ЭКОНОМИЧЕСКИЕ НАУКИ

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OIL PRICES AND SOLAR ACTIVITY: EVIDENCE OF STRONG TIES (1861-2019)

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In this work author is using methodological approach developed by W. S. Jevons and A. L Chizhevsky. Years of solar cycles were numbered in prescribed astrophysics manner, combined and compared against average values of Brent oil price. Grouping of data by years of solar cycle allowed developing regressive polynomial model where Brent crude oil price[1] is dependent variable and number of respective years in the solar cycle is independent. Resulting R-squared value is equal to 0.9897. This model allows forecasting of prices on oil basing solely on year number in solar cycle. Model suggests that 2020's Brent Crude price will decrease to USD 48.798 level per barrel and forecasted values of Crude Brent for 2021 and 2022 are USD 47.957 and USD 61.175 per barrel respectively.

Key words: Oil price, solar cycle, Wolf number, forecasting of oil price.

Dedicated to my father, the famous biologist
Alexey Nikiforovich Belkin

It goes without saying that oil price forecast has gained high relevance. Economic literature has great amount of publications showing strong ties between dynamics of oil prices and macroeconomic indicators of Russia. However, current situation with forecasting oil prices is well described in article of Nikita Krychevsky and Igor Astafiev name of which can be translated approximately as 'Finger to barrel'. In the article authors describe multiple facts of constant blunders in oil price forecasts from many prominent scientists, industry professionals and high-ranked public officers [2].

Author of this research published oil price forecast back in 2015 which showed further decrease in oil prices in 2016 and its downtrend reversal in 2017 and further growth to 2019. This proved to be accurate to a high degree. In the same publication author describes grounds for decrease of oil prices in 2020 [1. P. 24]. Forecast was based on the results of studying ties between oil prices and annual average sunspots numbers (Wolf numbers) between 1861 and 2015. Success of that forecast motivated author to continue research in order to advance forecast methodology based on sunspot numbers.

Conventional economics explains cycles of one economic indicator (for example, GDP) by cycles of another economic indicator such as propensity to save, innovations, credit interest rates, monetary stock, which nature (amplitude and cycle duration) is also unknown. This seems like explaining one unknown variable by another which is also unknown. It is obvious that main issue of forecasting of economic dynamics is hidden in establishing of independent variable.

Great scientists F. W. Herschel, W. S. Jevons and A. L. Chizhevsky found that such independent variable is solar activity and laid foundation to methodology of studying relation between the Sun and economic activity. For example, W. S. Jevons in his article "The solar-commercial cycles" compared sunspot number cycles with corn prices in Delhi between 1760 and 1810 [7. P. 227].

[1] Further on called as 'oil price' for short.

A. L. Chizhevsky built a chart comparing average solar activity cycle (Wolf number) with average annual incidence of cholera disease over 100 years between 1823 and 1923 in his monography 'Cosmic pulse of life. Earth in Sun's arms" in chapter 4 ('Sun and epidemic', chart number 33)[6.p.11].

In monography 'Terrestrial echo of solar storms' A. L. Chizhevsky placed chart of cereal crops yield in Russia and chart of solar activity (Wolf number) one below the other. This showed close link between those [5. P. 106]. Both graphs have significant timeseries length.

In this research author continues study solar-terrestrial links by investigating relationship between year number in a solar cycle and average annual oil prices in the period between 1861 and 2019.

Annual Wolf number was used as main indicator of solar activity. Wolf numbers were retrieved from database of World Data Centre for the production, preservation and dissemination of the international sunspot number [10]. This data can be found in column 2, table 1.

Oil prices were retrieved from British Petroleum database publicly available online [9]. All prices are valued in 2018 US dollar apart from price for year 2019 which was calculated by author as an average of monthly prices over the year. Data was retrieved from database of oil producer Petroleum & Other Liquids [8].

Year numbers in Table 1 are solar cycle years were year number 1 refers to the year when Wolf number reverses from its downtrend. Further numeration continues until the end of another downtrend where last year of the cycle is the last year of downtrend. Years of minimum values of Wolf number are given in bold in Table 1.

Solar cycle year numbers for years between 1861 and 1866 are assumed based on that year 1856 was the last year of previous solar cycle.

Table 1

Annual average Wolf number, oil price and solar cycle year for the period from 1861 to 2019

Year	Wolf numbers	Serial number of a year in solar cycle	Oil prices, $ 2018
1861	146.6	5	13.64
1862	112.1	6	26.30
1863	83.5	7	63.98
1864	89.2	8	128.88
1865	57.8	9	107.66
1866	30.7	10	63.88
1867	**13.9**	**11**	**43.12**
1868	62.8	1	68.20
1869	123.6	2	68.39
1870	232.0	3	76.34
1871	185.3	4	90.60
1872	169.2	5	75.99
1873	110.1	6	38.20

Year	Wolf numbers	Serial number of a year in solar cycle	Oil prices, $ 2018
1874	74.5	7	25.86
1875	28.3	8	30.74
1876	18.9	9	60.12
1877	20.7	10	56.83
1878	**5.7**	**11**	**30.84**
1879	10.0	1	23.08
1880	53.7	2	24.62
1881	90.5	3	22.29
1882	99.0	4	20.21
1883	106.1	5	26.84
1884	105.8	6	23.38
1885	86.3	7	24.49
1886	42.4	8	19.76
1887	21.8	9	18.65
1888	11.2	10	24.49
1889	**10.4**	**11**	**26.16**
1890	11.8	1	24.22
1891	59.5	2	18.65
1892	121.7	3	15.59
1893	142.0	4	17.81
1894	130.0	5	24.28
1895	106.6	6	40.88
1896	69.4	7	35.47
1897	43.8	8	23.75
1898	44.4	9	27.36
1899	20.2	10	38.78
1900	15.7	11	35.77
1901	**4.6**	**12**	**28.86**

Year	Wolf numbers	Serial number of a year in solar cycle	Oil prices, $ 2018
1902	8.5	1	23.12
1903	40.8	2	26.16
1904	70.1	3	23.94
1905	105.5	4	17.26
1906	90.1	5	20.32
1907	102.8	6	19.33
1908	80.9	7	20.04
1909	73.2	8	19.48
1910	30.9	9	16.37
1911	9.5	10	16.37
1912	6.0	11	19.18
1913	**2.4**	**12**	**24.04**
1914	16.1	1	20.22
1915	79.0	2	15.82
1916	95.0	3	25.28
1917	173.6	4	30.53
1918	134.6	5	32.99
1919	105.7	6	29.17
1920	62.7	7	38.46
1921	43.5	8	24.26
1922	23.7	9	24.1
1923	**9.7**	**10**	**19.71**
1924	27.9	1	20.99
1925	74.0	2	24.05
1926	106.5	3	26.66
1927	114.7	4	18.79
1928	129.7	5	17.14
1929	108.2	6	18.6

Year	Wolf numbers	Serial number of a year in solar cycle	Oil prices, $ 2018
1930	59.4	7	17.89
1931	35.1	8	10.71
1932	18.6	9	15.98
1933	**9.2**	**10**	**12.97**
1934	14.6	1	18.74
1935	60.2	2	17.73
1936	132.8	3	19.74
1937	190.6	4	20.63
1938	182.6	5	20.13
1939	148.0	6	18.43
1940	113.0	7	18.25
1941	79.2	8	19.43
1942	50.8	9	18.32
1943	27.1	10	17.41
1944	**16.1**	**11**	**17.26**
1945	55.3	1	14.64
1946	154.3	2	14.39
1947	214.7	3	21.35
1948	193.0	4	20.74
1949	190.7	5	18.74
1950	118.9	6	17.82
1951	98.3	7	16.51
1952	45.0	8	16.17
1953	20.1	9	18.10
1954	**6.6**	**10**	**18.01**
1955	54.2	1	18.09
1956	200.7	2	17.82
1957	269.3	3	16.93

Year	Wolf numbers	Serial number of a year in solar cycle	Oil prices, $ 2018
1958	261.7	4	18.06
1959	225.1	5	17.90
1960	159.0	6	16.09
1961	76.4	7	15.10
1962	53.4	8	14.93
1963	39.9	9	14.76
1964	**15.0**	**10**	**14.55**
1965	22.0	1	14.31
1966	66.8	2	13.92
1967	132.9	3	13.53
1968	150.0	4	12.99
1969	149.4	5	12.32
1970	148.0	6	11.63
1971	94.4	7	13.87
1972	97.6	8	14.89
1973	54.1	9	18.60
1974	49.2	10	59.00
1975	22.5	11	53.82
1976	**18.4**	**12**	**56.47**
1977	39.3	1	57.64
1978	131.0	2	54.00
1979	220.1	3	109.33
1980	218.9	4	112.24
1981	198.9	5	99.25
1982	162.4	6	85.79
1983	91.0	7	74.50
1984	60.5	8	69.56
1985	20.6	9	64.32

Year	Wolf numbers	Serial number of a year in solar cycle	Oil prices, $ 2018
1986	**14.8**	**10**	**33.06**
1987	33.9	1	40.75
1988	123.0	2	31.68
1989	211.1	3	36.91
1990	191.8	4	45.58
1991	203.3	5	36.87
1992	133.0	6	34.58
1993	76.1	7	29.49
1994	44.9	8	26.80
1995	25.1	9	28.04
1996	**11.6**	**10**	**33.08**
1997	28.9	1	29.87
1998	88.3	2	19.59
1999	136.3	3	27.09
2000	173.9	4	41.55
2001	170.4	5	34.66
2002	163.6	6	34.93
2003	99.3	7	39.35
2004	65.3	8	50.87
2005	45.8	9	70.10
2006	24.7	10	81.14
2007	12.6	11	87.67
2008	**4.2**	**12**	**113.43**
2009	4.8	1	72.18
2010	24.9	2	91.54
2011	80.8	3	124.2
2012	84.5	4	122.13
2013	94.0	5	117.12

Year	Wolf numbers	Serial number of a year in solar cycle	Oil prices, $ 2018
2014	113.3	6	104.95
2015	69.8	7	55.50
2016	39.8	8	45.76
2017	21.7	9	55.52
2018	7.0	10	71.31
2019	**3.6**	**11**	**64.39**

Sources:

a) Statistical Review of World Energy. BP. [online] Available at: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html [Accessed 23.01.2020.].

b) US Energy Information Administration. Petroleum & Other Liquids. Spot Prices for Crude Oil and Petroleum Products. Monthly. [online] Available at: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RBRTE&f=M [Accessed 23.01.2020.].

c) World Data Center for the production, preservation and dissemination of the international sunspot number. Sunspot Number. Yearly mean total sunspot number [1700–now]. [online] Available at: < http://www.sidc.be/silso/ssngraphics>, accessed 23.01.2020.

Data in Table 1 was grouped in Table 2 by year number in solar cycle. Column 2 of Table 2 contains number of occurrences of each solar cycle year between 1861 and 2019. For example, value ‘14’ in column 2 corresponding to year 1 means that first years of a solar cycle appeared 14 times in the period between 1861 and 2019. Accordingly, value ‘4’ corresponding to year 12 means that there were only 4 of 12th years of solar cycle. Column 3 contains average of Wolf numbers for corresponding year in solar cycle. Similarly, column 4 contains average oil prices for corresponding year in solar cycle between 1861 and 2019. All 159 years in range between 1861 and 2019 were included in the calculations.

Table 2

Grouped average Wolf numbers and oil prices by solar cycle for years 1861-2019

Serial number of the year solar cycle	Number of solar cycle years for the period 1861 to 2019	Average of the Wolf numbers for each solar cycle year for the period 1861 to 2019	Average of the price of oil for each solar cycle year for the period 1861 to 2019, $ 2018
1	14	27.86	31.86
2	14	91.41	31.31
3	14	150.99	39.94
4	14	163.18	42.08
5	15	154.71	37.88
6	15	126.50	34.67

Serial number of the year solar cycle	Number of solar cycle years for the period 1861 to 2019	Average of the Wolf numbers for each solar cycle year for the period 1861 to 2019	Average of the price of oil for each solar cycle year for the period 1861 to 2019, $ 2018
7	15	82.33	32.58
8	15	56.08	34.40
9	15	32.95	37.20
10	15	17.81	37.37
11	9	11.74	42.02
12	4	8.70	55.70
Total	159		

Column 2 and 3 were used to build chart (ref. Figure 1) which shows strong relation between oil price and year number in solar cycle between 1861 and 2019.

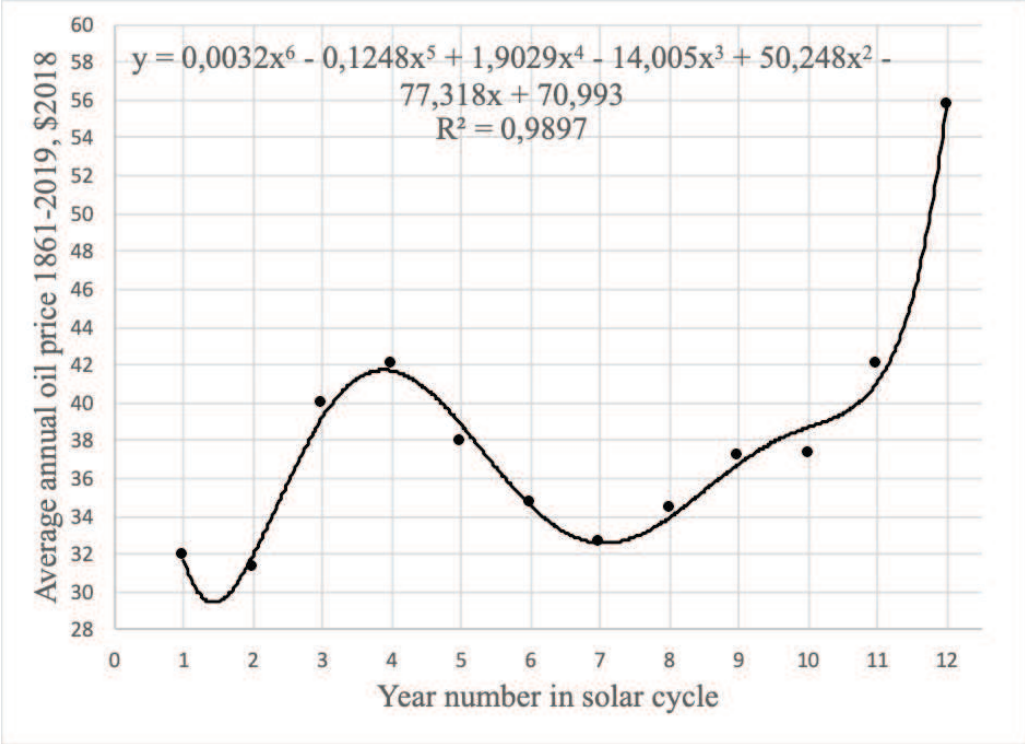

Fig. 1. Polynomial function of oil price and year number in solar cycle for 1861–2019

Polynomial regression where oil price is dependent variable and year number in solar cycle is independent has R-squared equal to 0.9897. This means that polynomial equation shown on Figure 1 closely describes strong relation between oil prices and therefore is a proof that oil price and year number in solar cycle have in fact strong relation. Contemporary science should accept this as economic and astrophysical fact.

Consequently, developed formula can be used in order to forecast movement of oil prices based on year number in solar cycle. For example, solar activity is expected to rise in 2020 after its minimum in 2019 (ref. Figure 2). This suggests that 2020 is the first year of new 25th solar cycle and 2020's solar cycle number is 1.

Relation of prices shown on Figure 1 can be used for forecasting oil prices. For example, from Table 2 we see that year 1 in solar cycle has average oil price of $31.86 and year 11 has average oil price of $42.02. Relation can be proportionally written as $31.86/$42.02 = 0.7582. Given that 2019's average oil price is equal $64.36 (ref. Table 1), we have that forecast oil price for 2020 is 0.7582 * $64.36 ≈ $48.80.

From same Table 2 we get that average oil price for the second year of solar activity, which should be 2021, is proportionally 0.9828 as $31.31/$31.86. Consecutively, forecast oil price for 2021 is 0.9828 * $48.80 = $47.96. Accordingly, oil price forecast for year 2022 is equal to $61.17.

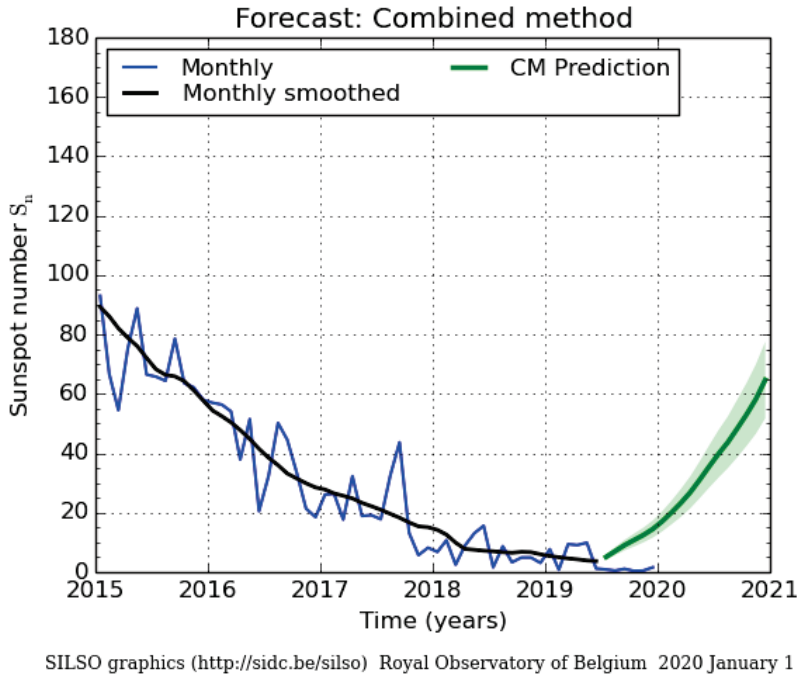

Fig. 2. Forecast of solar activity for 2020

RBK[2] published their forecast for oil price for 2020 which says: "Oil manufacturers and industry experts say that oil prices in next [2020] year will remain at levels of 2019 which is around $60 per barrel" [4]. This is significantly higher that my forecast of $48.80 per barrel.

Figure 3 was built based on columns 2 and 3 of Table 2. It shows strong relation average annual values of Wolf number and average annual oil price. R-squared is equal to 0.9082 which means that polynomial equation from Figure 3 closely describes original data.

It is noticeable that R-squared for year number in solar cycle (Figure 1) and Wolf number are somewhat different. It can be hypothesised that although Wolf number is considered as main indicator of solar activity but there are other influencing factors which might not be known to contemporary science.

Chart of average values of Wolf number and oil prices combined by year number in solar cycle for the period from 1861 to 2019 is given in Figure 4. It is seen that when values of Wolf number rise above 77.02 there is positive association between Wolf number and oil price and vice versa for Wolf number values below 77.02.

Author believes that it is important to acknowledge the mechanism of strong relation between solar activity and economic activity. Fact of such relation is clear and must be accepted by conventional economics.

[2] Leading Russian business consulting agency.

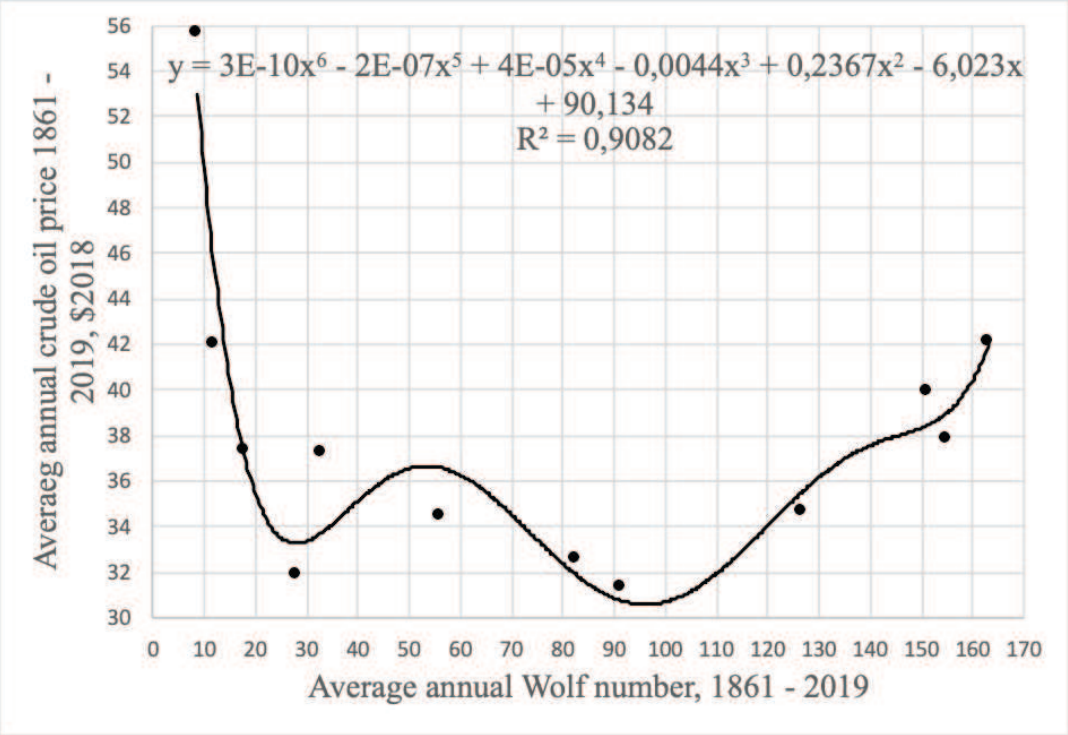

Fig. 3. Polynomial function of oil price and average values of Wolf number grouped by year number in solar cycle for 1861- 2019

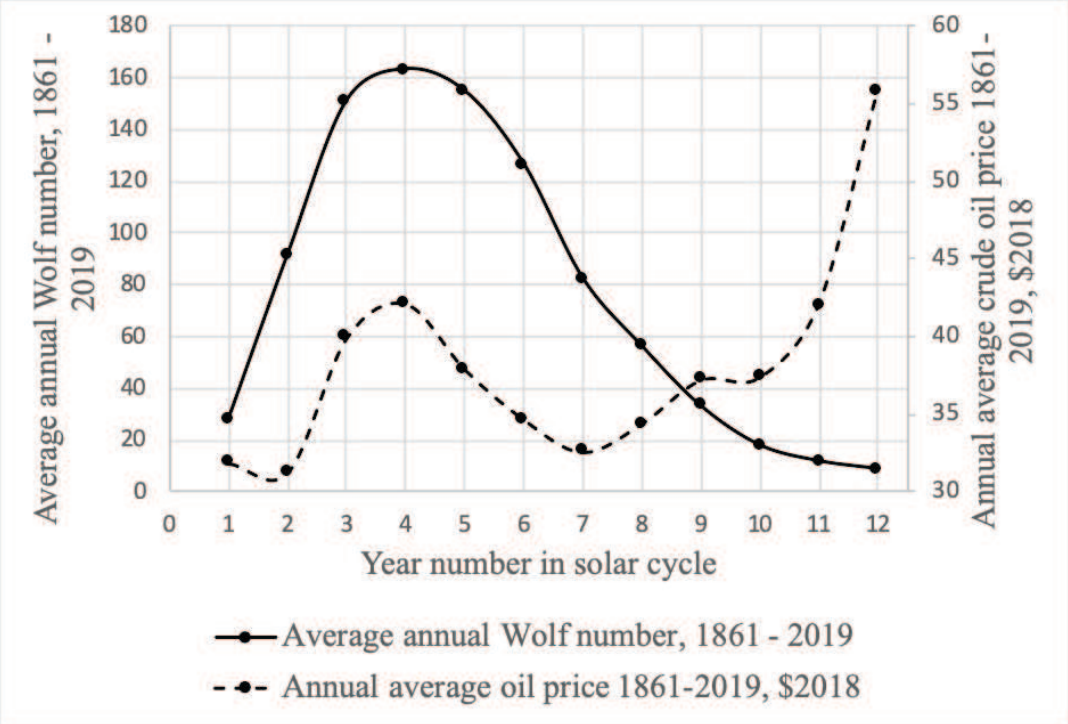

Fig. 4. Average annual values of Wolf numbers and oil prices grouped by year number in solar cycle for 1861–2019

It can be a lengthy conversation to discuss mechanisms of shown relations. In author's previous works, he made attempts to explain it based on works of leading helio-biologists like A.L. Chizhevsky, U.I. Gurfinkel, V.N. Obridko, O.B. Novik, F.A. Smirnov, A. Stupel who

proved negative influence of both maximums and minimums (A. Stupel) of solar activity on health and phycological condition of people.

PhD of physico-mathematical sciences V.N Obridko together with co-authors showed strong relation between Wolf numbers and unexpected magnetic storms. Correlation coefficient of those is equal to 0.872 ± 0.06 which is strong [3, p.159]. Therefore, graph of Wolf number values plotted on Figure 4 can be considered as graph of number of unexpected magnetic storms. Figure 3 shows, that oil price reaches its peak when Wolf numbers are on its very lows and highs or, interchangeably, it can be said to be low and high number of unexpected magnetic storms. Aforementioned helio-biologists also showed that number of medical disorders grows within same periods.

Practical application of this research is developed methodology of oil price forecasting by year number in solar cycle. Existence of such methodology underlines necessity to include Helioeconomics course in university programmes.

Limitation of this forecasting methodology is that it is based on forecast of solar activity which in its turn may not always be correct. For example, 2020 may appear not as 1st year in new 25th solar cycle but 12th year of preceding cycle if its Wolf number will be lower than the one of 2019. Though, as practice shows, solar activity forecast mistakes made by astrophysicists are less likely to occur as compared with forecasts of economists about economic dynamics. Even possible solar activity forecast error for 2020 would not diminish existence of strong links between cycles solar activity and cycles of oil prices.

Positive review on astrophysical part of the research was obtained from V. N. Obidko[3].

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