The Impact of Natural and Climatic Anomalies on the Dynamics of Economic Development

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Abstract. Crisis events in the economy of the first half of the 21st century are considered as a manifestation of their inevitable cyclicality based on the correlation analysis of statistics of anomalous natural and climatic phenomena. Using spectral analysis methods, the rhythm of these events in the past was investigated, and simultaneously with the use of a specially developed neural model, their cyclical manifestation is predicted for the coming period - until 2049. It is shown that the cyclical nature of natural and climatic phenomena can be considered as one of the economy's macroeconomic indicators when conducting long-term forecasting of its dynamics.

1. Introduction
The beginning of the 21st century was marked by some significant natural, climatic, artificial, social, financial, economic and virological disasters. It is sufficient to recall the accelerated increase in global temperature in the northern hemisphere with the onset of the millennium, a volcanic explosion in Iceland, hurricane Katrina, an accident at the Fukushima nuclear power plant, floods and forest fires in southern Europe and Siberia, colour revolutions in the Arab world, economic crises in 1998 -99 and 2009 [1]. And finally, the global world crisis in 2020, triggered by the coronavirus pandemic [2, 3]. There are too many coincidences for coincidences, including in their concentration in time. The frequency of these events falls at the beginning of the 2000s of the new century, at the turn of the first and second decades, and the beginning of the present-day [4].

Analyzing the statistical data of anomalous natural, political and economic phenomena, we can conclude that all crisis events manifest an inevitable cyclicity in their temporal dynamics, mainly due to periodic natural processes [5].

2. Description of the operation of the neural network with the mixed functions of the program
The calculations were carried out using the STATISTICA Neural Networks software package, which is the implementation of the entire set of neural network methods for data analysis. The program uses a neural network - a multilayer perceptron (MLP) with training by backpropagation of an error [6]. Due to many interrelated factors of economic statistics and anomalous natural and climatic phenomena, in these software products, there is a possibility of "mixing" other parallel inputs, thereby taking into account the influence of correlated processes.

The following algorithm is used to train a neural network:
Initialization. All weights of neural network connections are randomly filled with numbers from 0 to 0.01;

Training. Various samples are fed into the input. A selection is several successive values of a function preceding the resulting value. The number of such input points (f, "frame size") is determined by the user of the neural network. If it is necessary to smooth out the too detailed and noisy selection, it can preliminarily be done, for example, using Excel tools. The following expression describes the general scheme of the used neural network:

\[
(F (X [nf]), ..., F (X [n-2]), F (X [n-1]), F (X [n])) = F (X [n + 1]),
\]

where there are \( N \) functions \( F1...FN \) with \( n \) number of points. The frame size is specified in the settings = \( f \) (i.e. the number of points taken to calculate the next one). It is required to construct a forecast of \( n + 1 \) points of the function \( F1: F1 (X [n + 1]) \). The resulting value is \( F1 \) checked against the already known point. Obviously, during training, the last point of the function is never used as an input point but is only a test point.

Points are submitted starting from the first and shifting by one after the other run through the neural network. Further, the correctness of the result is assessed. The weights of connections between neurons are corrected: towards strengthening (increase) in case of correct operation of the relationship and towards weakening (decrease) in case of the incorrect connection process. This iteration is repeated a user-defined number of times ("number of learning epochs").

Forecasting. The input values are also fed to the input of the neural network, and the required values are obtained at the output. Since these values are initially unknown, no training correction of the weights takes place.

Further, each calculated point is taken as known and can be used as an input value to calculate the value following it.

"Mixing" of input functions. Sometimes there is a situation when, presumably, a specific function \( F1 \) correlates with a particular function \( F2 \) (in a more general case, a correlation with the functions \( F2 \) ... \( FN \)). In this case, it is necessary to explain this to the neural network at the training stage. The method chosen to accomplish this is as follows: the number of inputs and outputs of the neural network becomes more significant \( N \) times (\( N \) is the total number of functions) when \( N-1 \) functions are substituted. The input is now the values of the desired function and the values of other functions. The rest of the neural network continues to operate according to the same principles: the order of neural network training, activation function, etc., do not change. In this case, the correction of the weights during education is performed for all outputs. The number of test sample values for the admixed functions should be the same as for the desired function. After training, the same number remains at the stage of predicting the inputs (the network topology is unchanged). Still, the values of the admixed functions are not taken into account in the result but are used only to feed the neural network input when calculating subsequent values.

We do not describe the details of the algorithm here, but the results of the resulting predictions using the described procedure give satisfactory results.

3. Analysis and forecast of the cyclical nature of climatic phenomena and indicators of economic development

For a detailed analysis of the spectral characteristics of various curves of natural and economic dynamics, spectral analysis methods were used to identify the main statistical patterns of these phenomena and their comparison with the corresponding parameters of the economy (GDP). In particular, the study of the curves of the temporal relationship between the main dominant global natural factors - the temperature anomalies of the Northern Hemisphere (TNH), the international number of natural anomalies (NA) and financial and economic processes (using the example of GDP of the largest economy in the world - USA). The curves are plotted for the interval 1991 - 2020 with a further expansion to 2020 - 2050 due to the inclusion in the current series of forecast data obtained using the Institute of Energy Strategy [4,7,8]. It is important to note that due to many interrelated factors on the
market, there is a possibility of "mixing" other parallel inputs in the used neural model, thereby considering the influence of correlated processes.

As the initial information for the interannual variation of the air temperature anomaly in the Northern Hemisphere of the Earth (for the latitudinal location 0 - 90 °N), we used the average monthly average over the corresponding latitudinal zone. Air temperature near the Earth's surface (TNH curves) was obtained from the Berkeley Earth Climate Research Unit, University of East Anglia. The specified data are freely available on the website http://berkeleyearth.org/data/. 1951–1980 was used as the base averaging period for assessing air temperature anomalies; the methodology and algorithms for data processing and control of their quality at all stages are described in [9]. The initial data for the US GDP and the global number of natural anomalies (NA) were obtained from the open archive of the Laboratory of Global Data Changes at the University of Oxford "Our World in Data" (https://ourworldindata.org/). The NA number is the cumulative numerical index of the world's registered natural disasters in any given year. It includes annual manifestations of droughts, floods, extreme weather conditions, extreme temperatures, landslides, mudflows, forest fires, volcanic activity and earthquakes.

Analyzing the graph of the time curve TNH, NA, US GDP for 1991 - 2049 years (figure 1a), we can conclude that natural factors (TNH, NA) have similar characteristics, which indicates the presence of a pronounced correlation between the values of time curves TNH, NA rather than curves TNH, US GDP.

To confirm this assumption, an in-depth correlation analysis of these curves was carried out using scatterplots.

![Figure 1](https://example.com/figure1.png)

**Figure 1.** (a) - Time curves of NA, TNH, US GDP changes for 1991 – 2049; (b) - Scatter plot of TNH and NA; (c) - Scatter plot of TNH and US GDP. Source: author's calculations; berkeleyearth.org; ourworldindata.org.

For quantitative detection of correlations were constructed corresponding scatterplots (figures 1b, 1c); diagram obtained confirmed our hypothesis of the existence of a significant direct correlation.
between TNH and NA (with a correlation coefficient of $r = 0.54$) and less pronounced depending anomalies TNH on the US GDP ($r = 0.27$). It is important to note that there is also a visually statistically significant relationship between "global warming" and US GDP growth ($r > 0.5$).

The graph in figure 2a, a shows that the US GDP curve has relatively high volatility with clearly pronounced crises in 2009, 2020 and projected economic downturns in 2030 and 2041. The inter-crisis period, which is 10-12 years, coincides with the characteristic periods of the Sun's activity. However, crises at this time stage fall at the minimum level of the Sun's activity [7]. Whereas at earlier stages (up to 2006), they coincided with the peaks of solar activity. This fact, unfortunately, has not yet received a proper explanation. Other important factors may influence the current and future dynamics of economic development. The curve of economic dynamics of US GDP is given according to quarterly average data. Therefore, economic failures in mid-2020 are more pronounced than in the average annual graph shown in figures 1a and 2a. Inclusion in the forecasting algorithm of the smoothed temperature anomalies of the Northern Hemisphere TNH somewhat reduces this volatility, making the failure peaks of economic crises less pronounced (figure 2b). The results of neural forecasting of US GDP with the "mixing" of temperature data of TNH anomalies make it possible to visually see that the "orange" curve of GDP is well correlated with the smoothed trend "blue" curve of temperature anomalies.

The world's largest economy in the United States has a particular impact on the studied climatic parameters. Therefore, speaking of global warming, it should be recognized that the United States, along
with China, is to a greater extent (due to the higher level of economies and technogenic influence) responsible for the temperature rise in the Northern hemisphere of the planet.

4. Conclusions
The obtained results of spectral analysis and neural forecasting allow us to conclude that there is a specific cyclical nature of natural and climatic phenomena. They can be considered one of the macroeconomic indicators for long-term forecasting of GDP dynamics. It was found that the level of correlation between temperature anomalies and an increase in the number of natural anomalies is noticeably higher than the relationship between temperature anomalies and economic growth. However, a visually and quantitatively statistically significant relationship exists between "global warming" and economic dynamics (US GDP). In particular, considering the natural and climatic factors of "mixing" in the preparation of neural forecasts of economic indicators makes it possible to predict the onset of crisis phenomena in the economy more accurately. Some studies show that an increase in temperature anomalies can lead to a long-term negative impact on economic growth [10,11], which determines the importance of taking both direct and feedback "economy-climate" into account. For all the significance of the activities of humanity itself, its philosophical concept Noosphere essence suggests that not only human activity transforms nature, but the very heart of the Earth and the Cosmos determine the life of the economy and society. This is manifested, among other things, in the formation of cycles of economic and social life. New world challenges are associated with geopolitical confrontation, "bubbles" of the virtual economy, a transformation of the structure of the world energy, and the growth of natural energy activity.

5. References
[1] Dynkin A, Burrows M, Mikheev V V, Arbatov A G, Ivanova N I, Voitolovsky F G, Kuznetsov A V, Machavariani G I, Arbatova N K, Afontsev S A and others 2016 The global system at a turning point: paths towards a new normality World economy and international relations 60 5–25
[2] Malova T A 2020 What the paradoxes of the global economy signalize Vestnik MGIMO University
[3] Dynkin A A and Telegina E A 2020 Pandemic shock and post-crisis world World economy and international relations 64 5-16
[4] Bushuev V V, Klepach A N, Soloviev D A and Sokotushchenko N V 2020 Analysis and forecast of the cyclicity of socio-natural phenomena in the first half of the 21st century Environment and energy science 36-44
[5] Bushuevand Kopylov1998 Energocosmism of Russia 143
[6] IPKubat M 1999 Neural networks: a comprehensive foundation by Simon Haykin, Macmillan 1994 ISBN 0-02-352781-7 Knowl. Eng. Rev. 13 409–12
[7] Sokotushchenko N V 2013 Influence of solar activity on socio-political phenomena Energy policy 1 60–6
[8] Bushuev V V and Sokotushchenko V N 2015 Intelligent Forecasting (Moscow: Energy)
[9] Rohde R, Muller R, Jacobsen R, Perlmutter S, Rosenfeld A, Wurtele J, Curry J, Wickham C and Mosher S 2013 Berkeley Earth Temperature Averaging Process Geoinfor Geostat An Overv. 1
[10] Rudebusch G D and others 2019 Climate change and the Federal Reserve FRBSF Econ. Lett. 9
[11] Nefedova L V and Solovyev D A 2020 Assessment of the global climate change impact on Fuel and Energy Complex infrastructure and adaptation opportunities in the Russian Arctic IOP Conf. Ser. 1040

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