SPECTRAL ANALYSIS OF SALES EVOLUTION IN THE CASE OF BUILDING MATERIALS DISTRIBUTION COMPANIES IN ROMANIA

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Abstract

In physics, spectral studies have been observed and quantified since the 19th century. Thus, the Fourier series bearing the name of the French mathematician who proposed them are used in the analysis of periodic functions. Fourier J. (1822) used them in his analysis of thermal conduction.

Sometime later, while studying the Balmer hydrogen atom (1885), he noticed that there are four wavelengths that characterize the spectrum of hydrogen atoms. As a result of his research Fournier established that there is a number present in each spectral line of hydrogen, namely, 364.6 nm. Starting from this point, Balmer determined the equation that bears his name and which can determine the wavelength of the emission or absorption lines.

The first papers that dealt with spectral analysis in economics emerged in 1960 and consisted in analyzing seasonal adjustment procedures for time series at macroeconomic level. Starting from cross-spectral methods, methods such as series-motion analysis, time-frequency methods, etc. have been developed.

In economy, the different business sectors are mainly affected by different actions upon one of them: a government measure affecting a certain sector, the touch of the business cycle lowest area, or a crisis hitting business. Generally speaking, market sectors interact with each other, being in direct relationships, one influencing the other. In other words, if a sector such as civil and industrial construction is affected by the crisis, it would take a direct action on the transport sector that ensures materials' delivery to the building sites or from the factory to the distributors or on the light and heavy industry which processes the raw material in the profiles needed for constructions. Last but not least, the companies trading in building materials would also be affected. Further on in the given example, a similar influence of a potential crisis in the building sector is to be noticed in the tourism sector, where the repercussions would be the impossibility of finalizing the accommodation units that will ensure the development of the tourist areas or the development and rehabilitation of the tourist sights.

Regarding the fluctuating nature of the activities of different sectors of activity, different oscillations can be identified according to amplitude and frequency, as well as oscillations characterized by a higher or lower propagation period, which determines the evolution of the economic indicators. From an analytical prspective, the activity propagation periods are ranked according to the the characteristics that determine them in time units (time intervals). Thus, the frequency of oscillation will be given by the number of propagation activity periods. Depending on the oscillatory period, the average of them is determined, and the amplitude is determined by the peaks of the oscillatory line and the determined mean.

Starting from the ultraviolet spectrum in physics and the spectral analysis made by physicists, similarly, in economy, in the case of time series, there are elements that according to their oscillation frequencies form "color strips" and "spectrum".

On the basis of a fairly large number of numerical data related to an economic process evolution, we can make „spectral analysis" of such a fluctuating process in terms of frequency and amplitude.

Keywords: spectrum, wave, oscillations, frequencies, amplitudes, power, density, functions, variables, coefficients, sales

Classification JEL: C01, L11, L61

Introduction

In this paper the „spectral analysis" will be applied in the case of a Romanian company trading in materials for light, medium and heavy metal constructions and fabrications. The products that characterize this commercial area with direct implications in the construction and real estate market in general are wire and wire mesh for armatures, longitudinally welded or laminated pipes, rectangular or round, cornier, tee, plate, strip and table profiles in various shapes and sizes, black or thermally galvanized against corrosion.

As regards Romanian business environment, last decade brought about various extreme situations such as the 2009-2010 economic crisis, as well as more "intermediate" situations such as the following recovery period when major changes occurred as a result of the government policy measures. Concretely, if by 2009 the business environment in Romania was quite stable with steady increases in companies' business figures, the 2009-2010 economic crisis heavily affected it. The real estate blockage led to stopping new constructions and freezing some of the ones in different phases of construction.

The present analysis takes into account the period between 2010 and 2017.

This type of business carried out by the analysed firms is heavily influenced by weather conditions throughout the year, or in other words, it has a strong seasonality. Thus, in the first part of the year Romanian companies trading in metallurgical materials register drops in revenues due to low temperatures that do not allow the activity to be carried out freely. This time of the year, concrete tunnels, welding on site are performed under difficult conditions with additional work protection measures if not effectively blocked. All these measures involve high costs and lead building companies to profit losses, and to often preferring to block the site. The constructors' activity directly influences the raw material suppliers' sales revenue. With the coming of spring, the period of relaunching civil and industrial construction begins, which is also felt in the revenues of the companies selling the metallurgical materials. The upward trend is maintained throughout summertime, with small fluctuations due to extremely hot weather, when the cold season situation repeats but to a lower extent. In the last period of the year, the maximum invoice number is registered, followed by a fall in revenues with the coming of winter.

In the present paper, we aim to determine the extent to which the sales of a certain company in the line of business of building materials trade are affected by seasonality and cyclicality by means of the spectral analysis.

Literature review

Gheorghiu, A. (2007) classifies different economic models and uses a series of physical models in order to analyse economic phenomena. Gheorghiu, A., Spanulescu, I. (2007) studied aspects regarding the application of physics and mathematics in economic theories. Gligor, M., Ignat, M. (2003) analyzed the applications of theoretical physics in macroeconomic modeling. Bulinski, M. (2007) addresses the field of economics. Isaic-Maniu A., Mitrut C., Voineagu V (2004) analyzes indexes and calculates them as the average value ratio of value, physical volume and prices.

In terms of spectral analysis in the study of physical and economic phenomena, a number of contributions can be mentioned. For example, in his work, Roman physicist Danet A.F. (2010), made a thorough analysis of spectrometric methods, starting from electromagnetic radiation and electromagnetic spectrum. Crenga E. Sa. (2001) addressed the problem of spectral modeling of signals, using the spectral analysis of analogue, numerical and non-stationary signals. Granger C.W.J, Hatanaka M. (1964) addressed the problems encountered in analysing economic data in the form of time series. Thus, they used the spectral analysis methods that have been developed by communication engineering in time series analysis. English statistician Priestley M.B. (1971) took over from classical physics the concept of "power spectrum" that up to that time had applicability only for stationary processes and generalized this theory to processes whose statistical properties vary over time. A spectral analysis of the economic time series was made by Iacobucci A. (2003), addressing filtering problems of the business cycle components, following the application of cross-sectional spectral analysis introducing concepts such as "phase coherence and spectrum". Business cycle models were also addressed by Wang P. (2010) in the case of UK sectoral production. Spectrum analysis starts from UK GDP production data, tracking the extent to which the conditions of a white noise process are violated.

Research methodology, data, results and discussions

Approaching the possibility of approximating an oscillation can be made on the basis of a Fourier series which is given by:

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx) \qquad (1)$$

where: a_0, a_n, b_n are Euler-Fourier coefficients of the function f (x) is the angular frequency given by the relationship

$$n = f\,\frac{2\pi}{T} \qquad (2)$$

where: f = frequency

T = duration of the interval

Starting from the trigonometric series in which the function f (x) coefficients are calculated with the help of the Euler-Fourier formulas, and assuming that in economic processes there are several oscillations with different frequencies, the "periodic wave" of the process can be modelled by these oscillations whose frequencies although different bear certain things in common. Continuing reasoning, such an oscillatory evolution determined by the numerical string can be written in the form of a finite sum of sinus and cosinus functions:

$$y_t = \frac{a_0}{2} + \sum_{f=1}^{p} \left(a_f cos \frac{2\pi}{T} ft + b_f sin \frac{2\pi}{T} ft \right) + u_t \qquad (3)$$

where: a_0, a_f, b_f represents the parameters

T is the number of time units

f = represents the initially established frequency

and t has values in the interval [1, T]

We are interested in the estimates $\hat{a}_f$, $\hat{b}_f$ allowing for the approximation of the function f(t) by the finite sum of sinus and cosinus functions, which will be denoted by $y_{n(t)}$. Similary to the least squares method we follow the integral :

$$\frac{1}{2\pi}\int_0^{2\pi}\left[f_{(t)} - y_{n(t)}\right]^2 dt \quad (4)$$

The minimum value of the integral is reached when a_f, b_f, are Euler-Fourier coefficients of function f(t), so we can determine the estimated coefficients:

$$\hat{a}_f = \frac{2}{T}\sum_{t=1}^{T} y_t \cos\frac{2\pi}{T}ft \quad (5)$$

$$\hat{b}_f = \frac{2}{T}\sum_{t=1}^{T} y_t \sin\frac{2\pi}{T}ft \quad (6)$$

$$\hat{a}_0 = \frac{\sum y_t}{T} \quad (7)$$

These coefficients are required to continue the analysis and to determine the specifics of the „spectral analysis" such as amplitude:

$$A_f = \sqrt{\hat{a}_f^2 + \hat{b}_f^2} \quad (8)$$

The term „power spectrum" is closely related to the scattering intensity of the harmonic components analyzed and the mean cosinus transformation autocovariatie function. The power spectrum estimator is given by the relationship:

$$\hat{p}_f = \frac{1}{2\pi}\left[a\,cov_0 + 2\sum_{k=1}^{T-1} a\,cov_{(k)}\ \cos\frac{2\pi}{T}fk\right] \quad (9)$$

where: $0 \le \left(\frac{2\pi}{T}\right) \le \pi$; $f = \frac{1}{T}i$ and $0 \le f \le 0{,}5$

In order to identify areas of the spectrum of the analyzed process characterized by significant increases, it is necessary to use the „density function", whose estimation is given by the relation:

$$d_{(f)} = \frac{\hat{p}_f}{\hat{\sigma}_f} = 2\left[1 + 2\sum_{k=1}^{\infty} r_k \cos 2\pi \cdot fk\right] \quad (10)$$

where: $0 \le f \le \frac{1}{2}$, and r_k iar is the coefficient of autocorrelation

The analysis is applied to the monthly financial data of the analysed company during an eight years' time span, summarized in the following table.

Practically, the analysis involves a series of data corresponding to the ninety-six calendar months of the eight years considered.

Monthly business figures for the period between 2010 and 2017

Tabel 1

year 2010	year 2011	year 2012	year 2013	year 2014	year 2015	year 2016	year 2017
89399	162620	210764	232370	369670	319162	473988	378420
107225	197793	113728	284384	293718	570782	685981	386942
132822	279792	426761	440554	442350	609841	653295	564621
144832	240928	430534	426488	424422	632919	577528	497432
168732	341950	475636	400298	611449	551108	542995	591161
206909	349912	391453	475137	468145	586183	534484	570581
186225	281918	468319	575000	468260	552753	699147	488040
211728	291683	487474	458469	431979	572912	691666	531755
334223	304717	418868	557779	525000	588463	648905	590578
297915	393605	460644	570285	660418	647420	597383	698773
291859	362929	448212	568049	613509	586164	590611	670928
155296	203421	221322	426413	369406	493513	391128	391610

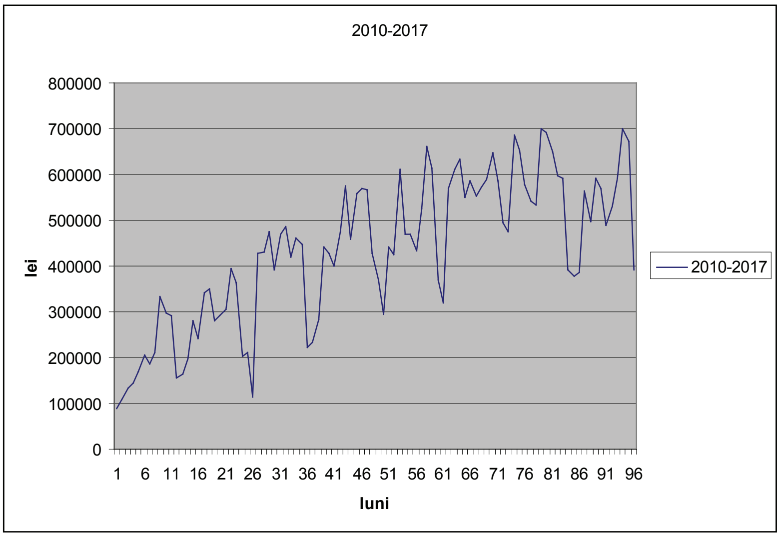
Data source: Monthly report for the period between 2010 and 2017 of the analyzed company.

According to the data presented in Table 1, a positive evolution of sales revenues and their oscillatory variation, due to seasonality, can be noticed. Thus, in January of 2010, revenues amounted to 89,399.00 lei, and in the same month of 2011 there are revenues of 162,620.00 lei and the upward trend continues to the value of 378,420.00 lei in 2017. Actually, there is an average increase in sales in 2017 as compared to 2010 by more than four times.

At the same time, the sales of the company in this domain are characterized by seasonality and according to the data centralized in Table 1, it can be seen that in January of 2010 revenues amount to 89,399.00 lei, followed by increases and reaching a maximum of 297,915 .00 lei in October, while in January of the following year revenues dropped to 162,620.00 lei. These oscillation pattern is maintained throughout the whole analysed period. For a better view of the ascending trend of sales and their oscillatory movement, the following figure was drawn. Sales values are written vertically and horizontally the months.

Representation of the company's sales in the period 2010 - 2017

Figure 1



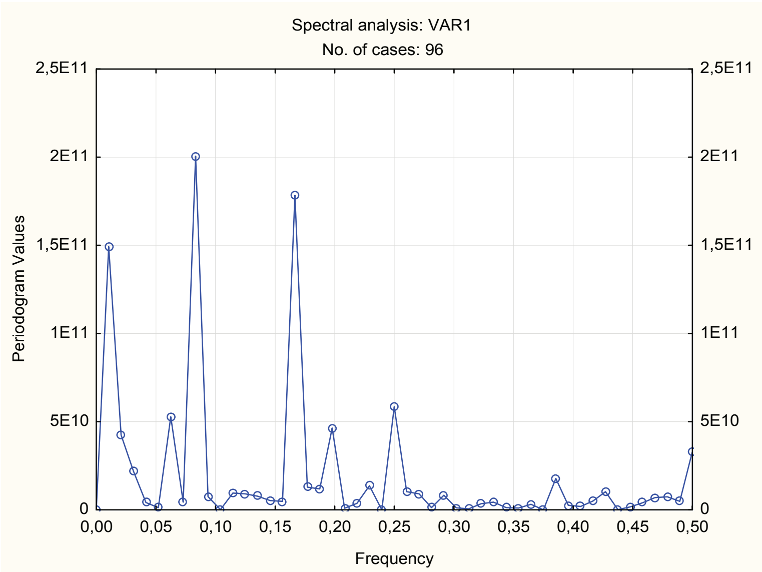
The maximum and minimum revenues figures are to be found in the graph above. Thus, in the cold season, namely, the period between December and February, the smallest sales receipts were recorded each year, followed by a peak in sales revenues between August and November. At the same time, fluctuations of lower amplitude are observed during each year corresponding to the periods between May and November. These fluctuations are generally the result of unfavourable meteorological phenomena during the summer that hamper building activity. Additionally, the influence of holiday periods in which the personnel directly involved in the procurement and project approvals is low has direct influence on the volume of data processed, etc.

Next, the influence of seasonality on the activity of metallurgical materials trading companies is analysed and, at the same time, the magnitude of the fluctuations throughout the year and their influence for the next period is quantified.

In order to analyse the fluctuation intensity generated by the process oscillations, the numerical series data was introduced into the STATISTICA economic analysis program. The program provides support for analysis, including the "spectral analytics" operating modules. Thus, according to the above mentioned module, Figure 8 below can be generated, including the values of the periodogram relative to the oscillation frequency.

Spectral analysis of the periodogram

Figure 2



In Figure 2 we identify on the horizontal axis the basic frequency $\left(\frac{1}{96}\right) = 0{,}01$ with its harmonics up to $\left(\frac{1}{96}\right) \cdot 48 = 0.50$; and the periodogram values are recorded vertically. These values are obtained by summing up the squares of the coefficients and multiplying the result of the addition with $\frac{T}{2}$.

Spectral analysis, calculated values

Table 2

Spectral analysis: VAR1 No. of cases: 96							
	Frequency	Period	Cosine Coeffs	Sine Coeffs	Periodogram	Density	Hamming Weights
0	0,000000		0,0	0,0	1,016440E-20	7,503126E+10	0,035714
1	0,010417	96,00000	-55536,0	-5179,2	1,493314E+11	8,301403E+10	0,241071
2	0,020833	48,00000	-27802,7	10554,6	4,245080E+10	6,037440E+10	0,446429
3	0,031250	32,00000	-908,5	21329,2	2,187646E+10	2,639197E+10	0,241071
4	0,041667	24,00000	7954,3	4912,4	4,195282E+09	1,086789E+10	0,035714
5	0,052083	19,20000	-2725,6	4496,0	1,326863E+09	1,526527E+10	
6	0,062500	16,00000	8003,8	-32181,7	5,278660E+10	3,224408E+10	
7	0,072917	13,71429	3045,1	9005,4	4,337727E+09	6,333234E+10	
8	0,083333	12,00000	-61566,0	-19702,4	2,005706E+11	9,430744E+10	
9	0,093750	10,66667	5559,4	-11285,0	7,596391E+09	5,227030E+10	
10	0,104167	9,60000	-1421,3	885,4	1,345936E+08	1,167361E+10	
11	0,114583	8,72727	7092,7	12163,2	9,516024E+09	7,024936E+09	
12	0,125000	8,00000	11089,7	-8160,1	9,099355E+09	8,437114E+09	
13	0,135417	7,38462	6804,1	-10801,4	7,822353E+09	7,482555E+09	
14	0,145833	6,85714	-8767,9	-5842,7	5,328624E+09	1,211978E+10	
15	0,156250	6,40000	-7584,9	6560,3	4,827255E+09	4,715286E+10	
16	0,166667	6,00000	-60811,0	3976,5	1,782619E+11	8,446576E+10	
17	0,177083	5,64706	15939,0	3782,9	1,288133E+10	5,342621E+10	
18	0,187500	5,33333	487,6	-15742,2	1,190661E+10	2,601968E+10	
19	0,197917	5,05263	-21900,0	22094,3	4,645279E+10	2,442921E+10	
20	0,208333	4,80000	-1539,8	-4176,8	9,512227E+08	1,342487E+10	
21	0,218750	4,57143	-2508,6	8396,7	3,686291E+09	6,827425E+09	
22	0,229167	4,36364	16831,3	1142,2	1,366064E+10	9,112811E+09	
23	0,239583	4,17391	337,1	142,6	6,431810E+06	1,790360E+10	
24	0,250000	4,00000	-27013,5	22125,0	5,852365E+10	2,942082E+10	
25	0,260417	3,84000	12978,7	6777,2	1,029009E+10	2,093460E+10	
26	0,270833	3,69231	-1650,2	13650,6	9,075012E+09	9,220024E+09	
27	0,281250	3,55556	-4411,0	2546,5	1,245194E+09	5,160954E+09	
28	0,291667	3,42857	13164,9	-597,2	8,336200E+09	4,637587E+09	
29	0,302083	3,31034	98,6	4842,4	1,126006E+09	2,821029E+09	
30	0,312500	3,20000	1163,8	3241,4	5,693130E+08	1,838027E+09	
31	0,322917	3,09677	-8135,0	-2812,9	3,556332E+09	2,873233E+09	
32	0,333333	3,00000	-1437,7	9472,7	4,406370E+09	3,189763E+09	
33	0,343750	2,90909	2413,4	4575,6	1,284511E+09	2,115547E+09	
34	0,354167	2,82353	164,2	-4535,6	9,887354E+08	1,683420E+09	
35	0,364583	2,74286	5865,9	5690,0	3,205653E+09	2,365956E+09	
36	0,375000	2,66667	-1111,8	-216,7	6,158831E+07	5,220941E+09	
37	0,385417	2,59459	14126,9	13088,3	1,780191E+10	8,780807E+09	
38	0,395833	2,52632	3509,4	6512,0	2,626699E+09	6,126553E+09	
39	0,406250	2,46154	3390,1	-5468,6	1,987107E+09	3,749562E+09	
40	0,416667	2,40000	9441,2	-4066,5	5,072292E+09	5,343129E+09	
41	0,427083	2,34146	10387,7	10407,7	1,037878E+10	6,013322E+09	
42	0,437500	2,28571	-1194,9	-901,3	1,075289E+08	3,285688E+09	
43	0,447917	2,23256	-5517,9	-2169,5	1,687378E+09	2,397474E+09	
44	0,458333	2,18182	3981,0	-8386,0	4,136303E+09	4,211850E+09	
45	0,468750	2,13333	-9965,3	6839,9	7,012398E+09	6,144852E+09	
46	0,479167	2,08696	8520,4	9028,1	7,396996E+09	7,480388E+09	
47	0,489583	2,04255	-452,7	-10056,0	4,863718E+09	1,225887E+10	
48	0,500000	2,00000	26096,1	0,0	3,268832E+10	1,746637E+10	

Following the introduction of numerical series data into the spectral analysis program in Table 2, the Fourier coefficients values, frequencies, periodogram and density, for each unit of time of the analysed period were generated.

The values representing the important periods in the series evolution are shown in table 3.

Calculated data edifying in spectral analysis

Table 3

STAT. TIME SERIES	Spectral analysis: VAR1 No. of cases: 96 Largest Periodog. values					
	Frequency	Period	Cosine Coeffs	Sine Coeffs	Periodogram	Density
8	0,083333	12,00000	-61566,0	-19702,4	2,005706E+11	9,430744E+10
16	0,166667	6,00000	-60811,0	3976,5	1,782619E+11	8,446576E+10
1	0,010417	96,00000	-55536,0	-5179,2	1,493314E+11	8,301403E+10
24	0,250000	4,00000	-27013,5	22125,0	5,852365E+10	2,942082E+10
6	0,062500	16,00000	8003,8	-32181,7	5,278660E+10	3,224408E+10
19	0,197917	5,05263	-21900,0	22094,3	4,645279E+10	2,442921E+10
2	0,020833	48,00000	-27802,7	10554,6	4,245080E+10	6,037440E+10
48	0,500000	2,00000	26096,1	0,0	3,268832E+10	1,746637E+10
3	0,031250	32,00000	-908,5	21329,2	2,187646E+10	2,639197E+10
37	0,385417	2,59459	14126,9	13088,3	1,780191E+10	8,780807E+09

It is noticeable that the most important oscillation occurs at eight months and is the size of 2.005706 multiplied by ten to eleven power. Also, great amplitude is recorded for the harmonics of this period at sixteen months and twenty-four months respectively.

In the case of periods of less than a year (in our case, the eight-month period), the amplitude is quite high, which indicates the presence of high seasonality.

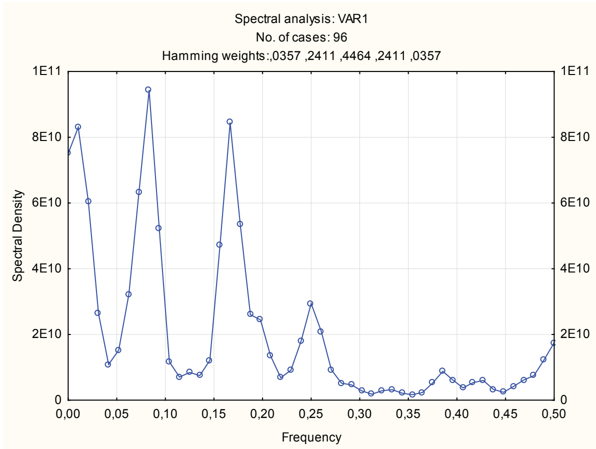
This trend in data series (easily identifiable in Figure 1) is also signaled by high amplitude values (reported in Table 3 periodograma, sixth column) for frequencies lower than the unit.

Due to relatively small amplitudes recorded for periods longer than one year, the presence of cyclicity cannot be confirmed.

Next, we will generate and present the evolution of the spectral density according to the magnitude of the frequency.

Spectral density analysis

Figure 3

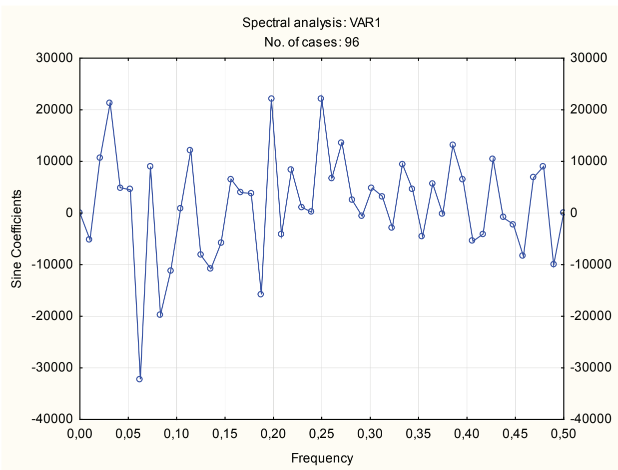


Spectral density is characterized by significant increases over periods of eight months, sixteen months and twenty-four months respectively (Figure 3). Basically, in our case, increases in spectral density are similar to the peaks values recorded in the amplitude periodograma. The appearance is expected to a certain degree as the density function by the computation formula represents the first derivative of the process spectrum function.

The employed spectral analysis program offers the possibility to separately analyse the Fourier coefficients, for which Figures 4 and 5 were generated.

Analysis of Fourier Coefficients (Sinus)

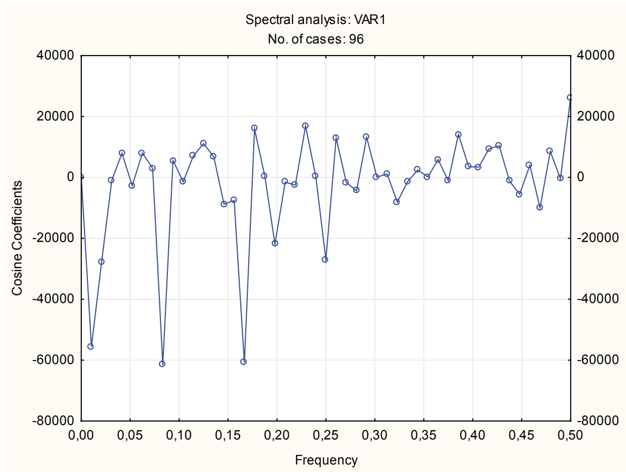
Figure 4



According to figure 4, Fourier's sinus coefficient is generally indicative of values ranging from -20000 to 20000. Exceptions are the peaks in the positive area corresponding to three months, nineteen months and twenty-four months, respectively. Regarding the maximum value of the sinus coefficient for the analysed data series, this is related to the six-month period having the value of -32181,70.

Analysis of Fourier coefficients (cosine)

Figure 5



Regarding the spectral analysis of cosinus coefficients for the analysed series, they have values as sinus coefficients ranging from -20000 to 20000, but somewhat more compact, i. e. closer to the absolute value of 15000, than the value of 20000. As far as the cosinus coefficients peaks are concerned, these are more pronounced around the absolute value of 60000 in the case of several periods of time, namely: the first, the eighth and the sixteenth month, respectively. The next value above the average area is recorded in the twenty-fourth month, namely, - 27013,50.

Therefore, according to the analysis, the maximum values of cosinus Fourier coefficients for the same frequency range coincide with the high amplitude monthly periods, which indicates a strong influence of cosinus coefficient on the amplitude as opposed to sinus coefficient.

Conclusions

The spectral analysis that has been in the attention of physicists since the 19th century has been taken over and used by economists since the second half of the 20th century. This statistical method is used in the analysis of large data series (with more than sixty data), whose analysis with other methods raises problems in terms of economic forecasting. At the same time, it is a method that is suitable for analyzing data series that exhibit fluctuations due to seasonality, economic cycle and other recurring events such as holidays, electoral cycle, etc.

At a microeconomic level, we consider that spectral analysis results of data series are useful to business managers as long as, using the financial data for a given period of time as input, the analysis can provide clear information related to business seasonality and, moreover, to business cycle and trends. With the help of this type of information, the decision to either continue investing or protect the business for the next period can be easier to make and can benefit the company in the eyes of competition, also leading to a decrease of bankruptcy risk.

The results of the spectral analysis as applied in this paper refer to the monthly data of a building materials distribution company and indicate the presence of sales seasonality and the absence of cyclicity.

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