Statistical Methodology for Evaluating Business Cycles with the Conditions of Their Synchronization and Harmonization

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Additional information is available at the end of the chapter

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Abstract

The importance of the topic of business cycle research and their interaction is due to the fact that the cyclical nature of development is a universal feature of the market economy (regardless of the level of development of the country's economy and the principles of its organization). In all cases, cyclical ups and downs depend not only on internal system cyclical processes and their factors in countries but also on the consequences of intercountry interaction. The ability to measure and predict business cycles, taking into account their mutual influence, is a prerequisite for the development of an adequate business policy of countries and their associations.

Keywords: business cycle, indicator, synchronization, harmonization, principle component, modeling

1. Introduction

This chapter is devoted to the substantiation of methods of statistical assessment and modeling of macroeconomic business cycles on the basis of their understanding as an integrated effect of changing business phases in different sectors, as well as the impact of synchronization and harmonization of business cycles in both the economy of one country and the intercountry levels.

The main directions of quantitative research of business cycles based on the econometric approach, which are widely presented in the literature, fall into two main groups. The first of these is the identification of stable cyclic components in the dynamics of macroeconomic indicators. In most cases, the authors of scientific publications use the real GDP (gross domestic product), as an indicator for investigation of macroeconomic business cycle. The development of this direction is the study of the interplay of the "total" business cycles identified in the GDP dynamics by countries. The second direction is the definition and quantitative description of the cyclic components in the dynamics of indicators characterizing the processes in individual sectors or spheres of the economy. The "specific cycles" thus estimated are the basis for the identification and quantification of the so-called common cycle using cluster analysis methods. In this case, the "common" (or as it is also called the "reference") cycle is represented as a multivariate value of the actual reaction of individual industries or economic subsystems, e.g., financial, investment, labor market, etc., observed with the help of statistical indicators. This chapter proposes a method for identifying and quantifying the common business cycle as a directly unmeasurable phenomenon, which manifests itself in fluctuations in the dynamics of the specific indicators of industries and economic systems, but has an objective and independent economic nature. In the author's opinion, specific cycles, even if they have a leading character with respect to the general cycle, are its economic consequence. The chapter suggests methods and their applications for identifying and quantifying the macroeconomic business cycle as a latent system-wide phenomenon, as well as methods for estimating intercountry synchronization and harmonization of common cycles. At the same time, the author gives her own definition of these forms of the interaction of business cycles. This approach is different to the view expressed in many publications about the identity of the concepts of synchronization, harmonization, concordance, and correlation of business cycles.

The chapter in addition to this introduction includes two main sections and a conclusion. The first section is devoted to the review of scientific publications that disclose the concept of the "business cycle," and also this section presents the author's systematization of the methods outlined in a number of publications for identifying cyclic components in the dynamics of macroeconomic indicators. In the second section of the chapter, an algorithm for quantifying the overall business cycle based on the principal component method is proposed, and methods for estimating synchronization and harmonizing business cycles are substantiated. The conclusion of the chapter contains a concentrated expression of scientific novelty of the author's methodological proposals of the business cycle quantification and the features of the algorithms for evaluating their synchronization and harmonization at the macroeconomic level.

The proof of the concept proposed in this chapter and the approbation of the corresponding algorithm were realized on the basis of statistics of Eurostat and Rosstat. Most of the examples in this chapter are compiled from the results of calculations for Germany and Russia, which allows a comparative analysis provided that there is a significant difference in the duration and stages of the history of the market economy that have a significant impact on the formation of sustainable multi-year business cycles.

Approbation of the proposed algorithm can be based on R-packages or the "STATISTICA" program.

2. A literature review of the definition of a business cycle and methods for extracting cyclic components

The number of scientific papers devoted to the theory and methods of quantifying business cycles is measured in hundreds. Nevertheless, there is a basis for their distribution into two large parts.

This basis is the definition of the concept of fluctuations in economic activity. This determines the choice of mathematical and statistical methods used to determine business cycles (Kijek [20]).

The first part includes the papers which are based on Burns and Mitchell's definition of a cycle [3]. According to them, a business cycle represents the four distinct phases of "aggregate economic activity" development that evolve from one into another: expansion, recession, depression, and revival.

The second part is the works based on a different view of business cycles, which was presented by Lucas [23], who does not interpret cycles as inevitable transitions between different phases of the cycle. He sees the business cycle as a process of oscillation of GNP around a long-term trend.

Some authors define the business cycle in accordance with Burns and Mitchell and then continue to measure the fluctuations of the macroeconomic aggregate values (GNP, GDP, industrial production, investment, and so on) relatively to the long-term trend.

This approach cannot be adopted without a preliminary study confirming that the observed cyclicality of the national economy is a violation of macroeconomic equilibrium rather than synchronous periodic fluctuations of various economic activities without changing of their balance.

The two basic approaches to the definition of the concept of a business cycle, mentioned above, were the basis for developing analytical tools for recognizing cycles.

Harding and Pagan [17] define three directions ("traditions") in the deviation of approaches presented in the literature on the development of cycle indicators from information available in a time-continuous random variable (yt).

The main idea of the first direction is changing of the initial time series (yt) by a series of binary random variable St, which includes turning points. In this case, peaks (troughs) are considered as local maxima (minima) in the series yt, and they are taking the value unity and zero otherwise:

$$\begin{aligned} \vee \mathrm{t} &= 1\ \left(y_t < y_{t\pm1} \le \mathrm{j} \le \mathrm{k}\right); \\ \wedge \mathrm{t} &= 1\ \left(y_t < y_{t\pm1} \le \mathrm{j} \le \mathrm{k}\right). \end{aligned} \tag{1}$$

where ∨t (∧t) are binary variables and k is the length of period for local maxima (minima) estimation.

Harding and Pagan [18] show that for Burns and Mitchell's specific cycle dating procedures it is necessary to set k = 5 for monthly data or k = 2 for quarterly data, but it is not the single variant. Mathematics and IT providing of extracting and estimation of turning points in structure of economic time series have been actively developing.

Other two directions, or "traditions," by Harding and Pagan [17] are combined because they both are based on the prior transformation of yt so as to remove a permanent component, leaving only a transitory one (zt). The first direction of them provides for the isolation of the cycle on the basis of an analysis of the presence or absence of peaks in the spectral density. The second direction combines the methods of extracting a cycle by the results of the analysis of serial correlations in zt series.

The abovementioned approach to the systematization of methods for extracting and quantifying cycles in long-term economic dynamics, set forth in papers of Harding and Pagan, is accepted by many scientists, but is not the only one. An example of a somewhat different classification of methods for isolating stable fluctuations reflecting business cycles is presented in the paper of Kijek [20].

According to this author's view, three dominant approaches are used to distinguish cycles. Two of them coincide with the groups of methods singled out by Harding and Pagan (the last two "traditions"). They are (1) the presentation of the time series as a difference-stationary process and the application of autoregressive integrated moving average (ARIMA) models and (2) the presentation of economic dynamics as a trend-stationary process and treat it as a sum (but also it can be multiple interconnection) of polynomial as deterministic trend and stochastic deviation around it. The last one is considered as a residual cyclical component, which includes business cycle's pattern and random deviation.

The third concept of time series decomposition according to Kijek [20] is the use of frequency filters, methodology, and software which are widely represented in the statistical literature.

Some authors include in the classification of methods for extracting from the time series of macroeconomic indicators of cyclic components adequate to real business cycles and groups of methods based on the evaluation of regression model parameters (such as the Fourier series models and multifactor models of the dependence of the cyclicality of GDP on the dynamics of factor variables).

We consider that it is not the methods of extraction of business cycles, but the methods for the next step of business cycle analysis—the quantification of cycle's characteristics (such as its phases, amplitude, duration of the period, and others).

The results of grouping of methods for extraction of cyclic components from the time series of macroeconomic indicators in conditions of its primly seasonal adjusting are presented in **Figure 1**. They include the group of "turning point" methods: methods for spectral density analysis and their realization with band-pass filtering (the statistical tools that *pass frequencies within a certain range and reject frequencies outside that range*) and methods for determining and subsequently evaluating cyclic components. We will not dwell on detrending methods in detail, since they are detailed in the articles, including in connection with the algorithms for isolating and quantifying the cycles (e.g., Canova [4]).

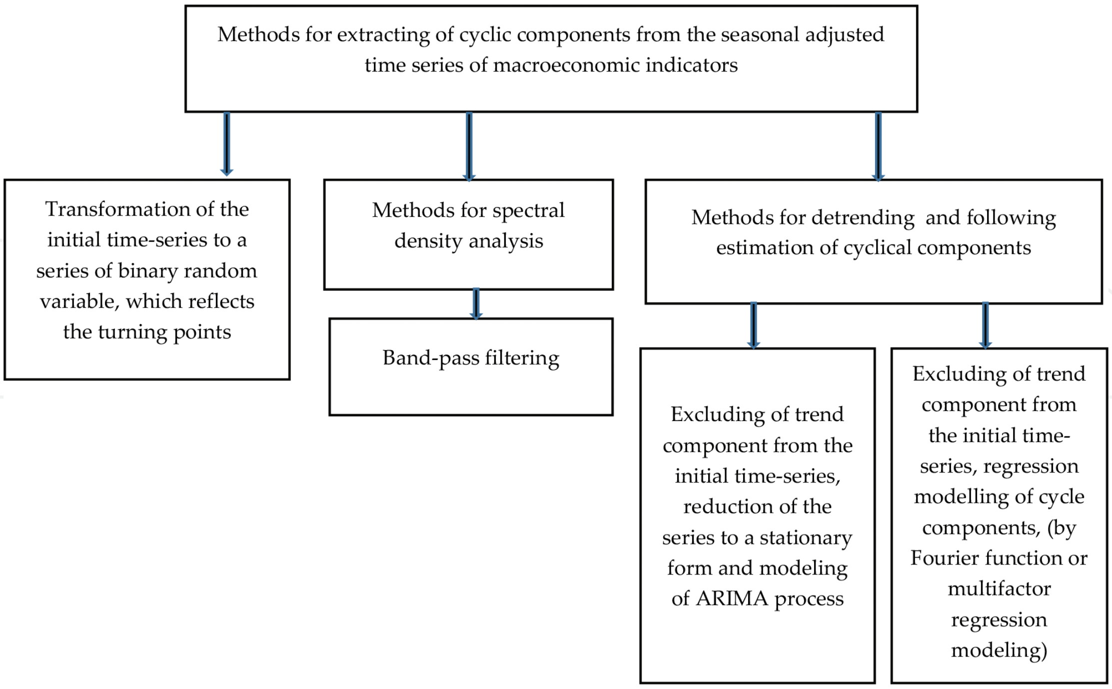

Figure 1. System of methods for extraction of cyclic components from the seasonal adjusted time series of macroeconomic indicators.

The above methods are detailed and combined in different documents, but we must take into account that "The crucial question is not which method is more appropriate but whether different concepts of cycle are likely to produce alternative information which can be used to get a better perspective into economic phenomena and to validate theories" (Canova [4]).

The purpose of this paper is to create and demonstrate the results of the application of the algorithm of business cycle synchronization and harmonization proceed from economic content definition of business cycle by Burns and Mitchell and methods of estimation of economic fluctuations presented in publications. The main idea of it is based on the two key features in Burns and Mitchell's definition of business cycles. They are determined in many articles in the same variant. For example, in the paper of Diebold and Rudebusch ([8], p. 1), we can read "The first (key feature) is the comovement among individual economic variables…In their analysis, Burns and Mitchell considered the historical concordance of hundreds of series, including those measuring commodity output, income, prices, interest rates, banking transactions, and transportation services…The second prominent element of Burns and Mitchell's definition of business cycles is their division of business cycles into separate phases or regimes."

We believe that the first point should be based on another focus of "aggregate economic activity" in determining the business cycles of Burns and Mitchell: not only as a combination of the abovementioned indicators characterizing aggregate economic activity but above all the multiple effect of the entry of various economic activities into one and the same phase of the business cycle (the second key features in Burns and Mitchell's definition of business cycles).

Consequently, at the macroeconomic level, the economic cycle is an integral result of business cycles of different economic activities that are at different or equal (to a greater or lesser extent) phases of the "common"[1] cycle.

According to this idea, we included following two points in the practical part of this article:

1. Explanation of the applied algorithm for measuring the business cycle in relation to different types of economic activities by countries and conducting cross-country analysis.
2. Interpretation of synchronization and harmonization of business cycles as economic definitions and their evaluation at the macroeconomic level.

3. Algorithm for the quantification of business cycles, their synchronization and harmonization, and its application

Measuring business cycles is necessary and usually the starting point of their research. Measurement in this context means quantifying the following characteristics of a business cycle (2002):

- The duration of the cycle and its phases
- The amplitude of the cycle and its phases
- Any asymmetric behavior of the phases
- Cumulative movements within phases

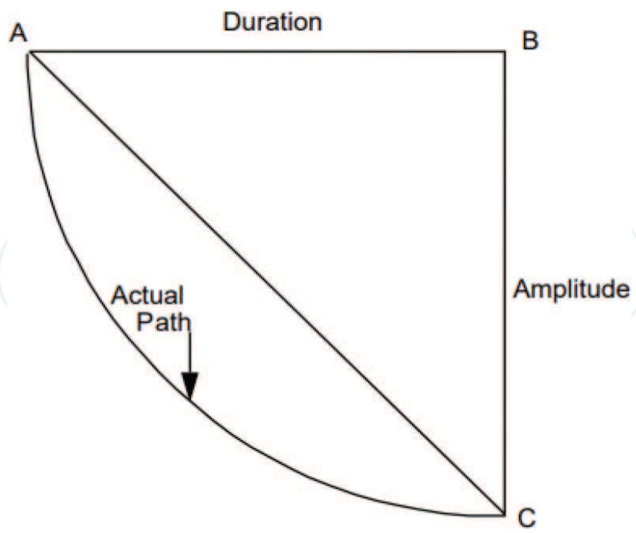

Figure 2. Stylized recession phase (Harding and Pagan [16]).

[1]The idea of the "common cycles" is presented by A. S. Blinder and S. Fischer [2].

Harding and Pagan [16] graphically showed and explained the ratio of the peak (A) and the trough (C) as an example of a stylized recession (**Figure 2**). The height of the triangle in this graph is the amplitude, and the base is the duration. In this article, the authors also rightly notice that the knowledge of these two elements for any cycle makes it possible to calculate the area of the triangle and thereby estimate (say) the total loss in the output from the peak to the trough.

For the purposes of quantification of the synchronization and harmonization of business cycles on the macroeconomic level and further cross-country comparison, we suggest the following algorithm, presented in **Figure 3**.

At the first stage of our algorithm, we extract trend, cyclical, and irregular components of the initial seasonal and calendar adjusted time series of quarterly indicators of gross value added by the types of activity (sectors) by country. Examples of implementation of the proposed algorithm of band-pass filtering and the following analysis are based on the seasonal and calendar adjusted time series of quarterly indicators of gross value added by the types of activity (sector) represented by Eurostat[2] and Rosstat[3]. The indicators used are presented in fixed prices and converted to the natural logarithm, so they reflect the relative growth of the value added, forming the output of gross domestic product (GDP).

According to the approach of Baxter and King [1], the ideal band-pass filter should satisfy the six requirements:

1. The filter must extract the specified range of periodicity, which means that it passes through time series components with periodic oscillations between low and high frequencies, defining a specific cycle. Baxter and King recommend a filter that approximates periodic oscillations between 6 and 32 quarters (according to the definition of the Mitchell cycle).

2. An ideal band-pass filter should not introduce a phase shift, i.e., do not change the time stamps of the turning points at any frequency.

3. The expression of the discrepancy between the exact and approximate filters should be expressed mathematically.

4. The application of the band-pass filter must extract of a deterministic trend from a time series and result in a stationary time series, even when applied to trending data.

5. The filter should allocate the same components of the business cycle, regardless of the length of the observation period. Baxter and King notes that "Technically, this means that the moving averages we construct."

6. Method of filtering must be operational.

[2]Eurostat: http://ec.europa.eu/eurostat
[3]Russian Federal State Statistics Service (Rosstat): http://www.gks.ru

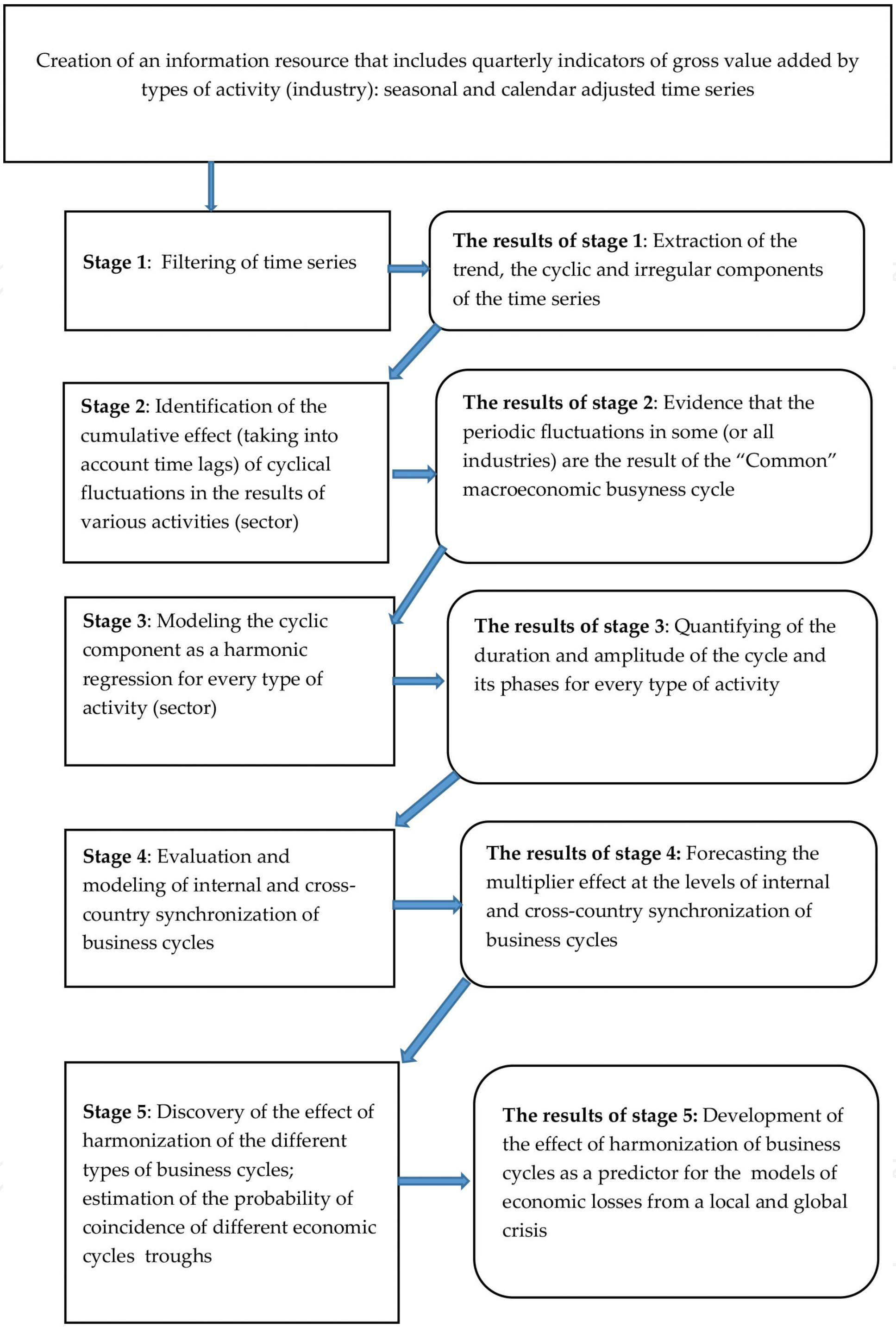

Figure 3. An algorithm for quantifying business cycles and their synchronization and harmonization at the macroeconomic level.

We applied two filters for calculations, which are widely represented in the economic literature: the Hodrick-Prescott (HP) filter and the Baxter-King (BK) filter. These filters, calculated in the "mFilter" package of R-CRAN [26], largely meet the above requirements.

Figure 4 shows that HP and BK filters on quarterly data give very close results.

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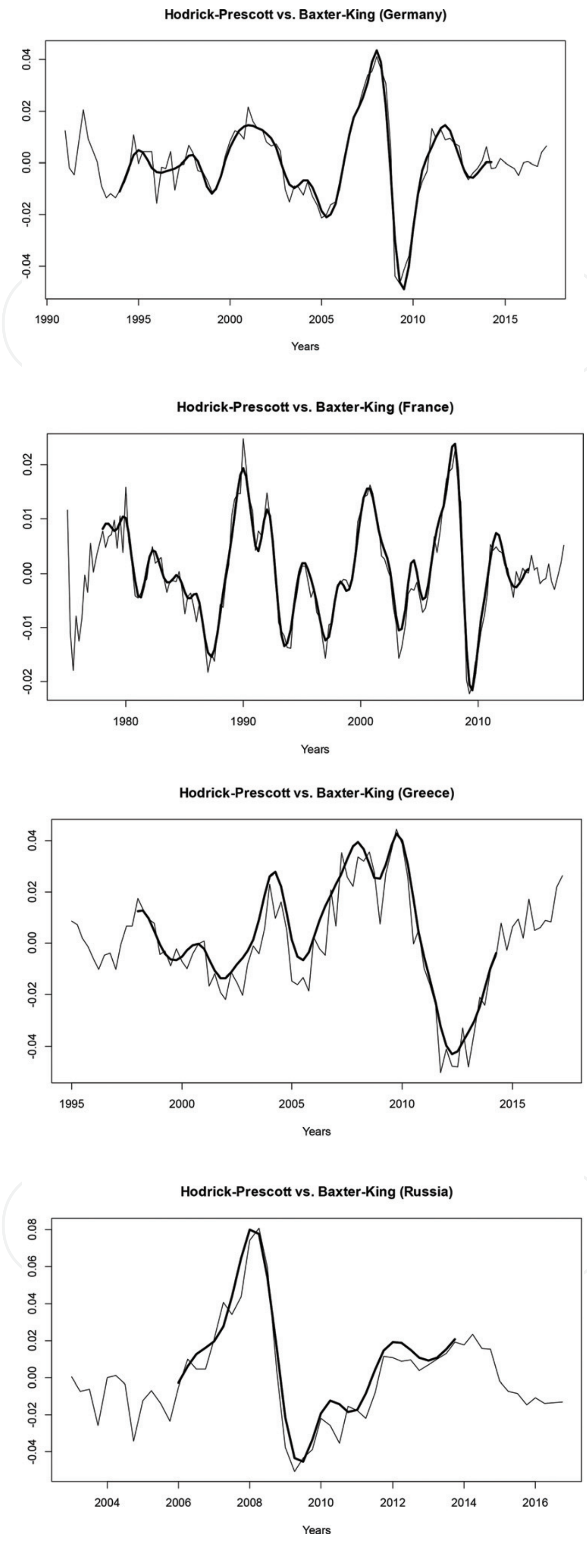

Figure 4. Comparison of business cycles extracted by filters HP (gray line) and BK (black line): Germany, France, Grease, and Russia.

The difference of the application of HP and BK filters is opened by Baxter and King [1]. As they note, the BK filter is easier in design and gives more exact results for data sampled at other-than-quarterly frequencies. However, the HP filter provides a longer cycle curve, because it is not based on moving average calculation (we can see it on **Figure 3**: the black line is shorter than the gray line).

Because we use the quarterly data by country, the HP filter is more suitable for business cycle extraction as a basis of further analysis.

At **stage 2** of our algorithm, we will evaluate the delays and correlations between the "total" business cycle reflected by the GDP curve and the business cycles of various economic activities (sectors) presented by added value curves, and on this basis, we will estimate the "common" cycle as the result of aggregating specific cycles by sectors. This approach corresponds to Mitchell's definition of business cycle presented above in this paper.

According to our approach, the difference between "total" and "common" cycle consists in the following:

"Total" cycle is a cyclical curve of any macroeconomic statistical indicator chosen for the purposes of measurement and analysis of business cycle (usually GDP or in our case the gross value added as a sum of added value by sectors (analogue of GDP). "Common" business cycle is a result of aggregation of different phases of sector's business cycles. The modern scientific problem is measurement of leading or lagging sector's business cycles relatively "common" cycle.

Coincidence of "total" and "common" cycles confirms the correctness of choosing the statistical indicator for measurement of business cycle on the macroeconomic level.

The results are presented by two countries (Germany and Russia) because of the limitation of an article volume.

The results presented in **Table 1** make it possible to conclude that in Germany the sectors enter the general cycle not simultaneously. Analyzed types of activities can be divided into three groups:

1. Industry production, information, and communications are the "leading" activities. Their phases are two quarters earlier as the same phases of the "total" cycle, reflected by fluctuations of the gross value added indicator. We can name them as "pro-cyclical," because they have the same (parallel) phases and shift peaks, relatively the peaks of "total" cycle in time (also as a shift of trough).

2. Agriculture, forestry and fishing, real estate activities, public administration, defense, education, health and social work are the economic activities which have lagging and "counter-cyclical" phases relatively the "total" cycle.

3. Construction, wholesale and retail, transport, accommodation and food service activities, financial and insurance activities, professional, scientific and technical activities and arts, entertainment and recreation, and other types of activities show simultaneous entry into the same phases with a "total" cycle. As the first group, these activities are "pro-cyclical."

Similar analysis for Russia (**Table 2**) led to the conclusion that the majority of sectors (D, F, G, H, I, J, K, N, O) show simultaneous and "pro-cyclical" oscillations with the "total" cycle. Such

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Types of activity (sectors) according to NACE2	Code	Lags of correlation with the "total" cycle in quarters				
		Lag = 0	Lag = −2	Lag = −4	Lag = −6	Lag = −8
Agriculture, forestry, and fishing	A	–	–	−0.343	−0.221	–
Industry (except construction)	B–E	0.840	0.855	0.320	–	−0.310
Manufacturing	C	0.857	0.863	0.311	–	−0.338
Construction	F	0.492	0.487	–	–	–
Wholesale and retail, transport, accommodation, and food service activities	G–I	0.803	0.802	–	−0.265	−0.419
Information and communication	J	0.568	0.573	–	–	−0.281
Financial and insurance activities	K	0.545	0.386	0.231	–	−0.293
Real estate activities	L	–	–	−0.266	−0.316	−0.307
Professional, scientific, and technical activities	M–N	0.680	0.680	–	–	−0.418
Public administration, defense, education, human health, and social work	O–Q	–	–	−0.321	−0.307	–
Arts, entertainment, and recreation: other service activities	R–U	0.479	0.471	–	–	–

Note: Dash indicates a statistically insignificant correlation

Table 1. Spearmen correlation coefficients of "total" business cycle estimated by gross value added and business cycles on different types of activity (sectors) with different lags of influence (in quarters of year) (Germany).

actions as "mining" and "public administration and defense and social security," demonstrate a statistically significant lagging "countercyclical" effect.

On the basis of the results of the previous stage of analysis, we can create a "common" cycle model as an aggregate of business cycles of various types of activity, taking into account their correlation and lagging effect interconnection with "total" cycle, which in this case plays the role of "connection bridge" between the business cycles of different types of activity and "common" cycle as a latent variable.

This conceptual approach determines the possibility of solving the problem of "Common" cycle estimation with the methodology of principle component analysis.

The factor loadings to "common" cycle are presented in **Table 3**. This and the following tables are the copies of the reports on the performed calculations in the software package of statistical analysis "STATISTICA," which gives an opportunity to imagine the practical side of the research (**Tables 3–5**).

The general cycle corresponds to the first principle component, since it is characterized by significant statistical relationships[4] with most types of activity, i.e., manifests its effect of the aggregated cycle by Mitchell's definition of business cycle. In both cases the first principle component will explain about 40% of the variance of the initial feature space.

[4]The statistically significant correlations are marked in red.

Types of activity (sectors) according to NACE2	**Code**	**Lags of correlation with the "total" cycle in quarters**				
		Lag = 0	**Lag = −2**	**Lag = −4**	**Lag = −6**	**Lag = −8**
Agriculture, hunting, and forestry	A	–	–	−0.381	−0.378	−0.295
Fishing and fish farming	B	–	0.281	–	–	–
Mining	C	–	–	–	0.437	0.598
Manufacturing	D	0.791	0.754	0.421	–	–
Production and distribution of electricity, gas, and water	E	–	–	–	–	0.313
Development	F	0.853	0.589	–	–	−0.423
Wholesale and retail trade, repair of motor vehicles, motorcycles, household goods, and personal items	G	0.901	0.670	0.231	–	−0.293
Hotels and restaurants	H	0.864	0.598	–	–	-0.493
Transport and communications	I	0.732	0.644	0.391	–	–
Finance	J	0.683	0.415	–	–0.337	–0.656
Real estate, renting, and business activities	K	0.531	–	–	–0.457	–0.744
Public administration and defense and social security	L	–	−0.309	−0.508	−0.563	−0.551
Education	M	–	–	−0.307	–0.336	–
Health and social services	N	0.663	0.349	–	–	–0.304
Other community and social and personal services	O	0.635	0.382	–	–	–0.512

Table 2. Spearmen correlation coefficients of "total" business cycle estimated by gross value added and business cycles on different types of activity (sectors) with different lags of influence (in quarters of year) (Russia).

In **Figures 5** and **6**, we can see the difference in the adequacy of the reflection of the business cycle in Germany and in Russia with the statistical indicator "gross value added" (accounting for almost 100% of GDP produced) (but in both cases, there are high correlation coefficients: 0.954 and 0.837).

Modeling the cyclic component as a harmonic regression on **stage 3** of our algorithm is necessary for quantifying the duration and amplitude both the "common" and specific cycles of different types of activity (sectors). For these purposes, it is expedient to use a Fourier series —the periodic function with a finite number of elements.

The business cycles extracted with the HP filter in accordance with the expansion of the Fourier series can be represented as a periodic function of time ($\hat{y}_t$) in order to decrease the number of allocated harmonics, (i):

$$\hat{y}_t = a_0 + \sum_{1}^{i} \left\{ a_{ij}\sin\left(b_{ij}t + k_{ij}\right) + a_{ij}\cos\left(b_{ij}t + k_{ij}\right) \right\}, \tag{2}$$

where $\hat{y}$ is the harmonic model of the business cycle

a_0 , a_{ij}, b_{ij}, and k_{ij} are the parameters of the harmonic model of the business cycle

j is the number of parameters

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Factor loadings (Germany)

Variable	Factor 1	Factor 2	Factor 3	Factor 4
A_HP_cycle	0,198073	0,785048	0,129719	-0,108655
B-E_HP_cycle	-0,863405	-0,334347	0,075096	-0,175139
C_HP_cycle	-0,877166	-0,340340	0,058312	-0,160360
F_HP_cycle	-0,501404	-0,328351	0,375376	0,463128
G-I_HP_cycle	-0,801096	0,048955	-0,075760	-0,327621
J_HP_cycle	-0,581831	0,627588	-0,213228	0,073480
K_HP_cycle	-0,478678	0,384939	-0,435818	0,335469
L_HP_cycle	0,083806	0,161735	0,298852	-0,783388
M_N_HP_cycle	-0,856272	0,211469	0,024162	-0,022431
O-Q_HP_cycle	0,126418	0,207386	0,804045	0,209514
R-U_HP_cycle	-0,508612	0,348817	0,434247	0,151990
Expl.Var	4,029837	1,731736	1,332873	1,189153
Prp.Totl	0,366349	0,157431	0,121170	0,108105

Factor loadings (Russia)

Variable	Factor 1	Factor 2	Factor 3	Factor 4
A_HP_cycle	0,094444	0,080303	-0,210250	0,508336
B_HP_cycle	0,070069	-0,345123	0,437569	0,650009
C_HP_cycle	0,136829	-0,796738	0,222348	-0,217219
D_HP_cycle	0,876800	-0,273916	0,130628	-0,069699
E_HP_cycle	0,269795	-0,829359	-0,119065	-0,051618
F_HP_cycle	0,891412	0,095851	-0,064286	0,230713
G_HP_cycle	0,881254	0,111121	0,265041	0,096117
H_HP_cycle	0,922355	0,185863	0,052287	0,108052
I_HP_cycle	0,895478	-0,041845	-0,074617	-0,124972
J_HP_cycle	0,618859	0,466097	0,364537	0,339480
K_HP_cycle	0,581893	0,675720	-0,096186	0,231458
L_HP_cycle	-0,008477	0,251555	0,110716	0,740297
M_HP_cycle	-0,014588	0,115452	-0,892138	0,064979
N_HP_cycle	0,484983	0,273436	0,582791	0,126600
O_HP_cycle	0,838983	0,139996	-0,161603	0,178450
T_HP_cycle	0,970514	-0,156671	0,052845	0,015257
S_HP_cycle	0,106961	0,280366	-0,147597	0,877965
NT_HP_cycle	0,959853	-0,178622	0,127146	-0,032557
Expl.Var	7,633587	2,560923	1,755843	2,366452
Prp.Totl	0,424088	0,142274	0,097547	0,131470

Table 3. Factor loadings of specific cycles of the types of activity to "common" cycle latent variable (with lagging effect of influence).

A. Parameters of the harmonic model of the "Common" business cycle

Dep. Var. : Com
Level of confidence: 95.0% (alpha=0.050)

	Estimate	Standard error	t-value df = 93	p-value	Lo. Conf Limit	Up. Conf Limit
a0	-0,0555	0,048280	-1,1504	0,252934	-0,1514	0,0403
a1	0,5742	0,070292	8,1691	0,000000	0,4346	0,7138
b1	0,4807	0,004161	115,5311	0,000000	0,4724	0,4889
k1	-18,5253	0,252296	-73,4268	0,000000	-19,0263	-18,0243
a2	-0,5185	0,071880	-7,2128	0,000000	-0,6612	-0,3757
b2	0,3876	0,005044	76,8433	0,000000	0,3776	0,3976
k2	-4,3764	0,301399	-14,5204	0,000000	-4,9750	-3,7779
a3	0,9591	0,070957	13,5167	0,000000	0,8182	1,1000
b3	0,2391	0,002912	82,1234	0,000000	0,2333	0,2449
k3	-1,7077	0,173945	-9,8172	0,000000	-2,0531	-1,3622
a4	0,7546	0,069935	10,7905	0,000000	0,6158	0,8935
b4	0,3217	0,004306	74,7113	0,000000	0,3132	0,3303
k4	-14,5931	0,241599	-60,4019	0,000000	-15,0728	-14,1133

Multiple correlation coefficient: R=0.892

B. Parameters of the harmonic model of the Manufacturing type of activity, (sector "C"), business cycle

Dep. Var. : C
Level of confidence: 95.0% (alpha=0.050)

	Estimate	Standard error	t-value df = 93	p-value	Lo. Conf Limit	Up. Conf Limit
a0	-0,008	0,003387	-0,2231	0,823970	-0,0075	0,0060
a1	-0,315	0,004729	-6,6675	0,000000	-0,0409	-0,0221
b1	3,091	0,006163	50,1595	0,000000	0,2969	0,3214
k1	-88,83	0,391287	-22,7020	0,000000	-9,6600	-8,1060
a2	0,062	0,004673	1,3285	0,187255	-0,0031	0,0155
b2	0,876	0,027448	3,1903	0,001938	0,0331	0,1421
k2	24,191	1,777769	1,3607	0,176888	-1,1112	5,9494
a3	-0,265	0,004596	-5,7744	0,000000	-0,0357	-0,0174
b3	3,896	0,006292	61,9178	0,000000	0,3771	0,4021
k3	-148,036	0,392890	-37,6786	0,000000	-15,5838	-14,0234
a4	0,263	0,004761	5,5150	0,000000	0,0168	0,0357
b4	2,352	0,008097	29,0474	0,000000	0,2191	0,2513
k4	-88,399	0,480367	-18,4024	0,000000	-9,7938	-7,8860

Multiple correlation coefficient: R=0.730

Table 4. Parameters of the harmonic models: (**A**) of the "common" business cycle and (**B**) of the manufacturing type of activity (sector "C") business cycle with estimations of their significance level *(p-value)* and confident intervals; Germany.

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A. Parameters of the harmonic model of the "Common" business cycle

Dep. Var. : Com
Level of confidence: 95.0% (alpha=0.050)

	Estimate	Standard error	t-value df = 49	p-value	Lo. Conf Limit	Up. Conf Limit
a0	-0,00379	0,060613	-0,0625	0,950428	-0,12559	0,11802
a1	0,61965	0,129919	4,7695	0,000017	0,35857	0,88074
b1	-0,19593	0,017425	-11,2443	0,000000	-0,23095	-0,16092
k1	9,01859	0,563702	15,9989	0,000000	7,88579	10,15139
a2	0,59223	0,129472	4,5742	0,000033	0,33205	0,85242
b2	0,26375	0,016224	16,2565	0,000000	0,23114	0,29635
k2	-5,00926	0,502540	-9,9679	0,000000	-6,01916	-3,99937

Multiple correlation coefficient: R=0.830

A. Parameters of the harmonic model of the Manufacturing type of activity, (sector "D"), business cycle

Model is: D=a0+a1*sin(b1*t+k1)+a2* cos(b2*t+k2) (RU_циклы_HP — копия
Dep. Var. : D
Level of confidence: 95.0% (alpha=0.050)

	Estimate	Standard error	t-value df = 49	p-value	Lo. Conf Limit	Up. Conf Limit
a0	-0,00047	0,004924	-0,0964	0,923559	-0,01037	0,00942
a1	-0,05082	0,006324	-8,0361	0,000000	-0,06353	-0,03811
b1	0,23708	0,010798	21,9558	0,000000	0,21538	0,25878
k1	-5,29867	0,335539	-15,7915	0,000000	-5,97296	-4,62438
a2	0,03601	0,006526	5,5179	0,000001	0,02290	0,04913
b2	0,39656	0,012630	31,3975	0,000000	0,37118	0,42194
k2	-7,88707	0,402672	-19,5868	0,000000	-8,69627	-7,07787

Multiple correlation coefficient: R=0.730

Table 5. Parameters of the harmonic models: (A) of the "common" business cycle and (B) of the manufacturing type of activity (sector "D") business cycle with estimations of their significance level (*p-value*) and confident interval; Russia.

The following tables (**Tables 4** and **5**) and figures (**Figures 7–10**) present the results of the assessment of harmonic models of "common" business cycles and the most closely related sectoral business cycles for Germany and Russia. We can see that the models as a whole and their parameters are significant.

The theory and methodology of measurement of the business cycle synchronization and harmonization can be divided into two groups: an approach based on the clustering of turning points and the evaluation of the concordance of business cycles.

For the implementation of **stages 3–5** of our algorithm (**Figure 3**), we suggest the next definitions of the synchronization and harmonization of business cycles in the general approach:

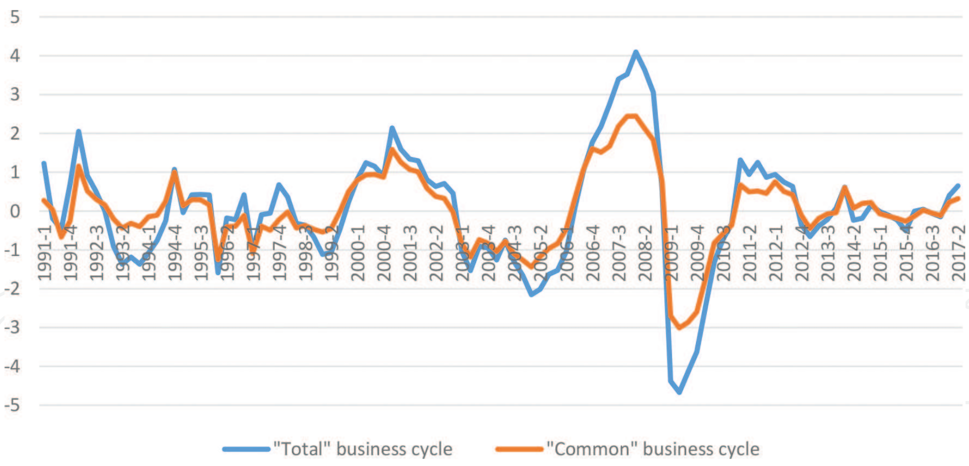

Figure 5. Business cycle graphs in Germany in "total" and "common" presentations.

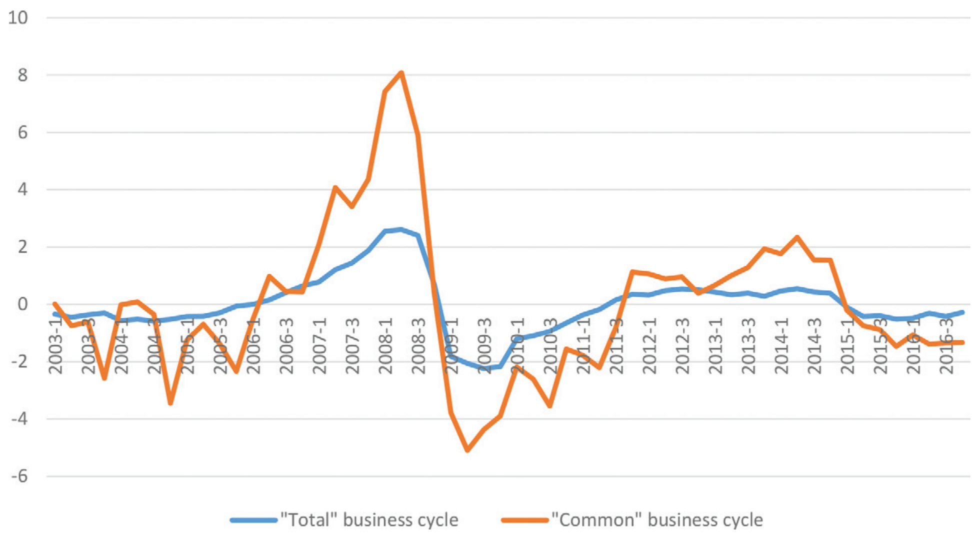

Figure 6. Business cycle graphs in Russia in "total" and "common" presentations.

- Business cycles are synchronous if their curves are parallel, with a possible shift in time.

For the comparison of two cycles, it can be described by the following mathematical conditions for any *i*-harmonics:

$$\begin{cases} \hat{y}_{it(1)} \cong \hat{y}_{it(2)} \\ T_{1,i} \approx T_{2,i}, \quad \text{for any } L_{2,i}\text{, where } L_{2,i} \text{ is any constant time shift } \hat{y}_{it(2)} \text{ relatively } \hat{y}_{it(1)}. \end{cases} \quad (3)$$

According to the theory of the Fourier analysis, for any business cycle harmonic model, the length of the period of the *i*-order harmonic is T(i) = 2π/ (i):

- Business cycles are harmonized if the peaks (or troughs) of these cycles fall on the same time point. The coincidence of the minima of the harmonic waves of such superstrong

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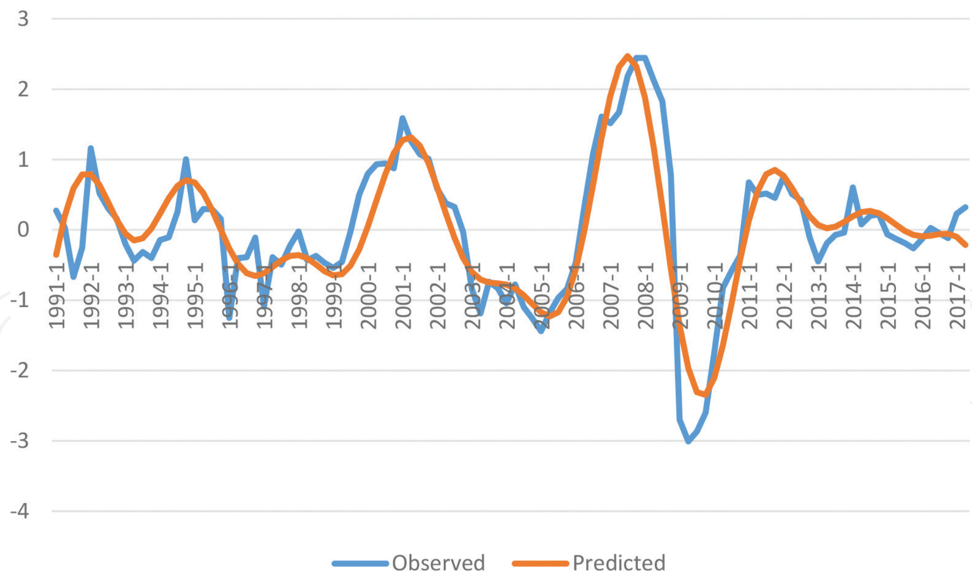

Figure 7. The "common" business cycle in Germany estimated above with principle components method (*observed*) and its harmonic model (*predicted*).

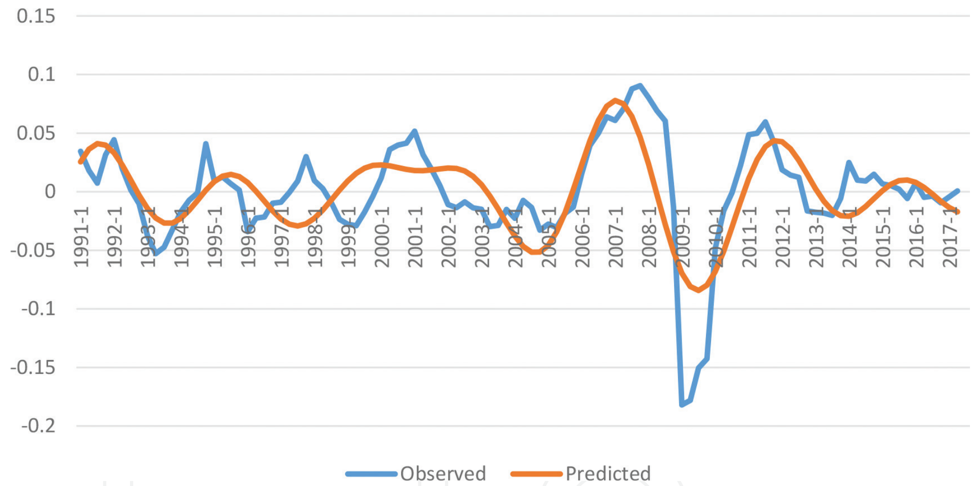

Figure 8. The manufacturing type of activity (sector "C") business cycle in Germany estimated above with principle components method (*observed*) and its harmonic model (*predicted*).

classical cycles as Kondratieff, Kitchin, Juglar, Kuznets, and others is the main cause of global economic crises, such as the 2007–2009 global financial and economic crisis or Great Recession [29]. Using the parameters of harmonic models of "common" and specific (by types of activity) cycles, we can estimate in-country and intercountry synchronization and harmonization of business cycles.

Using the parameters of harmonic models of "common" and specific (by types of activity) cycles, we can estimate in-country and intercountry synchronization and harmonization of business cycles.

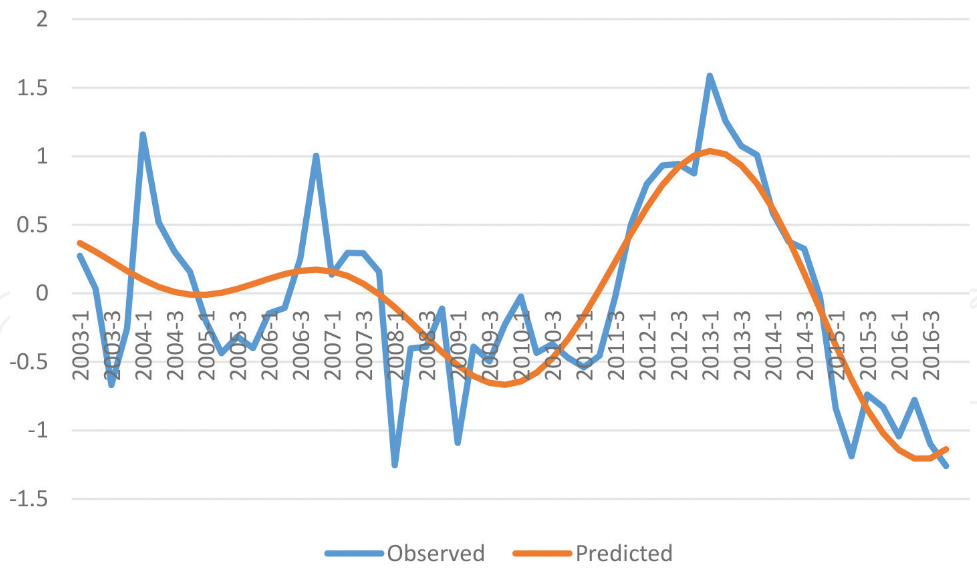

Figure 9. The "common" business cycle in Russia estimated above with principle components method (*observed*) and its harmonic model (*predicted*).

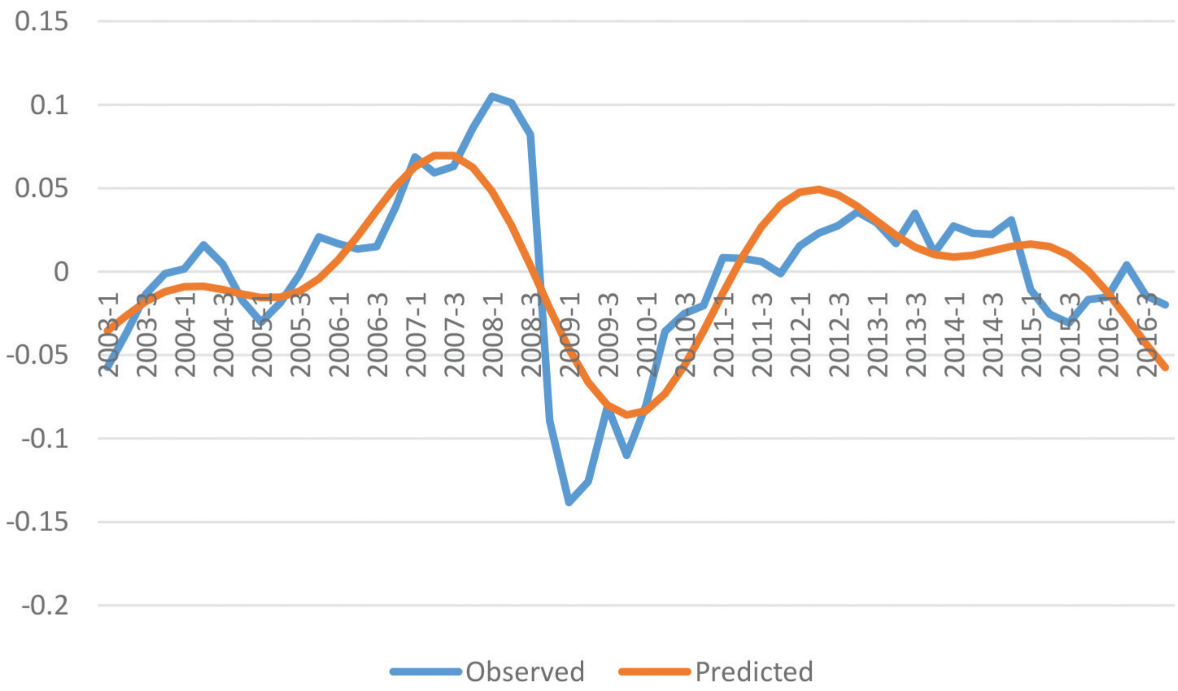

Figure 10. The manufacturing type of activity (sector "D") business cycle in Russia estimated above with principle components method (*observed*) and its harmonic model (*predicted*).

4. Conclusions

The approach proposed and tested in this chapter has a theoretical basis and originality. The theoretical basis of this approach is the classic definition of Mitchell's business cycle with an emphasis on its key position that the business cycle is an integrated multifactorial phenomenon. The effect of integration is understood as the interaction of business cycles of different types of activities (sectors), which are simultaneously at different phases of cyclicality.

The novelty of the approach is to assess the statistical relationship between the indicators of business cycles of sectors of the economy with a certain macroeconomic indicator characterizing the cyclical nature of the economy as a whole and representing a "total" cycle. There is an evaluation of some objective, but not directly measured, "common" cycle.

At the same time, the proposed algorithm takes into account the lagging effect of the mutual influence of business cycles, as well as their synchronization and harmonization.

Measurement of the effect of business cycle synchronization and harmonization is presented on the basis of the construction of harmonic models.

The above examples of calculations for Germany and Russia show the general and distinctive characteristics of the business cycles of these countries.

The results presented in the chapter can serve as a basis for further research in both theoretical and applied aspects. The main areas should be the development of methods for forecasting the entry of the economy into different phases of cyclicality and the expansion of groups of countries for analysis in-country and intercountry interaction of cycles.

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*Refs. 5, 6, 7, 9–15, 19, 21, 22, 24, 25, 27, 28 are recommended for reading for deep understanding of the topic of the article.

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