Assessment of factors influencing the stability of Ukrainian export based on the fractal analysis

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Abstract. The article considered the assessment of the sustainability of the export flow of Ukraine. It was determined that the markets of Slovakia, the Russian Federation, Germany, Poland and Lithuania possess long-term memory. Also, the main factors that affect the sustainability of export have been analyzed. Among cultural factors, a weak correlation was demonstrated by Long Term Orientation, Indulgence and Power Distance according to the Geert Hofstede method. At the same time, the cultural patterns according to the S. H. Schwartz method did not show a correlation with the long-term memory of product export. On the stability of the export flow, the role of the linguistic distance and the factor of the diaspora presence have been assessed. It was proved that the gravitational effect has the greatest impact on the stability of export; Power Distance, linguistic distance and the factor of the diaspora presence have the negligible impact as well.

1 Introduction

International trade in its nature is a self-organizing system under the influence of international politics, the politics of national states, the politics of international organizations, the politics of individual market entities, etc.

The influence of the international trade entities forms the cycles and trends in the market. Thus, even at first sight, the unstable markets, with a high level of price volatility and a wide range of trade volumes, in fact, may have a clear trade structure, which is subject to the seasonality factors, economic cycles within the country and international policies of their states.

To estimate the factor of a long-term memory, the market uses fractal analysis, which allows one to find patterns that cannot be estimated by the traditional statistical methods. And so that, to understand the trends that actually exist on the market, as well as factors that have a latent effect on the export of the products, which forms the relevance of this work.

2 Methodology

Fractal analysis is used to assess the stability of export flows taking into account the influence of cyclical factors. This method was founded by H. E. Hurst [1] and based by R/S analysis technique. R/S analysis reveals patterns to detect regularities and long-term memory in conditions where traditional methods do not allow it.

Using a temporal analysis approach, B. Mandelbrot [2], and later E. Peters [3] discovered the effect of long-term memory in the stock markets. The stock market has been proven to have a long-term memory.

E. Peters identified 3 types of markets, depending on the indicator that the Hurst coefficient took [3]:

- $0 \leq H < 0.5$ – fractal market with an antipersistent series – these markets are characterized by unstable dynamics and the tendency of the indicator to the "average" value;

- $H = 0.5$ – efficient market (EMH), where prices are set according to the theory of E. F. Fama;

- $0.5 > H \geq 1$ – fractal market with a persistent series. These markets are characterized by a stable trend and long-term memory.

Since the volume of sales depends on the price of the product, this indicator can be used to analyze the level of stability in the market.

Data for R/S analysis was taken from UN Comtrade Database [4]. The sampling interval for the analysis was from January 01, 2010 to December 31, 2020: monthly indicators. This sample was determined due to the fact that the average economic cycle in the world lasts 10 years. However, since at the time of submitting the work to the editorial office, there are no data for October 01, 2020 – December 31, 2020, they were predicted using a simple moving average. Upon that, the deviation of the Hurst coefficient from the real one will not exceed 1%, which will insignificantly affect the results of the work.

For R/S analysis the following algorithm was used [5]:

1. Conversion of the time series in the logarithmic number:

$$t_i = \ln \frac{x_i}{x_{i-1}} , \; i = 2 \ldots n \qquad (1)$$

2. Finding the divisor for dividing a logarithmic series into k intervals with b number of elements in each interval.

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Table 1. The results of assessing the export flow to Ukraine's main trading partners

Country	Hurst coefficient
Fractal market with persistence of trends	
Slovak Republic	0,9427
Russian Federation	0,9422
Germany	0,8939
Poland	0,8593
Lithuania	0,8537
Belarus	0,8316
United States	0,8303
Romania	0,8067
Georgia	0,7641
Moldova	0,7371
Bulgaria	0,7327
Hungary	0,7327
Chile	0,709
Brazil	0,6968
Azerbaijan	0,6949
Iran, Islamic Republic	0,6906
Sweden	0,6828
Italy	0,6795
Egypt, Arab Republic	0,6762
Spain	0,6761
France	0,6739
Turkey	0,6725
Armenia	0,6587
China	0,6479
Algeria	0,6271
Canada	0,6266
Austria	0,6238
Kazakhstan	0,612
Effective market (EMH)	
Jordan	0,5984
Israel	0,5979
United Kingdom	0,5927
Albania	0,5909
Ireland	0,5809
Japan	0,5793
Mexico	0,5742
Denmark	0,5705
Greece	0,5683
Estonia	0,5672
Finland	0,5619
Portugal	0,552
New Zealand	0,535
Latvia	0,4946
Fractal market with anti-persistence of trends	
Argentina	0,4348
Australia	0,4197
Peru	0,4106
South Africa	0,4078

Table 2. The gravity effect between Ukraine and main trading partners

Country	Gravity coefficient
Albania	34,8575
Algeria	35,8521
Argentina	33,654
Armenia	34,3709
Australia	34,5056
Austria	38,6596
Azerbaijan	35,2912
Belarus	38,4896
Brazil	35,469
Bulgaria	36,8507
Canada	36,1735
Chile	33,0968
China	38,5091
Denmark	37,9589
Egypt, Arab Republic	36,7419
Estonia	35,9915
Finland	38,009
France	39,1631
Georgia	34,7596
Germany	40,554
Greece	37,2181
Hungary	37,9761
Ireland	36,7848
Israel	37,1875
Italy	39,2376
Japan	36,9915
Jordan	34,9293
Kazakhstan	35,7818
Latvia	36,5566
Lithuania	37,7291
Mexico	35,0504
Moldova	36,9715
New Zealand	32,3209
Peru	33,0756
Poland	39,5154
Portugal	35,2591
Romania	37,9941
Russian Federation	40,5115
Slovak Republic	37,3133
South Africa	34,0342
Spain	37,8024
Sweden	38,4725
Turkey	38,9623
United Kingdom	39,0992
United States	38,522

4. Finding the accumulated deviation from the average value for each value and series:

$$X_{i,k} = \sum_{i=1}^{b} \left(t_i - \overline{t_i} \right) \qquad (3)$$

5. Calculating the range for each interval:

$$R_k = \max(X_{i,k}) - \min(X_{i,k}) \qquad (4)$$

3. Finding the average value of the interval:

$$\overline{S}_i = \frac{1}{b} \sum_{i=1}^{b} t_i \qquad (2)$$

Table 3. Correlation analysis of the impact of cultural factors on export sustainability

	Hurst co-efficient	Power Distance	Individualism	Masculitinity	Uncertainty Avoidanance	Long Term Orientation	Indulgence	Gravity Effect
Hurst coefficient	1							
Power Distance	-0,333	1						
Individualism	-0,111	0,75	1					
Masculitinity	0,039	0,1	0,3	1				
Uncertainty Avoidanance	-0,207	0,66	0,6	0,2	1			
Long Term Orientation	-0,451	0,24	0,1	-0,1	0,1	1		
Indulgence	-0,394	0,5	0,4	0,16	0,5	0,6	1	
Gravity Effect	0,594	0,1	0,3	0,1	0,1	-0,4	-0,2	1

6. Calculating the standard deviation for each interval:

$$S_k = \sqrt{\frac{\sum_{i=1}^{b}(t_i - \overline{t_i})^2}{b-1}} \qquad (5)$$

7. Finding the normalized range for the interval:

$$R/S_k = \frac{R_k}{S_k} \qquad (6)$$

8. Finding the average value of the normalized range over all intervals:

$$R/S = \frac{1}{k}\sum_{i=1}^{k} R_i \qquad (7)$$

9. Calculating the standard error:

$$V = \frac{R/S}{\sqrt{b}} \qquad (8)$$

10. Doing subsequent iterations of the algorithm increasing the number of b values in intervals.

Selecting the b values was carried out according to the principle: 3 months (quarterly cycle of companies), 6 months (half-year cycle of companies), 12 months (annual cycle of companies), 24 months (two-year cycle), 40 months (average duration of the economic cycle in the Ukrainian economy).

3 Literature review

Today, the fractal analysis is used mainly for analyzing the characteristics of the stock market and predicting price trends [6–9] and less often for forecasting the market [10–14]. First of all, it is necessary to highlight the work of T. Ikeda [6], who conducted the fractal analysis of the main stock markets of the world and proved the presence of fractality in them. This is the opinion of R. F. Mulligan in his work [7].

In the work of M. Frezza, S. Bianchi and A. Pianese [15], the authors use the fractal analysis capabilities to track propagation waves of the COVID-19 crisis. In the work of M. Karpiarz, P. Fronczak and A. Fronczak [16],

the fractal analysis was used to interpret the distance coefficient in the distance of the gravity model.

However, scientists practically did not use the fractal analysis to assess the export flow, which significantly limits the understanding of the foreign trade trends.

4 Impact and sustainability of export flows

The analysis of trends in the international trade in Ukraine shows that in 2019 the main partner in the export of products is the European Union, China, Russia, Turkey. The share of the Russian Federation in the export of products has been steadily decreasing over the past 6 years, which may indicate, at first sight, the instability of trade between the countries. Herewith, the trade with the EU and the PRC in the initial analysis of the data indicates stable dynamics [4].

The results of assessing the export flow using the R/S analysis are shown in table 1. The source of information is the UN Comtrade Database [4].

Also, despite a significant decrease in trade between the Russian Federation and Ukraine, the trade relations between the countries remain significant. The reason for this is the preservation of economic relationships that have existed since the USSR, cultural closeness, high gravitational influence of the Russian economy and low language barriers.

Further, it is worth noting the almost identical Hurst coefficient for Poland and Lithuania. This may indicate the preservation of the relationships between the countries, which has existed since the times of the Polish-Lithuanian Commonwealth. The high Hurst coefficient for Germany can be explained by the gravitational influence of the economy on Ukraine.

In the international trade, the gravitational effect lies in the hypothesis that trade volumes depend on the level of their GDP and are inversely proportional to the distance between the countries. To assess the gravitational effect between the given countries, a modified J. Tinbergen formula was taken [17]:

$$M_{ij} = \log \frac{Y_j \cdot Y_i}{D_{ij}^2} \qquad (9)$$

where M_{ij} — attraction of two countries,

Table 4. Assessment of linguistic distance and diaspora factor

Country	Level of English knowledge [23]	Diaspora factor [24]	Total
Australia	1	0	1
Austria	0,623	0	0,623
Azerbaijan	0,432	0,5	1,932
Argentina	0,566	0	0,566
Armenia	0,494	0,5	1,994
Belarus	0,513	0,5	2,013
Bulgaria	0,579	0	1,079
Brazil	0,49	0,5	0,99
United Kingdom	1	0	1
Hungary	0,598	0,5	1,098
Germany	0,616	0,5	1,116
Greece	0,578	0	0,578
Georgia	0,503	0,5	1,003
Egypt, Arab Republic	0,437	0	0,437
Ireland	1	0	1
Spain	0,537	0,5	1,037
Italy	0,547	0,5	1,047
Kazakhstan	0,412	0,5	1,912
Canada	1	0,5	1,5
China	0,52	0	0,52
Latvia	0,555	0,5	2,055
Lithuania	0,57	0,5	2,07
Moldova	0,589	0,75	2,339
Poland	0,596	0,75	1,846
Portugal	0,618	0,5	1,118
Russian Federation	0,512	0,75	2,262
Romania	0,589	0,5	1,089
Slovak Republic	0,577	0,5	1,577
United States	1	0,5	1,5
Turkey	0,465	0	0,465
France	0,559	0	0,559
Sweden	0,625	0	0,625
Estonia	0,566	0,5	2,066
South Africa	0,607	0	0,607
Japan	0,487	0	0,487
Finland	0,613	0	0,613
Albania	0,445	0	0,445
Algeria	0,442	0	0,442
Denmark	0,632	0	0,632
Chile	0,532	0	0,532
Mexico	0,440	0	0,440
Peru	0,482	0	0,482
New Zealand	1	0	1
Jordan	0,456	0	0,456

Y_j, Y_i — GDP of the countries i and j,

D_{ij}^2 — distance between the capitals of the countries.

The results of the gravitational effect assessment are shown in table 2. The source of information is the World bank database [18] and the Distance database [19].

Germany and the Russian Federation have the greatest gravitational effect on the Ukrainian economy. It is also worth noting the high gravitational influence of other EU countries on the economy of Ukraine, primarily France, Poland and Sweden. At the same time, the United States of America, although locates at a considerable distance from Ukraine, has an equal comparable to neighboring Belarus.

The second factor that affects the long-term memory of product exports is cultural factors. These include both cultural patterns and language barriers, as well as the presence of a diaspora in the partner country.

G. Hofstede [20] and S. H. Schwartz [21] indicators will be used to assess the cultural barriers. To assess the cultural difference between the countries, it is necessary to calculate the difference between the corresponding indicator for Ukraine and the partner country:

$$CD_{ij} = |CH_i - CH_j|, \qquad (10)$$

where CD_{ij} – cultural distance between the countries i and j;

CH_i and CH_j – G. Hofstede or S. H. Schwartz indicator for countries i and j.

The correlation analysis for indicators of gravity effect and cultural distance is shown in table 3.

The average correlation effect between the stability of export and the gravitational effect of 0,5939, as well as a weak influence between the Hurst coefficient and Long Term Orientation, Indulgence and Power Distance is preserved.

The presence of a negative correlation between individual cultural patterns confirms the thesis about the influence of cultural distance on the long-term memory of product exports. At the same time, the pattern of long-term "Long Term Orientation and Indulgence" has the greatest influence, which indicates the best interaction in export transactions between people of similar nature. As for the weak inverse correlation of Power Distance and Hurst coefficient, we can say that company employees prefer to work more with countries with similar governments and distance from society.

At this, there is no correlation between the Hurst coefficient and S. H. Schwartz indicators. Linguistic factors and factors of the presence of a common diaspora also affect the stability of export. Let's consider this factor. As a methodology for assessing the impact of linguistic distance and the presence of a diaspora, we use the approach proposed by L. Vlasenko [22].

The factor of knowledge of the English language was taken as a factor in assessing the linguistic distance. The EF EPI rating was used to assess the level of knowledge of the English language [23].

Table 5. Linguistic distance and diaspora factor correlation analysis

	Hurst coefficient	Linguistic distance and diaspora factor
Hurst coefficient	1	
Linguistic distance and diaspora factor	0,460836	1

Table 6. The results of the regression model

	Coefficient	Standard error	t-Statistic	P-Value	Lower 95%	Upper 95%
Hurst coefficient	-0,67428	0,26512	-2,54331	0,014951	0,033937	0,228792
Gravity coefficient	0,034611	0,00742	4,661742	$3,46 \cdot 10^{-55}$	-1,21011	-0,13845
Power distance	-0,00152	0,000632	-2,41061	0,020613	0,019606	0,049617
Linguistic distance and diaspora factor	0,131365	0,048206	-0,0028	-0,00025		

Moreover, in the countries where knowledge of the language is native, the indicator equals to 1. As for the diaspora, based on Ethnologue data [24] the indicator of the diaspora presence was assigned a value of 0 (in the absence of a significant common diaspora), in the presence of a significant common diaspora a value of 0,5, and in the presence of very significant common diaspora a value of 0,75.

The results of assessing the indicator of linguistic distance and the diaspora factor are shown in table 4.

The results of the correlation analysis are shown in table 5.

Thus, a correlation index of 0,46 indicates the presence of an average correlation between the linguistic distance and diaspora factor and with the Hurst coefficient. Consequently, the level of knowledge of the English language in a society affects the size of the cultural barriers that arise in trade. And in the context of globalization, an increase in the level of English proficiency in society will allow the formation of stable ties in trade, which will positively affect the trade flow.

Further, based on the factor of culture, gravitational impact, linguistic distance and diaspora, let's conduct a regression analysis to identify the level of influence of each of the indicators on the level of stability.

Thus, there is an average correlation between the gravity coefficient and the Hurst coefficient, the weak correlation between the Hurst coefficient and the Power Distance, and the linguistic distance and the diaspora factor. The results of a regression model building are shown in table 6.

Thus, all indicators are statistically significant. And the given t-statistic values are above the critical value of 2,039.

The indicators of the regression model quality are shown in table 7.

Table 7. Quality indicators of the regression model

Indicator	Value
Multiple R	0,723433
R Square	0,523355
Adjusted R Square	0,487607
Standard Error	0,095665
Fisher criterion	14,63998263
Approximation index	14,64%

As a result, the data presented indicate the statistical significance of the regression model. In fact, the Fisher's criterion is higher than the critical value (2,911). At the same time, the approximation indicator is 14,64%, which indicates the high quality of the model. To assess the level of influence of factors on the Hurst coefficient, an elasticity analysis has been performed.

The results are shown in table 8.

Table 8. The elasticity analysis

Indicator	Level of 1% variation
Gravity factor	1,846%
Power distance	1,843%
Linguistic distance and diaspora factor	0,194%
Other factors	0,979%

Thus, the analysis showed that cultural factors have the same influence as the factors of gravitational influence on long-term memory in export shipments. At the same time, the linguistic distance and the factor of the presence of a diaspora in the country have an insignificant effect on long-term memory.

This suggests that Ukraine's export instead of economic factors and economic benefits is more susceptible primarily to personal connections and preferences of the management of firms and managers who are engaged in the foreign economic activity.

5 Conclusion

As a result of the conducted study, it was established, first of all, that Ukraine's export supplies to the main partner countries are subject to fractality, which indicates the presence of a long-term memory in the market. Exports to the Russian Federation are indicative, the share of which in the total export structure was significantly reduced after 2014. However, despite this, a large number of companies still supply their products to the Russian market and depend on the economic processes that are taking place in the Russian Federation. At the same time, a high level of a long-term memory of export trade is also observed with the EU countries and the USA.

In this case, the size of the country's GDP and the proximity of its location have the greatest influence on the level of fractality, which was calculated using the Gravity factor. An interesting result is the fact that cultural affinity between countries plays an almost identical role to that of the Gravity factor. At the same time, the presence of a diaspora, as well as the level of knowledge of the English language in society, has little effect on the level of a long-term memory.

This trend is more negative than positive. The high level of dependence on key partner countries with a similar culture indicates the inability of Ukrainian management to

quickly navigate the constantly changing economic environment and get significant benefits from trading with new partners, giving preference to the old ones. As a result, Ukraine loses significant export benefits.

To improve this situation, it is necessary to train to increase the level of cross-cultural management of the companies and management of the foreign economic activity. This will help lower cultural barriers and, consequently, the level of fractality of markets, which will increase the efficiency of export trade. As for the knowledge of the language, as practice shows, the majority of foreign economic activity managers in Ukraine know English, which significantly reduces the level of linguistic barriers in the export deliveries.

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