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**ORDINAL NUMBERS OF YEARS OF SOLAR CYCLES (1960-2022)  
AND GROSS WORLD PRODUCT WITH A LAG OF 1 YEAR (1961-2023):  
EVIDENCE OF VERY STRONG CORRELATIONS**

*V.A. Belkin*

**Annotation.** Comparison of ordinal numbers of years of the average solar cycle (Wolf number cycle) for the period 1960-2022 and indices of gross world product with a lag of 1 year (1961-2023) allowed to reveal very strong correlations between them with correlation coefficients at different intervals in the range from 0.93 to 0.99. This allows us to predict the value of the gross world product indices. Namely, its value for 2024 is 2.108%, for 2025 1.593%, for 2026 2.449%, for 2027 3.672 (%).

**Keywords:** solar activity cycle, Wolf numbers, economic crises, gross world product, economic forecasting, economic cycle

The IMF in its January 9, 2020 World Economic Outlook Survey noted that “Global growth is projected to rise from 2.9 percent in 2019 to 3.3 percent in 2020...” [1]. This fact is a vivid illustration of the state of affairs with traditional economic theory and forecasting theory.

My article “Cosmic factors of economic cycles” was published in No. 2 of the journal “Socium and Power” for 2013. At the end of the article there is a forecast of financial and economic crises, namely 2014 and 2020 [2, P .73]. This forecast was highly justified because it was based on the forecast of extremes of the 24th solar activity (SA) cycle.

Great scientists - Frederick William Herschel, William Stanley Jevons and Alexander Leonidovich Chizhevsky in their works developed a methodological approach to the study of the relationship between solar and economic activity.

For example, in his article “Solar-Commercial Cycles”, WS Jevons placed one under another graphs of S A cycles (cycles of Wolf numbers) and cycles of corn prices in Delhi for the period 1760-1810. [3, P.227].

Chizhevsky in his monograph “Cosmic Pulse of Life: Earth in the Embrace of the Sun” in Chapter 4 “The Sun and Epidemics” in fig. 33 built a diagram, which shows the average for a hundred years cycle of S A (cycle of Wolf numbers) and the average for the years of the solar cycle of the number of cholera diseases in Russia for the period 1823-1923 [4, P.11].

In another monograph “Earth's Echo of Solar Storms”, he placed one under another graphs of grain yields in Russia and S A (Wolf numbers), which show a close direct relationship between them [5, P.106]. These graphs cover a long period of time.

In the present study, the years of the mean solar cycle are compared in order in one diagram, depending on the value of the mean annual Wolf numbers as well as the gross world product (hereinafter referred to as GWP) with a lag of 1 year .

The mean annual Wolf numbers, the main indicator of SA, were taken from the well-known astrophysical site on the determination, preservation, and

distribution of the international sunspot number [6]. They are presented in column 2 of Table 1.

The order numbers of years in column 3 of Table 1 are determined in accordance with the numbering of years adopted in solar astrophysics. Namely, the first year of the beginning of its growth, ie, the growth of the Wolf number, is considered to be the first in the SA cycle. Then the years are numbered in order, and the last year in the cycle is considered to be the year of the Wolf number minimum. The years of minimums of SA in Table 1 are highlighted in blue, and the years of maximums are highlighted in red.

Values of GDP indices for the period 1961-2023 were taken from the World Bank website [7] and are presented in columns 4 and 5 of Table 1.

**Table 1. Years, average annual Wolf numbers, ordinal numbers of years in SA cycles, and indices of gross world product**

The years	Wolf numbers, 1960-2022	The serial number of the year in the cycle of SA, 1960-2022	World GDP growth , annual , %, 1961-2023	World GDP growth with a lag of 1 year, annual, %, 1960-2022 .
1	2	3	4	5
1960	159	6	N.D.	3.969727787
1961	76.4	7	3.969727787	5.319004138
1962	53.4	8	5.319004138	5.01876407
1963	39.9	9	5.01876407	6.583204527
<b>1964</b>	<b>15</b>	<b>10</b>	<b>6.583204527</b>	<b>5.595768086</b>
1965	22	1	5.595768086	5.438370867
1966	66.8	2	5.438370867	3.735533243
1967	132.9	3	3.735533243	5.925679639
<b>1968</b>	<b>150</b>	<b>4</b>	<b>5.925679639</b>	<b>5.978931918</b>
1969	149.4	5	5.978931918	3.735703524
1970	148	6	3.735703524	4.307159041
1971	94.4	7	4.307159041	5.637430546
1972	97.6	8	5.637430546	6.408159763
1973	54.1	9	6.408159763	1.914298905
1974	49.2	10	1.914298905	0.526672164

1975	22.5	11	0.526672164	5.214261802
<b>1976</b>	<b>18.4</b>	<b>12</b>	<b>5.214261802</b>	<b>4.018430856</b>
1977	39.3	1	4.018430856	4.089214088
1978	131	2	4.089214088	4.182371471
<b>1979</b>	<b>220.1</b>	<b>3</b>	<b>4.182371471</b>	<b>1.881559196</b>
1980	218.9	4	1.881559196	1.926416031
1981	198.9	5	1.926416031	0.296537497
1982	162.4	6	0.296537497	2.586198895
1983	91	7	2.586198895	4.674320819
1984	60.5	8	4.674320819	3.702804328
1985	20.6	9	3.702804328	3.351357503
<b>1986</b>	<b>14.8</b>	<b>10</b>	<b>3.351357503</b>	<b>3724626509</b>
1987	33.9	1	3.724626509	4.591726239
1988	123	2	4.591726239	3.71718416
<b>1989</b>	<b>211.1</b>	<b>3</b>	<b>3.71718416</b>	<b>2.764541122</b>
1990	191.8	4	2.764541122	1.255826392
1991	203.3	5	1.255826392	2.019256604
1992	133	6	2.019256604	1.812976008
1993	76.1	7	1.812976008	3.323942443
1994	44.9	8	3.323942443	3.08461458
1995	25.1	9	3.08461458	3.574686427
<b>1996</b>	<b>11.6</b>	<b>10</b>	<b>3.574686427</b>	<b>3.929713861</b>
1997	28.9	1	3.929713861	2.853925344
1998	88.3	2	2.853925344	3.549717353
1999	136.3	3	3.549717353	4.531094789
<b>2000</b>	<b>173.9</b>	<b>4</b>	<b>4.531094789</b>	<b>2.025402869</b>
2001	170.4	5	2.025402869	2.302836989
2002	163.6	6	2.302836989	3.104275673
2003	99.3	7	3.104275673	4.469258855
2004	65.3	8	4.469258855	4.00586591

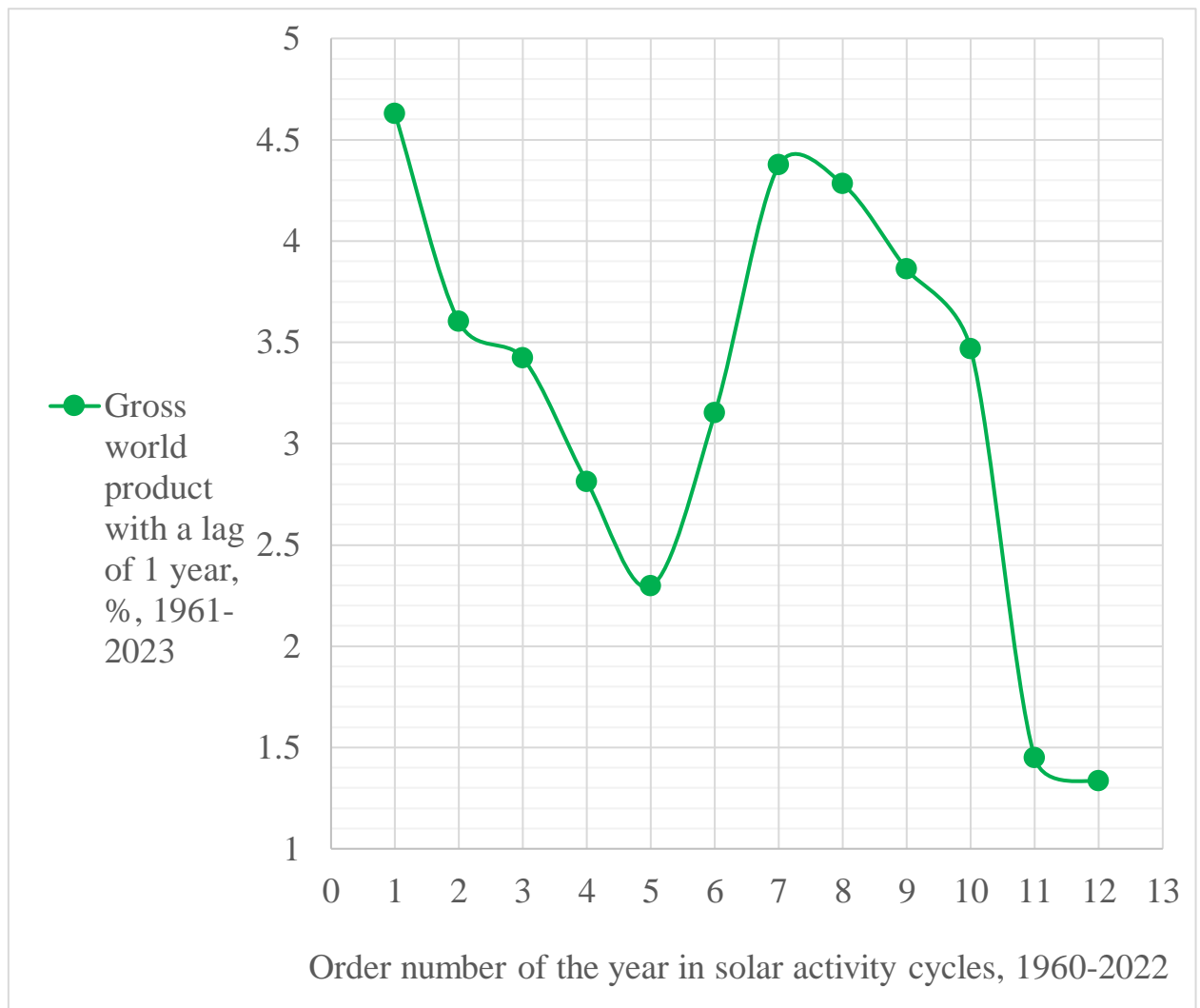
2005	45.8	9	4.00586591	4.442792696
2006	24.7	10	4.442792696	4.37327669
2007	12.6	11	4.37327669	2.062495933
<b>2008</b>	<b>4.2</b>	<b>12</b>	<b>2.062495933</b>	<b>-1.355782091</b>
2009	4.8	1	-1.35578209	4.529545973
2010	24.9	2	4.529545973	3.327132697
2011	80.8	3	3.327132697	2.709115158
2012	84.5	4	2.709115158	2.868222143
2013	94	5	2.868222143	3.12386991
<b>2014</b>	<b>113.3</b>	<b>6</b>	<b>3.12386991</b>	<b>3.126135588</b>
2015	69.8	7	3.126135588	2.820557285
2016	39.8	8	2.820557285	3.460239118
2017	21.7	9	3.460239118	3.286612988
2018	7	10	3.286612988	2.642216435
<b>2019</b>	<b>3.6</b>	<b>11</b>	<b>2.642216435</b>	<b>-2.932043344</b>
2020	8.8	1	-2.93204334	6.259851284
2021	29.6	2	6.259851284	3.089607464
2022	83.1	3	3.089607464	2.719333366
2023		4	2.719333366	

Next, the statistical data of Table 1 were grouped by the serial numbers of the years of the SA cycles. The results of grouping the data of Table 1 without column 4 are presented in Table 2. The year of the maximum of the average solar activity cycle for the period 1961-2022 is highlighted in red in this table. It turned out to be year number 4. The years of SA minima are highlighted in blue. They turned out to be years with numbers 10, 11 and 12.

**Table 2. Grouping of data from Table 1 without column 4 by ordinal numbers of years in SA cycles**

Serial number of the year in the cycle of SA	Number of years with this number for the period 1960-2022	Average arithmetic mean:		
		Wolf numbers (1960-2022)	world GDP growth with a lag of 1 year, annual, %, 1960-2022.	Change in the gross world product index with a lag of 1 year from previous year, %
1	2	3	4	5
1	6	22.95	4.627105632	3.29578125
2	6	77.2666666	3.600257731	-1.026847901
3	6	144.066666	3.421887212	-0.17837052
<b>4</b>	<b>5</b>	<b>163.82</b>	<b>2.810959871</b>	<b>-0.610927341</b>
5	5	163.2	2.295640905	-0.515318966
6	6	146.55	3.151078832	0.855437927
7	6	84.5	4.374085681	1223006849
8	6	60.25	4.280074628	-0.094011053
9	6	34.5333333	3.858825508	-0.421249121
<b>10</b>	<b>6</b>	<b>20.3833333</b>	<b>3.465378958</b>	<b>-0.39344655</b>
<b>11</b>	<b>3</b>	<b>12.9</b>	<b>1.44823813</b>	<b>-2.017140827</b>
<b>12</b>	<b>2</b>	<b>11.3</b>	<b>1.331324383</b>	<b>-0.116913748</b>
Total:	63			
Correlation coefficient, columns 1-4				
lines 1-5			-0.979086	
lines 5-7			0.9948278	
lines 7-12			-0.930872	
Correlation coefficient, columns 3-4				
Lines 1-7			-0.8974329	
Lines 7-12			0.81231124	

Based on the data in columns 1 and 4 of Table 2, a diagram was constructed (see Fig. 1). It shows a very strong connection between the ordinal numbers of years of the mean solar cycle and the GDP with a lag of 1 year.



**Fig. 1. Ordinal numbers of the average solar cycle and the index of gross world product with a lag of 1 year (1960-2022).**

The identified strong relationships can be used to forecast the dynamics of the GDP index. In my published work "Economic and Geomagnetic Cycles" a forecast was developed for a decrease in the GDP index in 2022 to 3.8% [8, p. 45]. According to the results of 2022, it decreased to a greater extent to a value of 3.08% (see Table 1). In my previous preprint published on this research topic, there is a forecast of the GDP index value for 2023, namely, 2.98% [9, p. 1]. In fact, its value was 2.72%, that is, the value of the forecast error decreased.

The calculation of the forecast values of the GDP indices for 2024-2027 is presented in Table 3. Since these calculations are based on arithmetic averages of GDP indices, the low forecast value of the 2025 GDP index (1.593%) implies a **high probability of a global economic crisis in 2025.**

**Table 3. Calculation of forecast values of indices of gross world product (2024-2027)**

Year.	The serial number of the year in the current 25th SA cycle.	Actual value of the gross world product index	Change to the previous year (See column 5 of table 2), %, 1960-2022	Projected value of the gross world product index , (%)
1	2	3	4	5
2023	4	2.719333366	-0.610927341	
2024	5		-0.515318966	2.108406025
2025	6		0.855437927	1.593087059
2026	7		1.223006849	2.448524987
2027	8			3.671531836

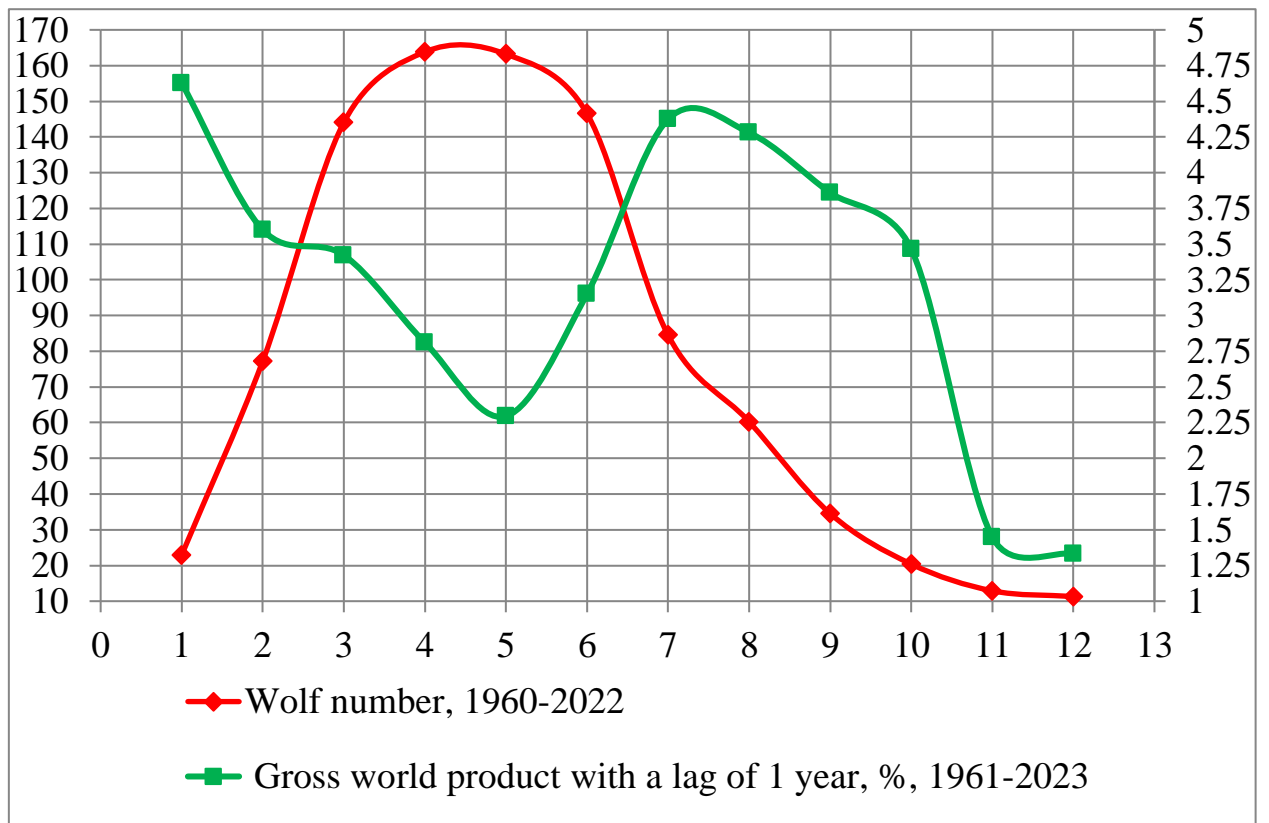
Thus, the bottom of the upcoming economic crisis will be reached in 2025. Based on columns 1, 3 and 4 of Table 2, the following diagram is constructed (see Fig. 2), which shows the graphs of the average Wolf numbers and the GDP indices with a lag of 1 year by the ordinal numbers of years of solar cycles for 1960-2022. The diagram shows that **the minimum values of the GDP index** are observed 2 years after the maximum of SA and the following year after the minimum of SA (the 10th, 11th and 12th years of the average SA cycle).

Based on columns 3 and 4 of Table 2, the following diagram is constructed (see Fig. 3), which shows that a significant decrease in the GDP index with a lag of 1 year occurs in the region of **maximum** and especially sharply in the region of **minimum** values of Wolf numbers, that is, in the region of extremes of Wolf numbers.

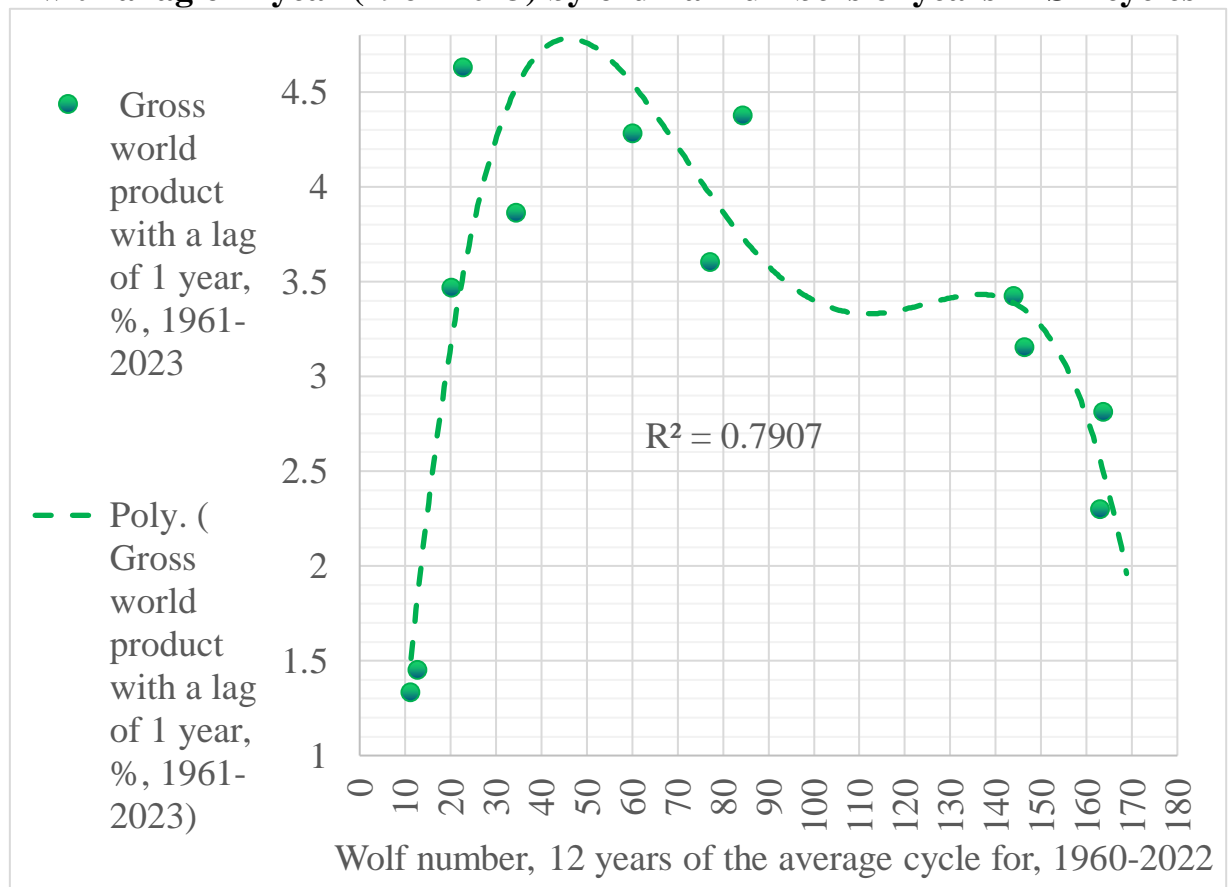
Table 2 presents the correlation coefficients between the arithmetic mean values of the Wolf and VMP numbers with a lag of 1 year. Their values for years 1-7 of the solar cycles are -0.8974329, and for years with numbers 7-12 they are 0.81231124, which means a strong connection between solar and economic activity.

Thus, up to and including year 7, there is a strong inverse relationship, and after year 7, there is a strong direct relationship between the Wolf numbers and the VMP with a lag of 1 year. This is shown in Fig. 2. The question arises as to why exactly year 7 is the year of the change in the direction of this relationship?



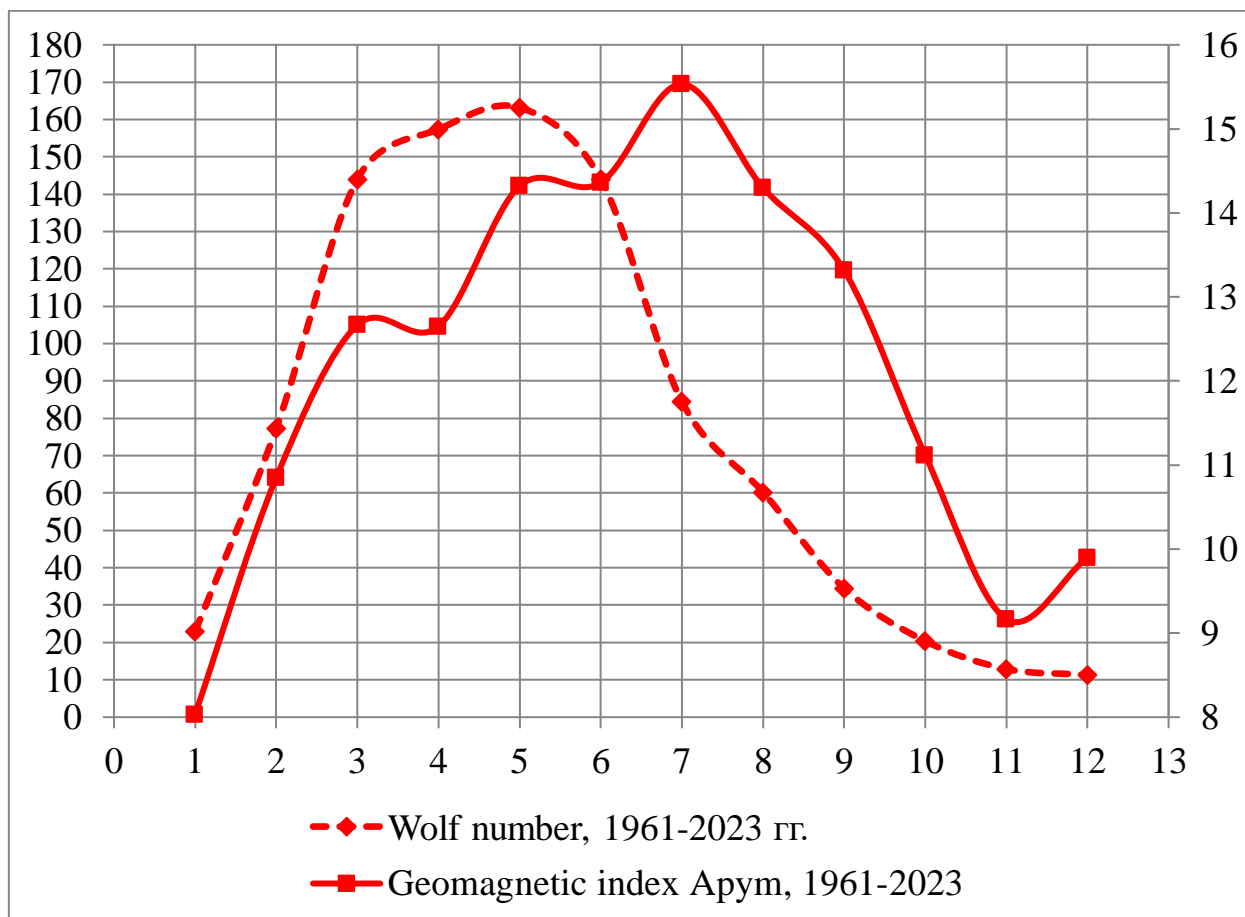


**Fig. 2. Average Wolf numbers (1960-2022) and indices of gross world product with a lag of 1 year (1961-2023) by ordinal numbers of years in SA cycles**



**Fig. 3. Arithmetic mean values of Wolf numbers (1960-2022) and gross world product with a lag of 1 year, (1961-2023), 12 years of SA cycles.**

.In my opinion, this is because it is in the seventh year of the solar cycle the maximum of the average value of the index of the geomagnetic activity index Apm and completes the repolarization, i.e., the change of the polarity of the Sun's magnetic field. This is shown by the diagram in Fig. 4. The annual average daily values of this index (Apym) were taken from the site of the Helmholtz Center Potsdam [10].



**Fig. 4. Arithmetic mean values of the geomagnetic index Apm and Wolf numbers, 12-year solar cycles for 1961-2023.**

From the 1st to the 7th years of solar activity cycles, the Apm index mainly increases and a strong feedback is in effect between the average Wolf and GDP numbers with a lag of 1 year. From the 7th to the 12th years of solar activity cycles, the Apm index mainly decreases and a strong direct connection begins to operate between the average Wolf and GDP numbers with a lag of 1 year.

PhD Igor Nikulin, senior researcher at the Sternberg Astronomical Institute, notes in an interview with Rossiyskaya Gazeta that “over millions of years of evolution, all living beings have adapted **to the average values** of these factors [temperature, pressure, atmospheric composition, magnetic field – V.B.], and even small deviations in one direction or another have a negative impact on their vital functions” [11].

In his work “Physiological and pathophysiological aspects of the influence of solar activity on the human body”, Doctor of Medical Sciences Yu. I. Gurfinkel presents the following results of scientific experiments at the Institute of Medical and Biological Problems within the framework of the Mars-500 program. “It is interesting,” he notes, “that not only geomagnetic **disturbances** , but also periods of **very calm** geomagnetic conditions affect capillary blood flow, **slowing it down** . This is indicated by a recently completed study with isolation at the Institute of Medical and Biological Problems of the Russian Academy of Sciences in healthy volunteers within the framework of the MARS-500 program, during which the state of capillary blood flow on randomly selected days was studied using a digital capillaroscope. The program participants did not receive information about the geomagnetic situation during the experiment. On the days of geomagnetic disturbances, the capillary blood velocity was  $389 \pm 167 \text{ } \mu\text{m/s}$ , which was statistically significant ( $p < 0.05$ ) in comparison with the capillary blood velocity for a normal quiet geomagnetic environment. We divided the quiet geomagnetic environment into two parts: very quiet (Amsk 1-4) and simply quiet (Amsk 5-7), since our study revealed a statistically significant difference in the capillary blood velocity. While in a normal quiet environment the capillary blood velocity was on average  $643 \pm 178 \text{ } \mu\text{m/s}$ , in a very quiet geomagnetic environment the capillary blood velocity was  $435 \pm 223 \text{ } \mu\text{m/s}$  ( $p < 0.02$ ). This phenomenon is possibly due to the influence of the increase in the intensity of galactic cosmic rays during the period of low solar wind speeds” [12, p.38].

“After a long search, when it seemed like all conceivable possibilities had been considered,” says Doctor of Medical Sciences Mikhail Blank in his interview with Rossiyskaya Gazeta, “we came to an unexpected discovery: hemodepression (deterioration of blood composition – V.B.) intensifies under **extreme conditions** of the geomagnetic environment – **under magnetic storms and magnetic calm** . But the average values of the magnetic field do not affect the composition of the blood” [13]. The text in bold in the quotes above is mine.

These results of medical experiments explain the mechanism of the relationship between the gross world product with a lag of 1 year and the average Wolf numbers, shown in Fig. 3.

A significant decrease in the capillary blood flow velocity and deterioration of blood composition during periods of magnetic extremes (maximums and minimums of Wolf numbers) appears to lead to an increase in pessimistic sentiments in all markets and, accordingly, a tendency to save, which ultimately leads to a decrease in the GDP index with a lag of 1 year. This lag may be explained by the fact that during the current year, contracts concluded mainly last year are being fulfilled.

It does not follow from the conducted research that solar activity is the only factor determining economic cycles. Military and political events, sanctions, trade wars, abrupt changes in the economic policies of leading economic countries, administrative decisions in the economy lead to the fact that the value of the approximation coefficient in the diagram in Fig. 3 is equal to 0.7907. Otherwise, it

would be significantly higher. It seems that an increase in the observation period will lead to an increase in the value of the approximation coefficient in the diagram in this Fig.

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