







# Analysis and Modeling of Globalization Processes in the Period of Crisis: The Impact of Military Actions in Ukraine on World Financial Markets

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**Abstract:** This research is applied. The article attempts to model and analyze the impact of the war in Ukraine on the world's globalization processes. This topic is relevant, but still little researched. Using the wavelet entropy method, models were built for the markets of natural gas, oil, gasoline, currency pairs EUR/USD, GBP/USD. Wavelet entropy is an indicator-precursor of crisis phenomena. The obtained results allow us to conclude that the war in Ukraine is a factor of crises in the studied markets and a factor that led to the reformatting of the world economic space.

## 1 INTRODUCTION


At the turn of the 20th-21st century, the problems and theoretical and methodological approaches of forecasting, analysis, and modeling of globalization processes under the influence of crisis phenomena of various etymologies are the objects of scientific research by scientists. The genesis of globalization theories from the Keynesian to the neoliberal model in the 20th century, which led to the construction and development of the post-industrial economy, testifies to its crisis in the modern world, as humanity faced such problems and manifestations of social life as political, social, economic instability (wars, the coronavirus crisis, the realization of the rights of nations to self-determination, the fight against hunger, the social stratification of the population by income level) and the challenges of human interaction with nature – ecological, energy, raw material, food, demographic crises.


All these challenges led to the conclusion that in


the 21st century economic growth trends will remain, but they will acquire a new direction due to the fact that services and their role in the world economy will change qualitatively, and their rapid digitalization will take place, and the vector of scientific and technological progress will change.


To date, globalization processes are associated with such trends as the division of world markets into core and periphery, which leads to the emergence of conflicting interests between hegemon countries and “peripheral” countries; integration of national economies and peoples into a single system with the emergence of powerful regional associations; polarization of incomes in connection with the objective tendency to increase production volumes, growth of labor productivity; efficient and quick movement of capital and speculative activities of the financial elite; the emergence of contradictions between the virtual and real sectors of the economy; the need to unite in order to oppose international terrorism, world crises, etc.


Thus, according to the famous French economist, Nobel Prize laureate Maurice Alle, “the comprehensive globalization of trade between countries with significantly different wage levels (according to the exchange rate of currencies) cannot but ultimately lead everywhere – both in developed and less developed


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countries – only to unemployment, falling rates of economic growth, inequality, poverty. It is neither inevitable, nor necessary, nor desirable” (Vedernikova, 2017).

We can partially agree with this statement, since globalization processes, in addition to positive effects on the development of the world economy, in particular monetary and financial systems, also have negative ones, namely: a decrease in the degree of sovereignty and economic, political, energy independence of individual countries; the rapid spread of financial crises from one region to another, the significant impact of political, food, and energy crises on the economy of dependent countries (for example, since the beginning of the war in Ukraine and with the blockade of its seaports, the possibility of a food crisis in grain-importing countries has arisen), an increase forced migration, rising unemployment.

Today, the highest level of globalization is observed in the financial and investment sphere, when financial flows in the world economy are redistributed through financial markets, which are mostly not related to real markets for goods and services – all this periodically leads to the emergence of financial crises that practically destroy individual financial systems and markets, lead to socio-economic, demographic, financial instability. For example, the current regional financial crises in the USA, China and other major players, the global coronavirus crisis, the consequences of which are felt in all spheres of society to this day.

The financial crisis at the beginning of the 21st century was partially offset by the financial investments of various regions of the world in the US economy and the wars in Afghanistan and Iraq launched by NATO countries in response to the terrorist acts of September 11, 2001. These wars led to the active development of the military industry of the United States and, through inter-industry connections, had a positive effect on their economy.

Because of the war in Ukraine and in connection with the provision of military aid to it, the military-industrial complex of the United States and certain European countries are currently increasing their production volumes, therefore they need additional financial investments, which cannot but affect the state of global and regional financial markets. Therefore, the relevance of the proposed research topic is beyond doubt, and scientists and state managers need to have a toolkit that will allow them to follow the trends of the further development of the globalized financial system, and in particular, financial markets.

Therefore, the issues of analysis and modeling of globalization processes in crisis periods, which affect

the state and development of financial markets, are becoming particularly relevant. Considerable attention is paid to the outlined scientific problem in the publications of both foreign and domestic scientists. Thus, the relationship between the bankruptcy rate of banking institutions and the deepest financial crisis in the emerging market of Turkey was investigated with sixteen different performance indicators using two alternative methods of stochastic analysis – frontier analysis (SFA) and data coverage analysis (DEA) (Isik and Uygur, 2021). The authors prove that efficiency indicators, as a rule, gradually deteriorate before a crisis, reach a “bottom” during a crisis and recover after a crisis.

Statistical analysis of financial relationships during the European sovereign debt crisis is used to model the movement of yields on the bond market (Campos-Martins and Amado, 2022). The resulting model allowed the authors to draw conclusions about the long-run and short-run contagion effects. Namely, it has been proven that in peripheral countries after the most acute phase of the sovereign crisis, there is a long-run contagion effect.

Many studies are devoted to the modeling of yield, volatility, the profitability of various financial instruments and the degree of their risk in financial markets using a wide range of methods. Thus, in the article (Labidi et al., 2018), the authors investigate the cross-quantile relationship between stock returns in developed and emerging markets with the study of time-varying characteristics using recursive sample estimates. The obtained results, based on the cross-quantile approach, show a heterogeneous quantile relationship of US, UK, German and Japanese stock returns to the returns of emerging market stocks. Systematic risk, according to the authors, as a rule, does not explain the dependence structure of regional and local markets, as it remains practically unchanged in the conditions of financial, geopolitical and economic uncertainties. Moreover, the cross-quantile correlation varies over time, especially in the low and high quantiles, indicating its tendency to jumps and breaks even in a stable dependence structure.

The multiplicative error model (MEM) is proposed for modeling the dynamics of illiquidity in financial markets (Xu et al., 2018). The authors empirically investigated the side effects of illiquidity and volatility in eight developed stock markets during and after the global financial crisis. It was found that the stock markets are interdependent both in terms of volatility and illiquidity, and in most of them, there is an increase in their side effects during the crisis. The authors conclude that illiquidity is a more important channel of shocks in stock markets compared to

volatility, and that the impact of illiquidity in US markets on other stock markets is significant.

GARCH models (ARMA-GARCH, ARMA-EGARCH and ARMA-FIGARCH) were used to study the impact of COVID-19 on the precious metals market (Bentes, 2022). The results of the study showed the presence of long memory in this market in the periods before and during the crisis. Conclusions were made regarding the significant impact of COVID-19 on the volatility of the precious metals market.

The high-dimensional conditional Value-at-Risk (CoVaR), which is based on the LASSO-VAR model, is used to study the systemic risks of financial contagion in crisis situations using the example of oil markets and G20 stock markets (Liu et al., 2022). The authors proved that in the event of a crisis in the oil markets, the stock markets of those countries that are connected with oil production will experience the greatest shocks.

Changes in the environment and depletion of natural resources have led to investment in renewable energy sources, and therefore to the need to analyze herd (collective) behavior in this market (Chang et al., 2020). In the article, the authors presented the results of testing the collective behavior of the renewable energy market using an empirical model during the periods of the global financial crisis and the coronavirus crisis. The authors proved the herd behavior of market participants during periods of crises in the oil markets. As a result, there is an invigoration of collective behavior in the stock markets as well. Attention is also paid to the study of contagion and the emergence of risks from fossil fuel energy markets to renewable energy stock markets.

One of the modern trends in monitoring, modeling and forecasting financial markets in crisis periods is the use of tools of nonlinear dynamics – fractal, recurrent, entropy, wavelet analyses, quantum modeling, etc. Thus, fractal and entropy analysis methods were used when modeling the cryptocurrency market in the conditions of the corona crisis (Danylchuk et al., 2020). The use of these methods made it possible to draw conclusions about cryptocurrency market trends and identify crisis situations. The wavelet entropy method, which was also used in the study, made it possible to conduct predictive analysis of the cryptocurrency market. The authors emphasized the universality of the methods for identifying crisis phenomena regardless of the nature of the crisis.

The article (Bielinskyi et al., 2021) is devoted to the identification of special conditions in the cryptocurrency market. The authors classified and adapted quantitative indicators to this market, analyzed their

behavior in the conditions of critical events and well-known cryptocurrency market crashes.

Danylchuk et al. (Danylchuk et al., 2019) use entropy methods to determine the investment attractiveness of countries. For this purpose, regional stock markets are studied, as they are a reflection of the economies of countries.

Quantum modeling, namely the heterogeneous economic model, has been applied to stock markets (Kuzu et al., 2022). With the help of “measurement of the temperature of the series” crisis periods in the markets were detected. This model made it possible to adequately compare the features of the flow and consequences of various crises.

Modeling the impact of geopolitical risks on the state and dynamics of financial markets under conditions of crises of various natures is a little-researched field. This issue becomes especially relevant in the context of the creation of political and economic alliances and recent political crises. The article (Choi, 2022) presents the results of using the method of multiple and partial wavelet-coherent analysis regarding the influence of geopolitical problems on stock markets in the countries of Northeast Asia. Abdel-Latif and El-Gamal (Abdel-Latif and El-Gamal, 2020) investigate the global dynamic interrelationship between the prices of petroleum products, oil, financial liquidity, geopolitical risk and economic indicators of the economies of countries dependent on oil exports. For this purpose, the authors use the global vector autoregression (GVAR) model.

In the conditions of a full-fledged war in Ukraine, a special vector of scientific research is aimed at identifying the impact of the political and socio-economic crisis on the state and dynamics of world financial markets, which is reflected in a number of publications. Bounou and Yatié (Bounou and Yatié, 2022) provide empirical evidence of the negative impact of the war in Ukraine on the profitability of the global stock market. The largest decrease in the indicator was demonstrated by the markets of those countries geographically bordering Ukraine and Russia, as well as countries that condemned the war.

The impact of the war in Ukraine on financial markets is studied in the article (Lo et al., 2022) from the point of view of the dependence of the studied countries on Russian goods. The authors note that the war has increased instability in markets for all countries, but its degree is directly proportional to a country's dependence on Russian goods.

Boubaker et al. (Boubaker et al., 2022) came to the conclusion that more globalized markets were more affected by the war in Ukraine. However, the US market showed growing trends, Asian markets did

not react to this crisis.

So, modern crises of political, social, military and pandemic nature have led to a certain change in globalization trends in financial markets, which requires more detailed research and analysis from scientists. Classical methods of analysis and modeling do not always allow adequate assessment and forecasting of these processes, and therefore, there is a need to use a complex, interdisciplinary approach to solving this scientific task.

## 2 RESEARCH METHODS

In this study, the wavelet entropy method is used to model and analyze the impact of the war in Ukraine on globalization processes using the example of the gas, oil, petroleum products, and currency markets. The method of wavelet transformations is proposed for the analysis of periods in time series with the aim of detecting the evolution of parameters (Foster, 1996). Wavelet analysis based on wavelet entropy allows obtaining information about dynamic complexity (Sello, 2003).

We can describe wavelet entropy based on the work of Zunino et al. (Zunino et al., 2007). When studying the time series, which consists of sample values  $x_i, i = 1, \dots, M$ , when using a set of scales  $1, \dots, N$ , we will get a wavelet transformation (expansion)

$$X(t) = \sum_{j=1}^N \sum_k C_j \psi_{j,k}(t) = \sum_{j=1}^N r_j(t), \quad (1)$$

$r_j(t)$  contains information about the series  $X$  in scale  $2^{j-1}$  and  $2^j$ .

Application of the theory of Fourier expansions allows us to determine the energy on each scale using

$$E_j = \|r_j\|^2 = \sum_k |C_j(k)|^2. \quad (2)$$

The total energy of the series can be calculated by

$$E_{tot} = \|X\|^2 = \sum_{j=1}^N \sum_k |C_j(k)|^2 = \sum_{j=1}^N E_j. \quad (3)$$

The next step is to determine the relative wavelet energy

$$p_j = \frac{E_j}{E_{tot}}, \quad (4)$$

which provides hidden characteristics of the series in time and frequency spaces.

Using the concept of Shannon entropy, we can determine the normalized total wavelet entropy

$$E_{WT} = \frac{-\sum_{j=1}^N p_j \ln p_j}{X_{max}}. \quad (5)$$

The improvement of the wavelet entropy calculation algorithm was the use of a window procedure (Quiroga et al., 1999). The following formula is used to calculate the wavelet energy for a time window

$$E_j^{(i)} = \sum_{k=(i-1)L+1}^{iL} |C_j(k)|^2, i = 1, \dots, N_T. \quad (6)$$

The total energy in the window is calculated by

$$E_{tot}^{(i)} = \sum_{j=-N}^{-1} E_j^{(i)}. \quad (7)$$

The change in time of relative wavelet energy and normalized total wavelet entropy is obtained by

$$p_j^{(i)} = \frac{E_j^{(i)}}{E_{tot}^{(i)}}, E_{WT}^{(i)} = \sum_{j=-N}^{-1} p_j^{(i)} \cdot \frac{\ln p_j^{(i)}}{X_{max}}. \quad (8)$$

## 3 RESULTS AND DISCUSSIONS

Oil is considered to be the benchmark of world economic activity. The price of crude oil reflects such market properties as stability/volatility and liquidity.

The article examines the oil, gas and gasoline market. The most popular grades of oil are Brent and West Texas Intermediate (WTI). For this purpose, daily values of Brent and WTI brand oil indices, natural gas and gasoline for the period from January 2015 to September 2022 were used. All calculations were performed in Matlab. Calculation parameters: window width 100 points, step – 10 points. Calculations were made according to the official website Yahoo Finance (Yahoo Finance, 2022).

In figures 1, 2 shows the dynamics of indices. Arrows indicate the periods of 2020 (the beginning of the coronavirus pandemic) and 2022 (the beginning of the war in Ukraine).

From figures 1, 2 we can note 2020 a drop in oil and gasoline indices. And in 2022, all indices experienced a rapid decline. The situation regarding 2020 is quite obvious and understandable. The announcement of the pandemic halted and slowed down economic activity. Demand for oil and gasoline fell.

The fall in 2022 is due to various factors, but in our opinion, the war in Ukraine should be considered the main one. Although the events unfold on the territory of Ukraine, the consequences are felt by almost all countries. European Union countries, Great Britain, the USA, Turkey, etc. support Ukraine not only with military aid, but also with the introduction of political and economic sanctions. Russia was a strong player in the oil and gas markets. The introduction of sanctions, the refusal of Russian gas forces the market and

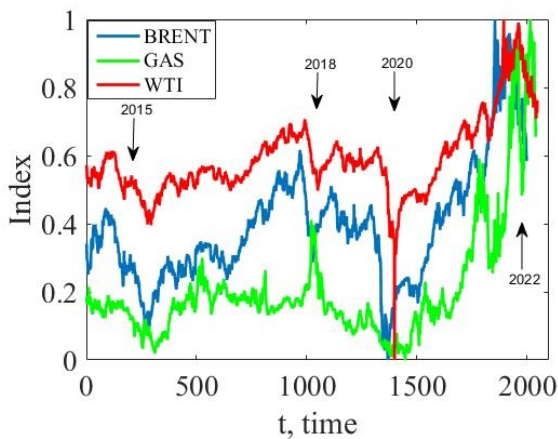


Figure 1: Comparative dynamics of oil (Brent and WTI) and gas indices.

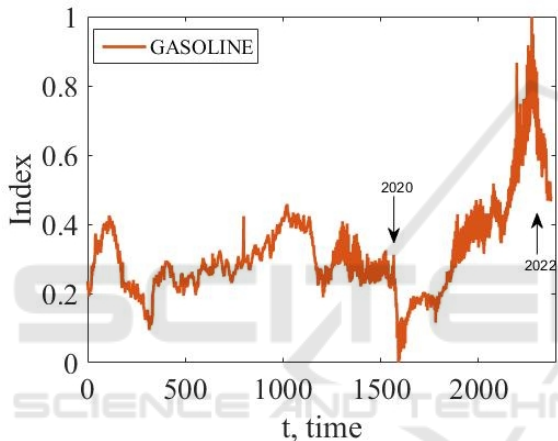


Figure 2: Dynamics of the gasoline index.

all market participants to quickly reorient themselves and reformat connections (e.g. increasing oil production in Norway, expected deliveries from Nigeria and Venezuela).

The use of wavelet entropy is due to the illustrative nature of this indicator and its predictive properties. The formation of three increasing entropy wavelet waves is a proven indicator-precursor of crisis phenomena of various natures (Soloviev et al., 2010). As soon as the third wave exceeded the maximum of the second wave, it can be argued that the market is waiting for a crisis ahead. The maximum of the third wave is a crisis itself. Therefore, the use of such an indicator allows for predicting a crisis and having time to take measures that can mitigate the consequences of the crisis. In addition, the wavelet transform provides a time-frequency representation of the signal, which allows you to obtain additional information that is not reflected in the time representation of the signal.

In figures 3–10 shows the results of wavelet entropy calculation for the gas, oil, and gasoline mar-

kets.

Analysis of the energy surface of the wavelet coefficients (figure 3) allows us to draw conclusions about the crisis situation in the gas market. On a small scale, there is a manifestation of disturbance. In wavelet analysis, small scales correspond to high frequencies.

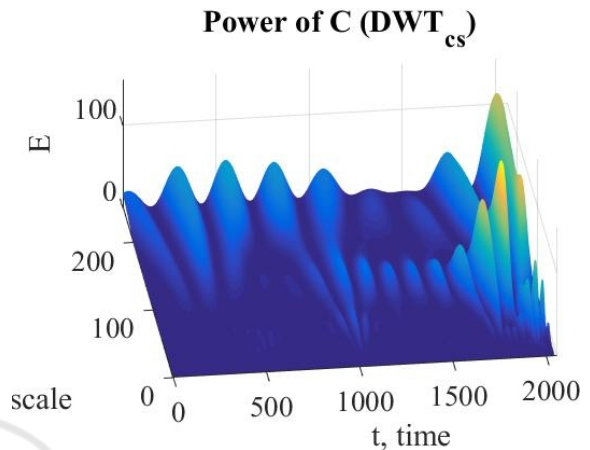


Figure 3: Wavelet coefficient energy for gas index.

Figure 4 shows the dynamics of wavelet entropy. We observe the formation of three waves in a neighborhood of 1750–2000 points, which is an indicator of the crisis. This crisis is the market’s reaction to Russia’s refusal to supply natural gas to Europe and the introduction of sanctions.

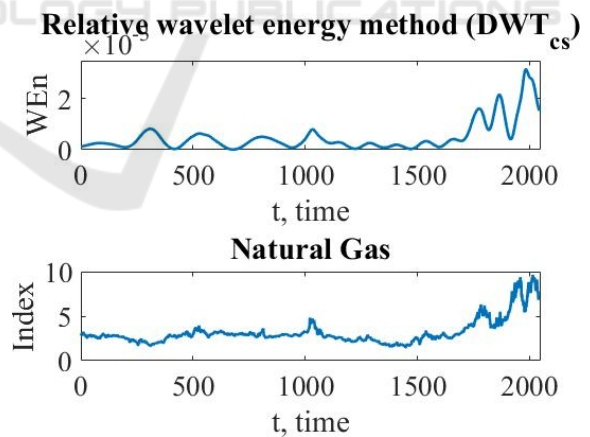


Figure 4: Wavelet entropy and dynamics of the gas index.

In figures 5, 6 shows the results of calculations for Brent oil, and figures 7, 8 – for WTI oil.

The energy of the wavelet coefficients shows a different situation for these two oil brands. This can be explained by the fact that Brent oil is traded on the markets of Europe and Asia, while WTI oil is traded on the US markets. But for the current time, the situation for these two brands of oil is similar. We see

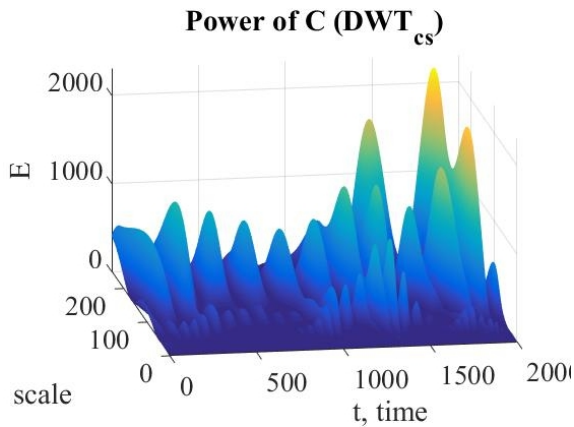


Figure 5: Wavelet coefficient energy for oil Brent index.

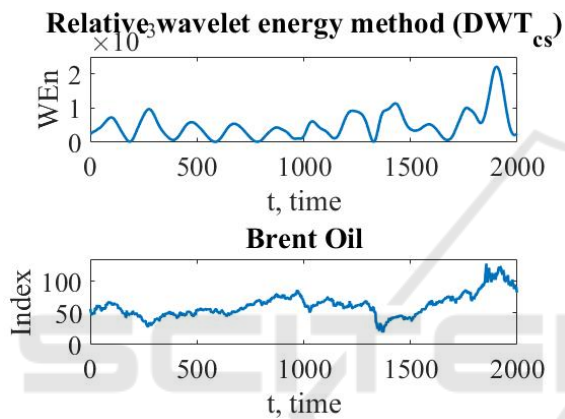


Figure 6: Wavelet entropy and dynamics of the oil Brent index.

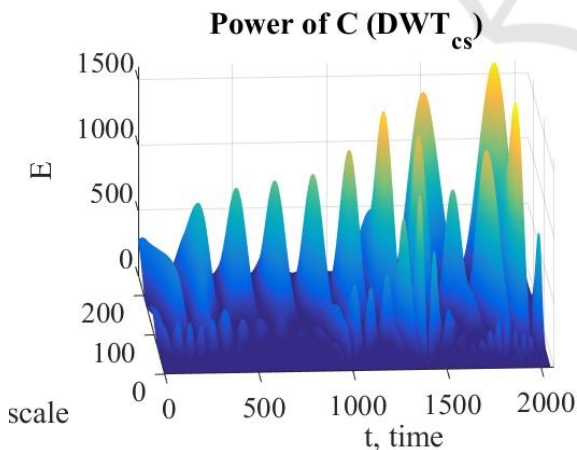


Figure 7: Wavelet coefficient energy for oil WTI index.

the formation of stable three waves, which indicates a crisis. What is happening in the oil market? It can be seen that the price of Brent and WTI oil benchmarks continue to fall. In our opinion, this is related to the war in Ukraine and the risk of recession. The

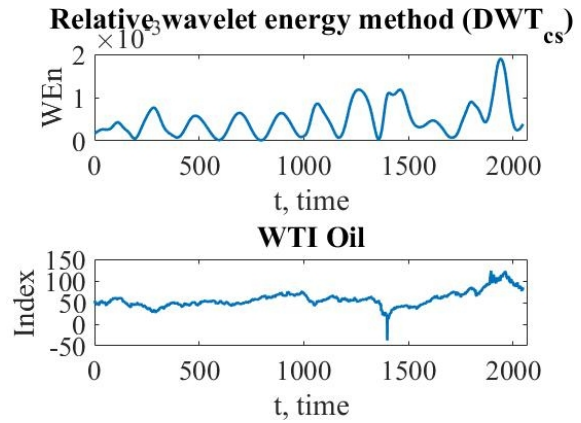


Figure 8: Wavelet entropy and dynamics of the oil WTI index.

European Union in the eighth package of anti-Russian sanctions “included a ceiling” on oil prices. In addition, the EU plans to ban sea imports of crude and refined oil from Russia. In response to the EU sanctions, Russia decided to reduce oil production by 3 million barrels per day, arguing that this is a lever to increase oil prices on the market. For Russia, the imposition of sanctions is a blow, as this is a budget-forming article (about 40% of budget revenues are in the form of taxes on hydrocarbon exports, and direct and indirect revenues related to this export make up to 60%). That is, the consequence of the introduction of sanctions will be a reduction in revenues from oil and gas. That is, it is precisely in this sector that Russia’s “Achilles’ heel” is, but the refusal of Saudi Arabia and other large Middle Eastern players to replace the Russian share of the oil market leads to fluctuations in its price, which in some way neutralizes the measures of the EU and the US countries regarding the oil embargo against Russia. They are trying to regulate the oil market. Thus, OPEC+’s decision is to reduce oil production by 2 million barrels per day, which should lead to an increase in oil prices. However, such a decision by OPEC+ has a reverse side. In particular, the United States began selling oil from reserves.

So, according to the results of the calculations, it can be stated that the oil and gas market is in a state of crisis, which was formed as a result of the war in Ukraine and the efforts of the main players to carry out its transformation, blocking Russia and reducing its influence on the world market. One such move by the global anti-Putin coalition (producing countries account for 60% of global GDP) is the declared creation of a buyers’ cartel that has set a “price ceiling” for Russian oil and oil products. Even if India and China do not join the “price ceiling”, the path of Russian oil to the world market will be difficult in December 2022, as the EU, Switzerland and Great

Britain will not only ban their factories and traders from buying it, but will also introduce sanctions on insurance, financing and ship freight, which will lead to the need for Russia not only to look for new sales markets, but also to build alternative supply chains to the world market from scratch.

In figures 9, 10 shows calculations for the gasoline market. Gasoline is a derivative of oil. Therefore, the behavior of the gasoline market should be similar to the behavior of the oil market. If oil becomes cheaper, then the price of gasoline should also fall.

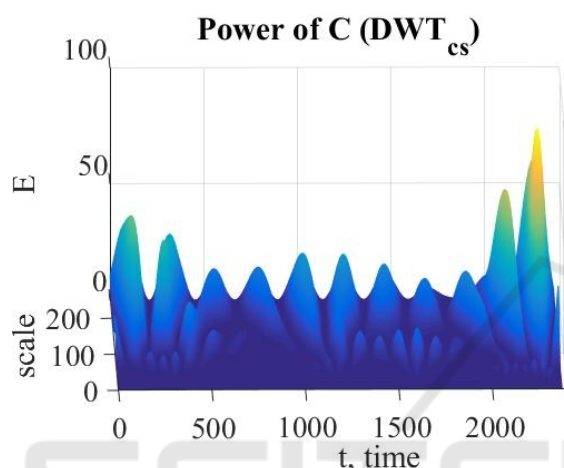


Figure 9: Wavelet coefficient energy for gasoline index.

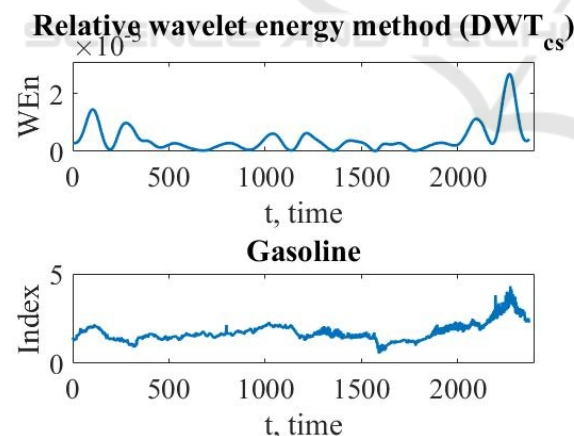


Figure 10: Wavelet entropy and dynamics of the gasoline index.

Comparing figure 9 from figure 5 and figure 7, we see that the energy surface for the gasoline market differs from the energy surfaces for oil. As you can see, the gasoline market is not stable. But starting from around the point of 1800, which corresponds to the year 2022 (figure 10), we observe the appearance of a triad of growing waves. And from this period, the behavior of the gasoline market becomes similar to the

oil and gas market. And we state the crisis state of the market. What is the impact of the war in Ukraine? The world market of oil, oil products, and gas is being reformatted, and connections are changing. Ukrainian markets are also undergoing transformation, reorienting themselves towards the EU. It is obvious that the change of players in the market (both strong and not so) leads to instability, problematic issues of redistribution of resources.

The foreign exchange market is an important component of the financial market. Modeling and analysis of the currency market will allow an understanding of the economic and organizational relations between the participants.

In figure 11 shows the comparative dynamics of currency pairs EUR/USD and GBP/USD. These currency pairs are the most traded, which influenced the selection for the study.

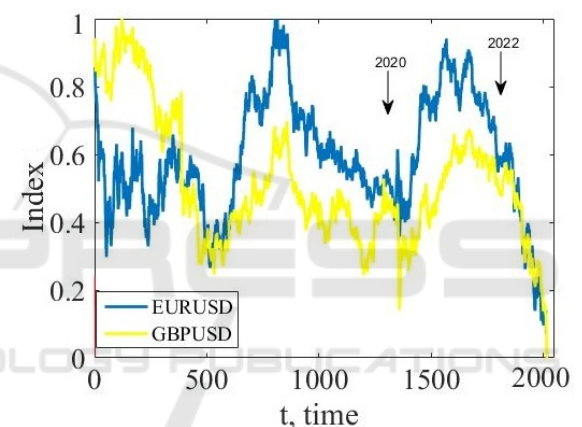


Figure 11: Comparative dynamics of indices of currency pairs EUR/USD and GBP/USD.

Figure 11 shows the sharp decline of currency pair indices in 2020. As for 2022, there is a drop in indices, but it is not of a rapid nature.

Applying the wavelet entropy method to the currency market allows you to get an answer to the question of the existence of a crisis in it. For both currency pairs, the formation of three waves, which is an indicator-precursor of the crisis phenomenon, was observed during 2015-2017 (within points 50-520, see figures 13, 15). The same situation is observed for the currency pair GBP/USD during the pandemic period (figure 15). The current situation for both currency pairs is marked by a gradual drop in the index values. The reasons for the subsidence may be the war in Ukraine, sanctions against Russia, the dependence of European states on Russian gas supplies, the political crisis in the EU regarding the support of sanctions and aid to Ukraine. The euro is the base currency, but it is also a tool for speculation.

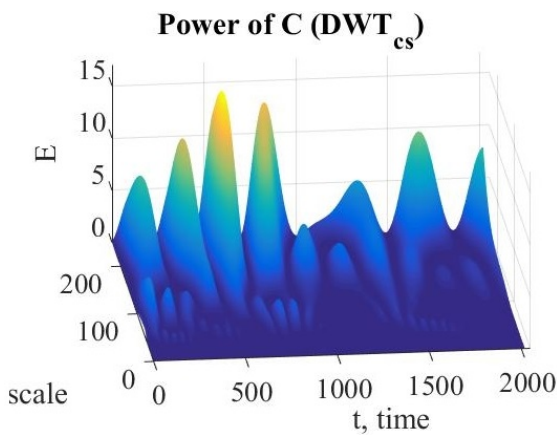


Figure 12: Wavelet coefficient energy for the currency pair EUR/USD.

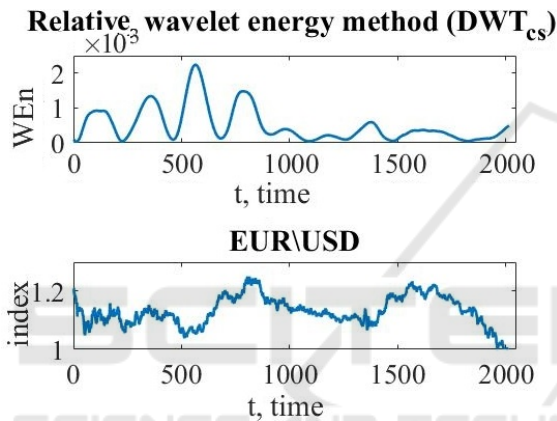


Figure 13: Wavelet entropy and dynamics of the currency pair EUR/USD.

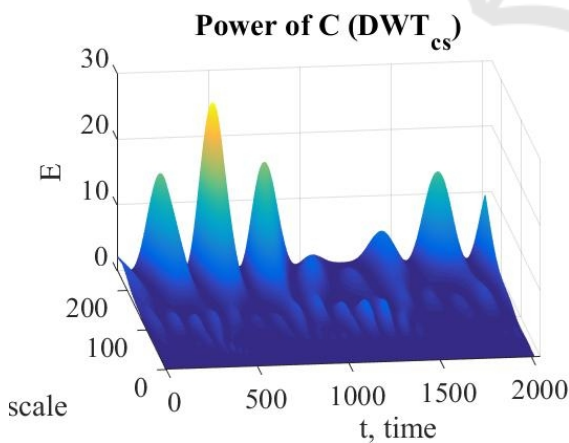


Figure 14: Wavelet coefficient energy for the currency pair GBP/USD.

Therefore, the simulation results indicate the absence of a crisis state at the time of the study. This market needs further monitoring, as the next wave is still in the process of formation.

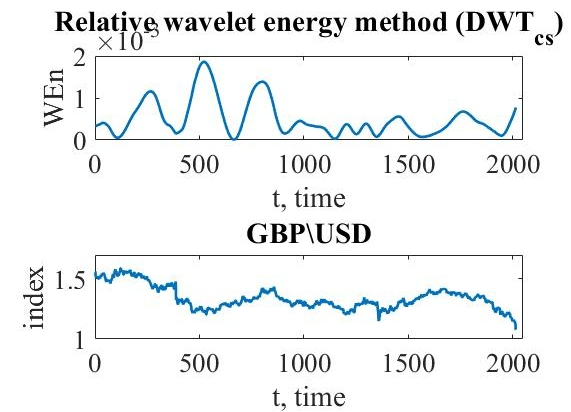


Figure 15: Wavelet entropy and dynamics of the currency pair GBP/USD.

#### 4 CONCLUSION

So, based on the results of modeling and analysis of oil, gas, oil products and foreign exchange markets using the wavelet entropy method, we can conclude that the war in Ukraine can be considered an influential factor in the crisis phenomena that are already present or are forming in these markets. Wavelet entropy models demonstrated the existence of a crisis in the oil, gas and gasoline market. In the currency market, the main currency pairs show a gradual, but rather long-term, decline. The currency market has its own characteristics and requires constant monitoring. Using the wavelet entropy method to model this market will allow early identification of a crisis state. The obtained results do not contradict the conclusions that the oil market has a heterogeneous effect on all financial assets, the peak of its influence falls precisely during the war in Ukraine (Adekoya et al., 2022), and globalized markets are more affected by the war in Ukraine (Boubaker et al., 2022) and others. Globalization processes in the world economic space carry with them, in addition to advantages, certain threats. Today, these threats exist in the market of oil, gas and other energy carriers. The war in Ukraine, unleashed by Russia for its own self-assertion, a huge desire for world domination and an overwhelming fear of losing what it has, forced the international community to review the structure, connections and processes of globalization in world economic activity.

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