SPECTRUM ANALYSIS METHOD FOR BUSINESS-CYCLE ISOLATION

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Keywords: economic cycle, business-cycle, state of the market, movement, cyclic component, spectrum analysis, power spectral density, Fourier transform.

This work deals with the analysis of the most frequent economic cycles in literature. The cycle-isolation methodology on the basis of Fourier transform and spectrum analysis is suggested and represented as an algorithm that includes Levinson-Durbin iterative method for optimal power spectral density calculation. As an example short- and long-term cyclic components are isolated in "Lukoil" stock quotes movement.

In the course of time in business systems both qualitative features reflecting the relationships between people during production, distribution and exchange of material goods and quantitative features such as the amount of products, the employment rate, producing capacity utilization, price level, profit, interest rate, money supply, etc. change. As these changes accumulate, the forces that gave them the start increase and the business system starts to move in opposite direction. So business processes continuation has cyclic nature: growth is accompanied by recession without fail, and after that comes the revival and new growth.

The reasons of business cycles may be both internal (fluctuation of aggregate expenditure, renewal of basic production assets, consumption and investment, government economic policy) and external factors (wars, revolutions, major discoveries and inventions, demographic processes). The influence of these factors on the business system depends on its internal structure and the capacity for adapting to change. So, a business cycle is the result of internal self- development process interaction within a business system and an external impulse from the outside.

The problem of cyclicality has always attracted economists and is one of the most disputable and not studied problems. There are more than 1300 types of cyclicality depending on its duration (periodicity) and motive forces.

Economists have been researching the crisis phenomenon and the cyclicality problem in economics from the beginning of 19th century. Many famous scientists studied economic cycles: J. Sismondi, K. Marx, C. Juglar, J. Schumpeter, A. Gelfand, J.van Gelderen, S. de Volff, N.Kondratiev. There are a lot of theories of economic cycles. The main types of cycles are:

1. Long-term cycles:

♦ centenarian cycles, which describe one or more centuries tendencies;

♦ long-wave cycles, which include some decades ("Kondratiev long waves" of nearly 50 years).

2. Medium-term cycles:

♦ the Juglar cycles of 10 years, which happen as a result of monetary-credit system violation;

♦ the Kuznets infrastructural investment cycles of 15-20 years, which are characterized by the change of demand for industrial facilities and residential building renewal;

♦ industrial cycles of 8-10 years are identified by the renewal of capital assets duration.

3. Short-term cycles:

♦ low cycles which are caused by inventory fluctuations (2-4 years);

♦ seasonal cycles which are half-years-old;

♦ short-term sectoral market fluctuations (store, house building, interest, sales, etc.) which range from 1-2 days to month or half a year.

There are some theories of cyclicality - political business cycle theory, equilibrium business cycle theory, real business cycle theory, impulse-spread business cycle theory. Each of them reflects the reasons of cyclic fluctuations. But there is no uniform theory which was approved by all schools of economic thought. Economists don't have a unified opinion about economic cycle duration and isolation methods of economic cycles from economic factor movement.

There is no theoretically substantiated method of different-term cycles isolation. Spectrum

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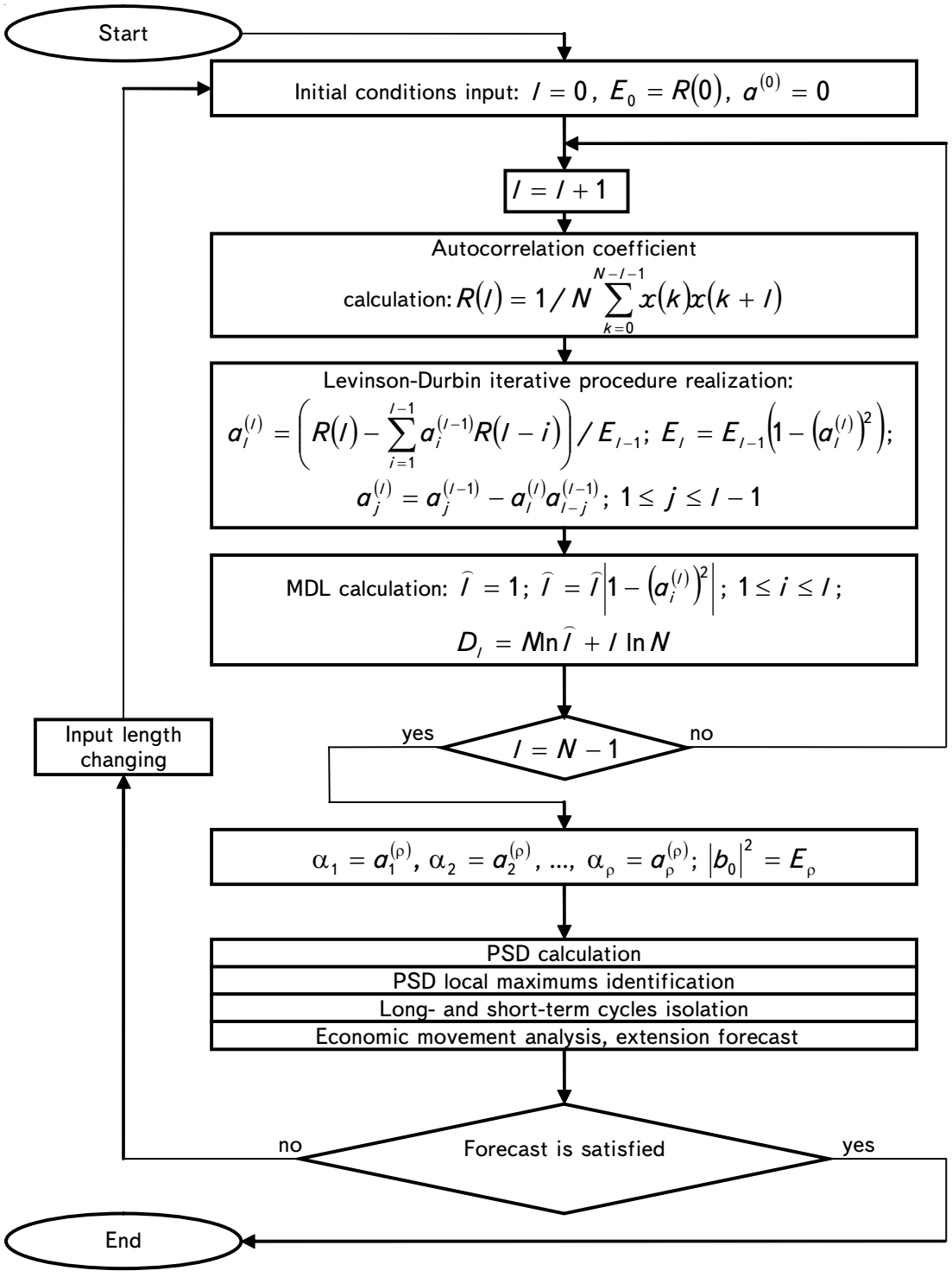

Fig. 1. **Isolation cycles scheme based on spectrum analysis**

analysis, technical method, is suggested to be adopted for economic systems. This statement is the meaning of Fourier theorem (1807). To determine (nonrandom) process transition from signal time domain to frequency domain we need the means of Fourier transform. If input function is discrete then Discrete Fourier Transform (DFT) can be used:

$$X(m) = \sum_{k=0}^{N-1} x(k) e^{-i2\pi km/N} =$$

$$= \sum_{k=0}^{N-1} x(k)\left[\cos(2\pi km/N) + i\sin(2\pi km/N)\right],$$

where $X(m)$ is m-th component of DFT; $x(k)$ is k-th component of time domain; m is the

DFT number of frequency domain; N is the length of input time series; k is input component number of time domain; i is imaginary unit, which equals $\sqrt{-1}$.

Not all the discovered harmonic components have equal importance. Some of them are the result of random components influence which is called "white noise". For harmonic component importance identification the spectrum needs to be estimated. As a rule random process is presented by power spectral density (PSD). PSD is a Fourier transform of random process autocorrelation function. There are a lot of PSD calculation methods, but in this case Maximum entropy method is used. On its basis autoregressive model with order ρ is:

The parameters $\alpha_1, \alpha_2, ..., \alpha_\rho, b_0$ of AR-model identification are performed by $\rho + 1$ Yule-Walker equation:

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where $R(i-j)$ $(1 \le i \le \rho+1,\ 1 \le j \le \rho+1)$ are autocorrelative coefficients, which are calculated as follows:

$$R(i-j) = \\ = 1/N \sum_{k=0}^{N-1-|i-j|} x(k)x(k+|i-j|).$$

For Yule-Walker equations Levinson-Durbin algorithm is used (fig. 1). The special feature of this algorithm is iterative type.

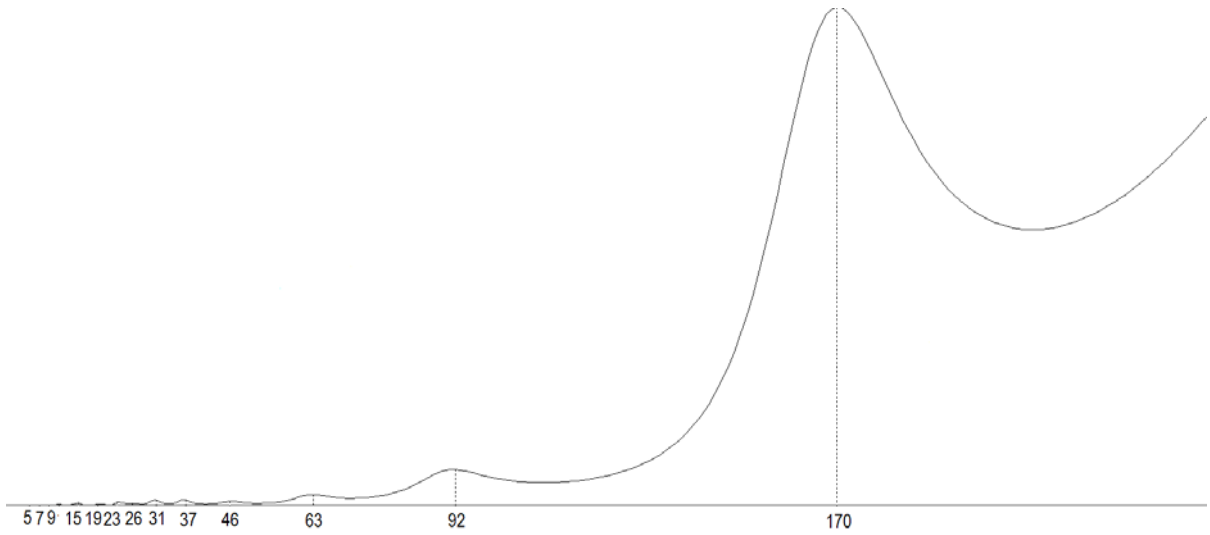

Fig. 2. **Power spectral density of "Lukoil" stock quotes movement in 2008**

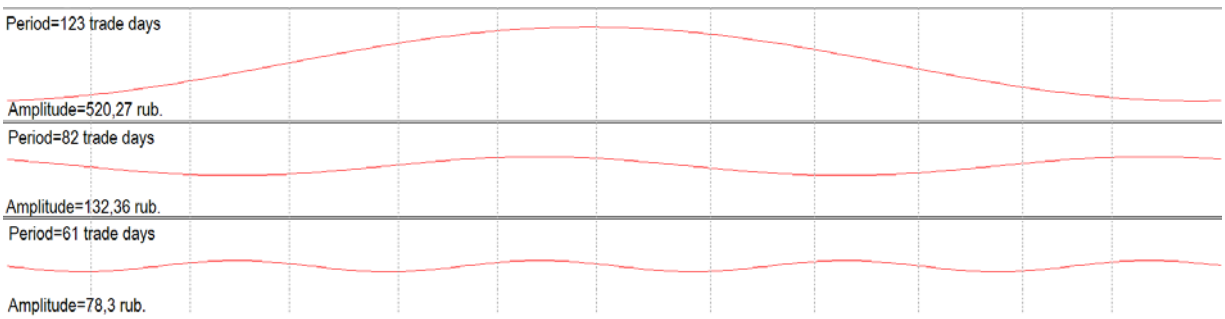

Fig. 3. **Harmonic components of "Lukoil" stock quotes movement in 2008**

AR-model order is identified by Minimum Description Length (MDL) criterion:

$$MDL[\rho] = N \ln \hat{\rho}_\rho + \rho \ln N,$$

where is AR-model order; is the assessed value of white noise dispersion, which is used as a linear prediction error.

For example, power spectral density calculated with maximum entropy method for "Lukoil" stock quotes movement is presented in fig. 2.

The biggest cyclic components are presented in fig. 3. The basic cycle has the biggest period (123 trade days or half a year) and the biggest amplitude (520,27 rub.). So there are spring growth, summer slowdown and tendency turn, autumn fall, winter bottom and recovery on stock market.

Conclusion: This article dealt with economic cycles analysis and the most frequent economic cycles in scientific literature. In general the cycle-isolation methodology on basis of Fourier transform and spectrum analysis were suggested. As an example short- and long-term cyclic components were isolated from "Lukoil" stock quotes movement. The economical cycles isolation algorithm was worked out. It included Levinson-Durbin iterative method for optimal power spectral density calculation.

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