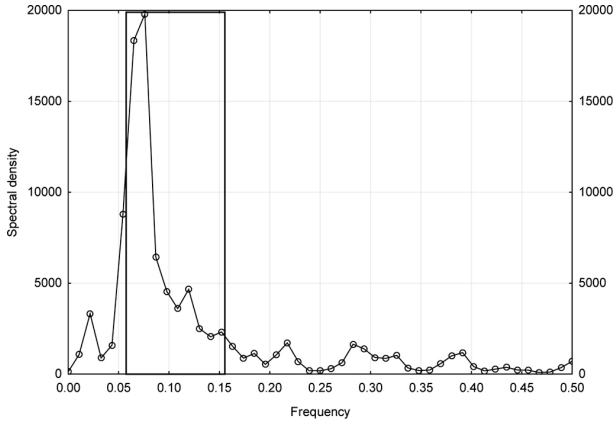


Fig. 1. Spectral density for the cyclical component of the BDI.

Table 1. Characteristic of the significant harmonics of the cyclical component of the BDI.

| Number of harmonic | Frequency | Period [quarters] | Spectral density |
|---|---|---|---|
| 5 | 0.054 | 18.4 | 8798.7 |
| 6 | 0.065 | 15.3 | 18353.1 |
| 7 | 0.076 | 13.1 | 19794.1 |

It results from the analyses that the BDI, which describes the state of the dry bulk freight market, is characterized by a significant periodicity. The apex corresponds to a periodicity identifiable with contemporary economic fluctuations. The section marked with a frame in the chart corresponds to a cycle length from 8 to 32 quarters. Thanks to this it is clearly visible that the greatest variability of the cyclical component of the BDI is contained in the relevant period. In terms of the classical division of economic cycles, it would fall into the range of the Kitchin and Juglar cycles.

### *3.2. CONNECTIONS BETWEEN CYCLICAL CHANGES OF THE GDP AND FLUCTUATIONS OF THE BDI*

The time series representing the cyclical variations of the GDP were expected to confirm the regularity in accordance with the literature stating the greatest significance of fluctuations with a duration of 2 to 8 years (i.e. 8-32 quarters). The variables were prepared for the analyses and their stationarity confirmed, just as in case of the BDI. The occurrence of cycles of different lengths is illustrated by the spectral density charts, which reveal the most significant frequencies for each series. Corresponding results are presented in figure 2 and table 2.

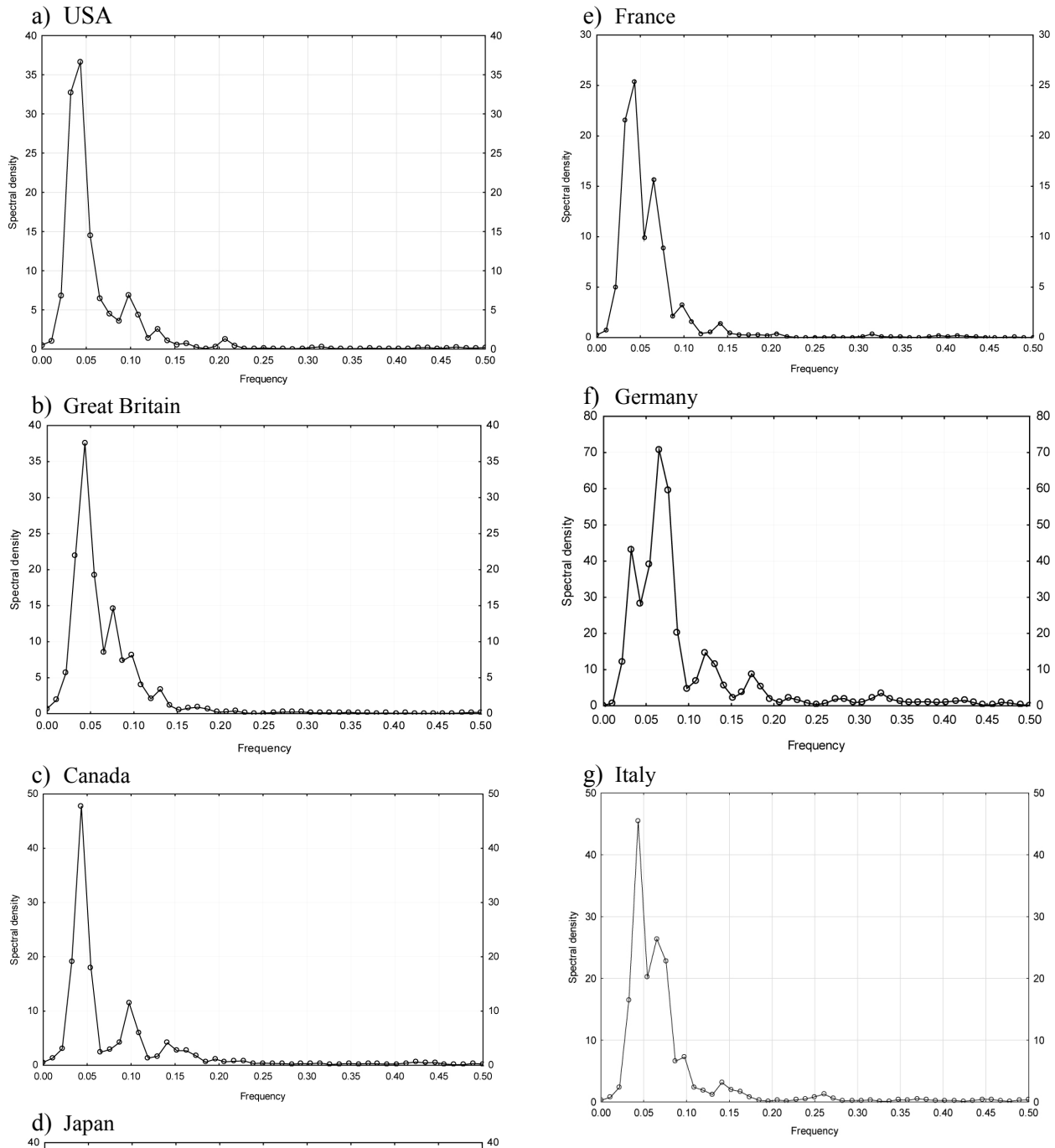


Fig. 2. Spectral density for the cyclical component of the GDP of the analyzed countries.

The calculations reveal certain common features of the harmonic structure of the GDP series of the individual countries. The highest points visible in figure 2 correspond in five cases to harmonics with a length of 23 quarters and for the other two countries of 15.3 quarters. The peaks with a length of 23 quarters are the most important ones for the USA, Great Britain, Canada, France and Italy.

Further proof of the similar characteristics of the series analyzed in terms of periodicity is

provided by the close group of the most important harmonics. Very significant are periods with a length of 23, 15.3 and 18 quarters. Important is, that for all countries the significant harmonics are located within a range considered as typical for contemporary business cycles (corresponding to a periodicity of 8-32 quarters). Only concerning Japan, one other peak of 7.6 quarters outside this period is significant.

Noteworthy are the charts for the GDP of Japan and Germany, which show that in these countries short periodicities are more important than in other countries. In both countries a group of harmonics of 13.1 and 15.3 quarters play the dominant role. This is exactly the same pair of harmonics as in case of the BDI.

Table 2. Characteristic of the significant harmonics of the cyclical component of the GDP according to countries.

| Number of harmonic | Frequency | Period [quarters] | Spectral density |
|---|---|---|---|
| **USA** | | | |
| 3 | 0.036 | 30.6 | 32.74 |
| 4 | 0.043 | 23 | 36.64 |
| 5 | 0.054 | 18.4 | 14.54 |
| 9 | 0.098 | 10.2 | 6.91 |
| **Great Britain** | | | |
| 3 | 0.036 | 30.6 | 22.01 |
| 4 | 0.043 | 23 | 37.59 |
| 5 | 0.054 | 18.4 | 19.22 |
| 7 | 0.076 | 13.1 | 14.64 |
| 9 | 0.098 | 10.2 | 8.10 |
| **Canada** | | | |
| 3 | 0.036 | 30.6 | 19.10 |
| 4 | 0.043 | 23 | 47.82 |
| 5 | 0.054 | 18.4 | 18.03 |
| 9 | 0.098 | 10.2 | 11.44 |
| **Japan** | | | |
| 3 | 0.036 | 30.6 | 24.29 |
| 4 | 0.043 | 23 | 19.82 |
| 5 | 0.054 | 18.4 | 21.56 |
| 6 | 0.065 | 15.3 | 35.18 |
| 7 | 0.076 | 13.1 | 28.74 |
| 12 | 0.130 | 7.6 | 15.99 |
| **France** | | | |
| 3 | 0.036 | 30.6 | 21.58 |
| 4 | 0.043 | 23 | 25.36 |
| 6 | 0.065 | 15.3 | 15.63 |
| 7 | 0.076 | 13.1 | 8.87 |
| **Germany** | | | |
| 3 | 0.036 | 30.6 | 43.24 |
| 5 | 0.054 | 18.4 | 39.23 |
| 6 | 0.065 | 15.3 | 70.84 |
| 7 | 0.076 | 13.1 | 59.69 |
| **Italy** | | | |
| 4 | 0.043 | 23 | 45.47 |
| 6 | 0.065 | 15.3 | 26.39 |
| 7 | 0.076 | 13.1 | 22.77 |

The identification of the periodicity of individual series justifies the continuation of the analyses and an additional cross-spectral analysis. The following analyses concerned only the statistically significant harmonics. The cross-spectral analysis was applied only for those frequencies which are significant both for the reference cycle (GDP) and the BDI. With this restriction the defined extent of analysis, squared coherency and time shifts were calculated.

The squared coherency is presented in table 3.

Table 3. Squared coherency between the GDP and the BDI for significant periodicities.

| USA | G. Britain | Canada | Japan | Germany | France | Italy |
|---|---|---|---|---|---|---|
| | **18.4** | | | | | |
| 0.29 | 0.47 | 0.30 | 0.08 | 0.09 | - | - |
| | **15.3** | | | | | |
| - | - | - | 0.71 | 0.51 | 0.69 | 0.57 |
| | **13.1** | | | | | |
| - | 0.92 | - | 0.96 | 0.65 | 0.73 | 0.74 |

The results show a strong connection between many of the variables analyzed in pairs. The squared coherency exceeds in most cases 0.50 and is often higher than 0.70[2]. Higher values were obtained for the shortest periodicity of slightly over 3 years. This periodicity was the most important one for the BDI. The highest factor values were obtained for relations with Japan and Great Britain.

The second indicator calculated based on the cross-spectral density was the time shift. The high squared coherency between the harmonics of the analyzed variables presented above does not mean that their courses coincide in terms of time. The value of the time shift shows the relation between a pair of harmonics of the same period value. The results of the calculations are shown in table 4. A positive time shift means that the given harmonic of the freight index leads the GDP harmonic of the same period. A negative number,

[2] The description of the obtained factors as strong confirms the fact that the literature assumes a value of the squared coherency factor of over 0.30 as one of the criteria for including a variable in the group of important leading variables, comp. O. Brunet, R. Nilsson, *Composite Leading Indicators for Major OECD Non-Member Economies*, „OECD Statistics Working Papers" 2006, No. 1, p. 33.

on the contrary, indicates that the freight cycle is delayed in relation to the GDP cycle. A result of zero would mean an ideal temporal coincidence of the two sinusoids.

Table 4. Time lag L(ω) between the GDP and the BDI [quarters].

| USA | G. Britain | Canada | Japan | Germany | France | Italy |
|---|---|---|---|---|---|---|
| | **18.4** | | | | | |
| -2.81 | -2.96 | -2.31 | 7.09 | -7.56 | - | - |
| | **15.3** | | | | | |
| - | - | - | **0.41** | -0.51 | **0.02** | **0.58** |
| | **13.1** | | | | | |
| - | **0.04** | - | **0.23** | **1.61** | **1.42** | **1.33** |

When assessing the results based only on the time shift it becomes obvious, that for the clear majority of the pairs of variables, the analyzed harmonics of the freight indices lead the fluctuations of the GDP. The results within this group are in boldface. It included all the results obtained for the most important harmonic of the BDI – of a period of 13.1 quarters.

In accordance with the approach of considering only the time shift we can say, that the BDI, acknowledged as the most representative for the entire dry bulk cargo market, is an indicator which leads the GDP cycle in most analyzed cases.

The interpretation of the time shift results would look different, however, if the variables were divided into three groups. Assuming we accept a time shift of one quarter for simultaneous indicators, the BDI in relation to the GDP would be:

- coincident for $-1<L(\omega)<1$,
- leading for $L(\omega)\geq 1$,
- lagging for $L(\omega)\leq -1$.

This classification corresponds to the division of indicators applied in the indicators method of business cycle analysis. This approach shows that the BDI for the periodicity of 13.1 quarters is a leading indicator for Germany, France and Italy and a coincident indicator for Great Britain and Canada. As for the – in terms of importance - second periodicity (15.3 quarters) the BDI is in each case a coincident indicator.

For a longer period of 18.4 quarters the results for the English-speaking countries are very similar. In case of the USA, Great Britain and Canada, the BDI is delayed by 2-3 quarters. These results confirm the thesis of the similarity of the economic cycles within the group of English-speaking countries put forth by the literature.

The analysis of the results leads to the conclusion that in the absolute majority of cases freight cycles can be treated as coincident or leading indicators for the economic activity of the respective country. At the same time it was proven that with regard to the significant differences between the results obtained for the fluctuations of the GDP of the individual countries, it is necessary to establish the values of the time shifts individually for each country.

### *3.3. FLUCTUATIONS OF THE INDUSTRIAL PRODUCTION AND THE BDI*

The purpose of the following analyses was to compare the cyclical fluctuations of the BDI with the second reference variable included in the present analyses, which reflects the periodicity of economic activity. This was the index of the industrial production (PI)[3]. The analyses were conducted so as to allow for the comparison of the obtained results with those obtained in the previous part of the article. Most interesting is the juxtaposition of the similarities and differences between the regularities found in the analyses of the freight cycle with regard to the GDP and the PI. The PI underwent the same preparatory procedures as the BDI and GDP. The cyclical component was isolated and its stationarity confirmed.

The charts of the spectral density function (figure 3) and table 5 present the results of the analyses. Most of the charts show clearly dominating peaks indicating the most important periodicity of the analyzed PI series.

[3] In this point, the PI of Canada was not included due to lack of adequate statistical material.

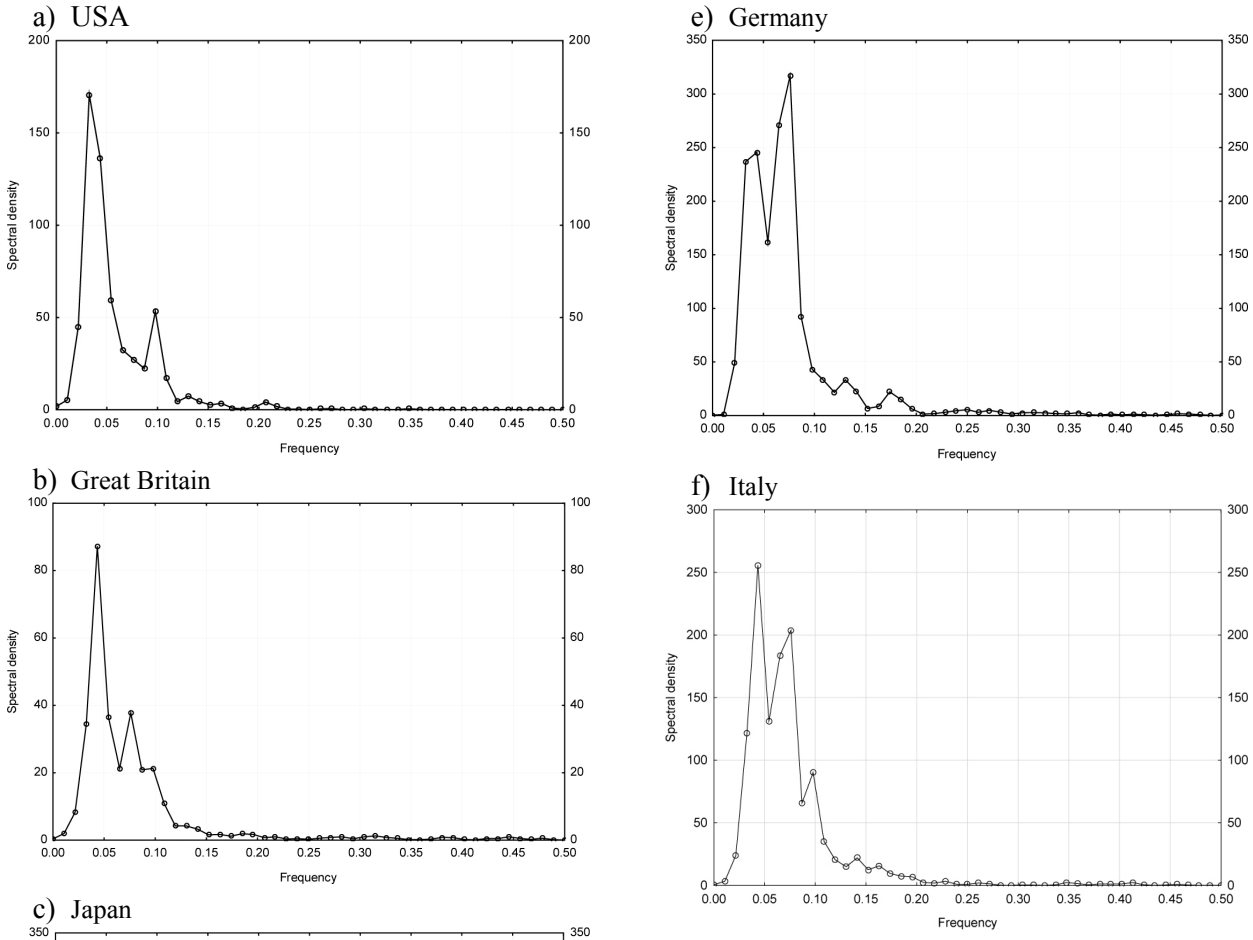


Fig. 3. Spectral density for the cyclical component of the PI of the analyzed countries.

The highest peaks of the spectral density of the PI sequences lie within the range identified with the business cycles, i.e. within the scope of 8-32 quarters. This section includes also the dominating cycles of the BDI.

The characteristics of the PI fluctuations can be compared with the results for the GDP obtained in the previous part. Many charts show similar characteristics, some indicate a shift of the dominating periodicities towards shorter cycle periods, which makes them similar to the BDI. The greatest conformity of the periodicity of the two economic indicators – the GDP and the PI appears between Great Britain and Italy. The similar form of the curve in figure 2 and 3 indicates the greatest similarity of the internal structure of the GDP and the PI. For both countries the most important periodicity for the GDP of 23 quarters dominates also in the PI chart. As for the USA, a change of the leading periodicity of 23 to 30 quarters can be observed. It is, however, always the same two harmonics which have the greatest influence on the structure of the series. In case of three countries –

Japan, France and Germany – we can observe a shift of the dominating harmonics towards shorter periodicities. In all three countries, the most important periodicity is of 13.1 quarters, exactly the same as for the BDI. For two of these countries – Japan and Germany - the same pair of harmonics dominates as in case of the BDI, i.e. of 13.1 and 15.3 quarters.

Table 5. Characteristic of the significant harmonics of the cyclical component of the PI according to countries.

| Number of harmonic | Frequency | Period [quarters] | Spectral density |
|---|---|---|---|
| **USA** | | | |
| 3 | 0.036 | 30.6 | 170.77 |
| 4 | 0.043 | 23.0 | 136.22 |
| 5 | 0.054 | 18.4 | 59.14 |
| 9 | 0.098 | 10.2 | 32.51 |
| **Great Britain** | | | |
| 4 | 0.043 | 23.0 | 87.24 |
| 5 | 0.054 | 18.4 | 36.40 |
| 7 | 0.076 | 13.1 | 37.77 |
| 9 | 0.098 | 10.2 | 21.31 |
| **Japan** | | | |
| 3 | 0.036 | 30.6 | 285.42 |
| 4 | 0.043 | 23.0 | 213.47 |
| 6 | 0.065 | 15.3 | 294.22 |
| 7 | 0.076 | 13.1 | 323.59 |
| 9 | 0.098 | 10.2 | 119.94 |
| 12 | 0.130 | 7.6 | 182.66 |
| **France** | | | |
| 3 | 0.036 | 30.6 | 110.38 |
| 4 | 0.043 | 23.0 | 114.20 |
| 5 | 0.054 | 18.4 | 99.52 |
| 7 | 0.076 | 13.1 | 141.54 |
| **Germany** | | | |
| 3 | 0.036 | 30.6 | 236.98 |
| 4 | 0.043 | 23 | 245.57 |
| 6 | 0.065 | 15.3 | 271.00 |
| 7 | 0.076 | 13.1 | 316.95 |
| **Italy** | | | |
| 3 | 0.036 | 30.6 | 121.86 |
| 4 | 0.043 | 23.0 | 255.64 |
| 6 | 0.065 | 15.3 | 183.78 |
| 7 | 0.076 | 13.1 | 203.78 |
| 9 | 0.098 | 10.2 | 90.29 |

What distinguishes the cycles based on the GDP and the PI is that for the PI fluctuations of shorter duration (of 13.1 quarters) are more important. This means that the characteristics of the freight cycles are more similar to those of the PI cycles than of the GDP cycles.

In the next part of the analysis consisted in calculating the squared coherency and the time shift by taking into account the statistically significant variables. The squared coherency, which measures to what extent the variables correlate for a given period length, is presented in table 6.

Table 6. Squared coherency between the PI and the BDI.

| USA | Great Britain | Japan | Germany | Italy | France |
|---|---|---|---|---|---|
| **18.4** | | | | | |
| 0.44 | 0.40 | - | - | - | 0.47 |
| **15.3** | | | | | |
| - | - | 0.81 | 0.59 | 0.75 | - |
| **13.1** | | | | | |
| - | 0.92 | 0.94 | 0.80 | 0.96 | 0.84 |

The correlation between the variables is not the same for all frequencies. The obtained results show a very pronounced correlation for the periodicities of 15.3 and 13.1 quarters. In most cases the factors exceed 0.80.

The next step was to verify the time shifts of the freight indices with regard to the reference indicator, i.e. the PI, for the analyzed harmonics (table 7).

Table 7. Time lags L(ω) between the PI and the BDI [quarters].

| USA | Great Britain | Japan | Germany | Italy | France |
|---|---|---|---|---|---|
| **18.4** | | | | | |
| -3.40 | -2.25 | - | - | - | -5.62 |
| **15.3** | | | | | |
| - | - | -0.39 | -0.37 | -0.51 | - |
| **13.1** | | | | | |
| - | 0.25 | 0.06 | 1.36 | -0.04 | 1.15 |

The calculations show that, for the period of 18.4 quarters, the freight cycle is lagged in relation to the PI. For the other two analyzed periodicities, however, the BDI is in most cases of a coincident or leading nature in relation to the PI. Limited time shifts (-1.1) allow to qualify the BDI as a coincident indicator. This is the character of the BDI with regard to 15.3 quarters for Japan, Germany and Italy as well as for the period of 13.1 quarters for Great Britain, Japan and Italy. Only in case of Germany and France the factors exceeded a quarter for the period of 13.1 quarters, which means that in these situations the BDI is a leading indicator in relation to the PI.

## 4. CONCLUSIONS

This article presents an analysis of the connections between business cycles and the freight index for the dry bulk cargo market, and in particular the determination of the significance of fluctuations in the economic activity for the cyclical changes of the analyzed freight market.

Based on BDI time series, the hypothesis that the periodicity on the freight market is not a collection of random fluctuations but that regular cycles can be found within the internal structure, was verified. The established dominating length of cycles on the freight market is contained within the period which is equated in the literature with the length of business cycles (8-32 quarters). In terms of the classical division of economic cycles, the established freight cycles are contained in the periodicity of the Kitchin and Juglar cycles.

The determined freight cycles were compared with the business cycles assumed for the analysis of the countries. The research was conducted so as to determine, if there is a common periodicity for both groups of variables. The analyses revealed common periodicities for the business cycles and the freight cycles. The length of the cycles was determined. The dominating lengths of the freight cycles – 13.1, 15.3 and 18.4 quarters – belong to the group of significant periodicities of the GDP and the PI for all analyzed countries. A greater convergence can be observed when comparing the internal structure of the BDI to the PI than when comparing it to the GDP. This is particularly obvious with regard to the cycle period of 13.1 quarters. In case of France, Japan and Germany, both for the BDI and the PI, this period was identified as the one with the greatest influence on the periodicity.

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