Big Data Analysis for Structuring FX Market Volatility due to Financial Crises and Exchange Rate Overshooting

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Abstract

Big Data Analysis is used in various spheres. Financial crises, which are an integral part of the modern economy, require new approaches to analysis. The research hypothesizes the existence of a link between financial crises and shocks in foreign exchange (FX) market, and it is proven using Big Data Analysis information technology. The information base of the research was data on exchange rate fluctuations during the financial crises in Ukraine (2008, 2015, 2020), as well as similar data on COVID-19 Pandemic Crisis in Ukraine, Russia, Belarus, Georgia and Poland. In the course of the research, data structuring, data visualization, analysis of statistical links and regularities among data series were performed, in particular, using F-statistics and Student's t-test. The results of the research have showed that the Big Data Analysis makes it possible to identify trends in unstructured and poorly structured data, in particular regarding exchange rate fluctuations.

Keywords 1

Data Analysis, Big Data, financial crisis, panic, exchange rate overshooting, volatility, FX market, COVID-19 Pandemic Crisis

1. Introduction

Historically, there has been clear evidence of exchange rate overshooting during episodes of macroeconomic turbulence or crisis. Exchange rate overshooting refers to the phenomenon in which the initial (short-run) depreciation rate is larger than the long-run depreciation rate. In other words, the post-crisis exchange rate tends to be lower than the short run peak level [9].

The economic crisis triggered by COVID-19 in early 2020 is a clear example of the country's financial system's ability to cope with financial shocks. Despite that the crisis causes arose outside the economic, the ability to overcome its negative effects and the time lag needed to stabilize the FX market in many countries were quite similar.

It is possible to understand the links between the phenomena caused by different factors, occurring in different countries and at different time intervals by using Big Data information technology. This technology allows to analyze large amounts of accumulated unstructured data and draw conclusions about the existence of links between fragments of information [18].

2. Literature review and research relevance

Big Data Analysis is used in various spheres, also it can be used in the research of economic phenomena and processes. L. Einav and J. Levin [7] interpret the application of Big Data Analysis in

COLINS-2021: 5th International Conference on Computational Linguistics and Intelligent Systems, April 22–23, 2021, Kharkiv, Ukraine
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economics as data revolution in economic analysis. The methods of Big Data Analysis are thoroughly described in the works of L. Bychkovska-Lipinska, Y. Bolubash, V. Lytvyn, I. Rishnyak, H. Rishnyak, N. Shakhovska, V. Vysotska, O. Veres, [18, 19, 27, 30]. Features of Big Data and prospects of its impact on live, work, and think are revealed by V. Mayer-Schonberger and K. Cukier [21]. Using SMART Big Data, analytics and metrics to make better decisions and improve performance is proposed by B. Marr [20]. Big Data Dimensional Analysis is thoroughly researched by V. Gadepally and J. Kepner [11]. Technologies based on Big Data Analysis are used by V. Lytvyn, V. Vysotska and A. Rzheuskyi [17] for specialists' recruitment procedures and by V. Vysotska, V. Lytvyn, V. Danylyk , S. Vyshemyrska, M. Luchkevych and I. Lurie [33] for detecting items with the biggest weight.

Summing up the analysis of scientific publications on Big Data Analysis, we can say about the high attention to this information technology, its thorough detailing and the possibility of its practical application for data analysis during financial crises.

Research on exchange rate dynamics and the overshooting hypothesis has been relevant for decades. The same named work by J. A. Frenkel and C. A. Rodriquez, published in 1982, even in the languages of 2021 and the Pandemic Crisis contains allows using the Big Data Analysis to draw conclusions about the causes and consequences of economic fluctuations [10]. The authors emphasize the effectiveness of corrective actions for exchange rate dynamics in FX market, which becomes especially relevant in terms of floating exchange rate. S. Kim and S. H. Kim analyze the relationship between financial panic and exchange rate overshooting during financial crises [13]. However, they do not consider exchange rate fluctuations during financial crises. The research is based on the assumption that the expectations (and, consequently, demand) are formed rationally in terms of full awareness of the FX market functioning. Such situation is uncharacteristic of financial crises, which is the cause of exchange rate fluctuations, so our research is particularly relevant. FX market volatility modeling make Š. Lyócsa, T. Plíhal, T. Výrost [16], C. Eom, T. Kaizoj, J. W. Park, E. Scalas [8], but they do not differentiate exchange rate fluctuations in crisis and stability periods, do not offer different models for analyzing currency fluctuations during financial crises.

As Ukraine switched to a floating exchange rate regime only in 2015, and started to implement currency liberalization in 2019 (the Law of Ukraine "On Currency and Currency Values" adopted in 2018 came into force on February 7, 2019), exchange rate fluctuations today ambiguously perceived by the society and provoke panic in FX market. In order to objectively FX market regulating, it is necessary to have a clear understanding of exchange rate fluctuations during financial crises, its dynamics, velocity and features of the course.

F. Benguria and A. M. Taylor study the situation in the financial markets after the panic, as well as reveal the consequences of the implementation of shocks of supply and demand during financial crises [3]. The authors emphasize the expediency of fiscal and monetary stimulation of supply and demand during financial crises, the link between financial crises and trade collapses. But their research, although thoroughly reveal the course of financial crises and their impact on supply and demand from a macroeconomic point of view, do not disclose the peculiarities of exchange rate fluctuations during financial crises and do not offer the tools of Big Data Analysis for financial crisis in general and for exchange rate overshooting in FX market in particular. Panic during financial crises is widely analyzed by T. Daniëls [5], emphasizing the need to rationalize panic in conditions of strategic uncertainty.

J. S. Hodges focuses on the comparison of different financial crises according to their reasons [12]. The focus is on comparing Global Financial Crisis (2008) and the Great Depression. His research is based solely on US data and he compare causes and consequences for the US economy of these two crises. However, the author does not focus on the FX markets volatility.

C. P. Kindleberger and R. Z. Aliber analyze the financial crises of the 17th-20th centuries from the standpoint of cyclicality [14]. The thesis of this book is that the cycle of manias and panics results from the pro-cyclical changes in the financial system. They prove that the nature of the shock varies from one speculative boom to another. However, taking into account the period in which the research was conducted, it should be remembered that the crises of 2008-2020 were not considered by the authors. In terms of the historical period at this time there are significant differences in organizing financial systems, FX regulation and monetary mechanisms totally.

E. Kohlscheen, F. H. Avalos and A. Schrimpf distinguish distinct commodity-related drivers of exchange rate movements, even at fairly high frequencies [15], but their research does not focus on analyzing the specifics of financial crises through the prism of FX market shocks and exchange rate

changes. P. Turner [29] has similar research, where he emphasizes that the exchange rate is the key endogenous variable in the transmission of external shocks (financial and real) to small open economies. As Ukraine's economy is just that - a small open economy, analyzing exchange rate volatility during financial crises becomes a priority and a key variable to be relied upon when making decisions in crisis conditions.

The theoretical foundations of currency crises are the object of researches by T. Visyna, V. Visyna, T. Polianska [32], H. Yilmazkuday [34], S. C.W. Eijffinger, B. Karataş [6]. The currency crises of the 1990s are studied by M. Cavallo, K. Kisselev, F. Perri and N. Roubini [4]. They propose a model of small open economy, which allows to explain the crisis exchange rate fluctuations, based on the size of the country's external debt, and also prove that both with a fixed exchange rate and a floating exchange rate, the negative effects of the crisis will be felt for the economy. Daniëls T. [5] also explores the currency crisis. In fact, one of the main themes of currency crises is that they have become increasingly intertwined with what happens on financial markets. However, there are not many theoretical studies that can explain the nature of financial crises and exchange rate fluctuations that occur during this period, and for Ukraine there are no such studies in the works of foreign scholars, and among Ukrainian scholars' studies of financial crumbs in Ukraine are mostly limited to one of the crises. In particular, Z. Rudenko explores the causes and consequences of the financial crisis in Ukraine in 2014-2015 [26].

Data analysis is applied to different spheres of life. Financial crises, which are an integral part of the economy, also need new approaches to analysis. Data sources are diverse, poorly structured or unstructured, so the use of Big Data information technology is a priority for data analysis during financial crises [27, 30, 31]. One of the biggest problems is the lack of a clear classification of Big Data Analysis methods and an unambiguous approach to their implementation. Their presence would greatly facilitate the choice of optimal and efficient algorithm for analyzing these data depending on their structure. Taking into account the data sets that need to be analyzed to make effective decisions in a crisis, Big Data Analysis is the tool that will qualitatively identify the main parameters of the phenomena and processes to be analyzed. Large amounts of input data require a clear understanding of the criteria for limiting the data set and forming a sample of the study - time series. In particular, innovative methods for analyzing speculative fluctuations in FX market are used by D. Alaminos, F. Aguilar-Vijande, J. R. Sánchez-Serrano [1], choosing for these purposes the neural networks formation. N. Tak and A. Gök [28] propose to use the fuzzy index for dating currency crises and designing early warning systems. Authors [31] propose application of data mining to exchange rate influence identification.

Today there is no difference in the use of the terms Big Data and Big Data Analytics. These terms describe both the data themselves and management technologies and methods of analysis [11, 18, 20]. Big Data Analytics is a development of the Data Mining concept: the same tasks, applications, data sources, methods and information technologies. From the moment of the Data Mining concept to the advent of the Big Data era, analyzed data volumes have changed in a revolutionary way, information systems of high-performance computing, new information technologies have appeared [18].

The literature review has showed that the chosen topic of the research is relevant, insufficiently disclosed and needs innovative approaches to the analysis of exchange rate overshooting in the FX market during the financial crisis.

3. Hypothesis and information base of the research

The main hypothesis of the research is: "Financial crises and shocks in FX market, which manifest themselves due to significant exchange rate fluctuations, accompany all economic crises, regardless of the primary factors that cause them".

We consider three economic crises to prove or disprove the hypothesis for the Ukrainian FX market:

- 2008 – Global Financial Crisis;
- 2015 – Military Conflict Crisis;
- 2020 – COVID-19 Pandemic Crisis.

Each of these crises was accompanied by exchange rate fluctuations, different from fluctuations under normal conditions. First of all, such exchange rate fluctuations are caused by panic among the society, which, fearing to lose the last thing it has, begins to buy foreign currency. Hypothesis testing

will also reveal whether the spikes in FX market are identical during the action of various external factors that cause society panic.

We have formed time series to study exchange rate fluctuations during crises in Ukraine. Every time series is signs of panic and is characterized by high volatility:

- 18/11/2008-18/12/2008;
- 01/02/2015-01/03/2015;
- 01/03/2020-01/04/2020.

The choice of the panic period was made on the basis of visual data analysis. The initial date of each episode is selected on the basis of visually analyzing the data and identifying a break in the movement of currency. The initial level of the exchange rate is a 30-day average of the value of the currency around the initial date. The peak level and date of each crisis episode is visually clear and we select the highest level of exchange rate after the start of the crisis. The extent of overvaluation depends on the percentage difference in the highest level of exchange rate achieved during the crisis from the post crisis stable value of the exchange rate. The stable value is calculated as the one-month average of the exchange rate after the moving coefficient of variation of the exchange rate has dropped below 2% [9].

For Ukrainian FX market these three crises are provoked by completely different external factors, so comparing the dynamics of exchange rate fluctuations and identifying the period required to stabilize the FX market will be the basis for confirming or refuting the hypothesis. During the financial crisis, the society seeks to convert a currency that devalues into a more stable currency and assets, which in turn provokes panic in the FX market.

Also we propose to use data on Poland (09.03-23.03.2020), Georgia (09.03-27.03.2020), Russia (06.03-24.03.2020), Belarus (09.03-24.03.2020) for analyzing and testing the hypothesis because these periods are characterized by panic in FX markets of the above-mentioned countries under the influence of quarantine and imposed lockdown. Accordingly, a comparison of exchange rate fluctuations in FX markets in different countries will reveal whether FX market in different countries is developing equally (statistically), as the sample includes the Eurozone, Russia and Belarus, which did not impose quarantine at all.

Time series for each of the countries and for each of the crises in Ukraine were formed on the basis of analyzing the growth rate of the exchange rate, starting from the day when its excess (non-standard) volatility begins, ending with the day when the exchange rate stabilizes and deviations are not more than 2% [9].

Big Data - a set of approaches, tools and methods for processing structured and unstructured data of huge volumes. One of the tasks of Big Data Analysis is statistical data analysis. The research of exchange rate fluctuations during financial crises is devoted to this analysis.

4. Data visualization

At the first stage we decided to analyze the growth rate of the exchange rate during COVID-19 Pandemic Crisis. To do this, we propose to use such method of Big Data Analysis as data visualization. This will allow us to detect trends in time series without performing significant amounts of calculations and the use of more sophisticated Big Data Analytics technologies.

In the analyzed countries, the period of time required for the exchange rate to reach its maximum (from the beginning of panic in FX market to the moment of stabilization of exchange rate fluctuations) was different. In particular, **Figure 1** shows how quickly exchange rate fluctuations were stabilized.

The least time was spent on stabilizing FX market in Poland - only 11 days. At the same time, Ukraine spent 31 days (3 times more time) on a similar stabilization. The average rate of FX market stabilization during the financial panic is 2 weeks (in Ukraine - more than 4 weeks). The time required to stabilize FX market is an indicator of the effectiveness of the central bank's measures to balance the FX market, as well as an indicator of confidence in the central bank's policy in general. Ukraine's negative experience in these issues, provoked by the duration and negative consequences of previous crises in FX market, is one of the key factors of public distrust in the central bank’s actions same in general, same in crisis times.

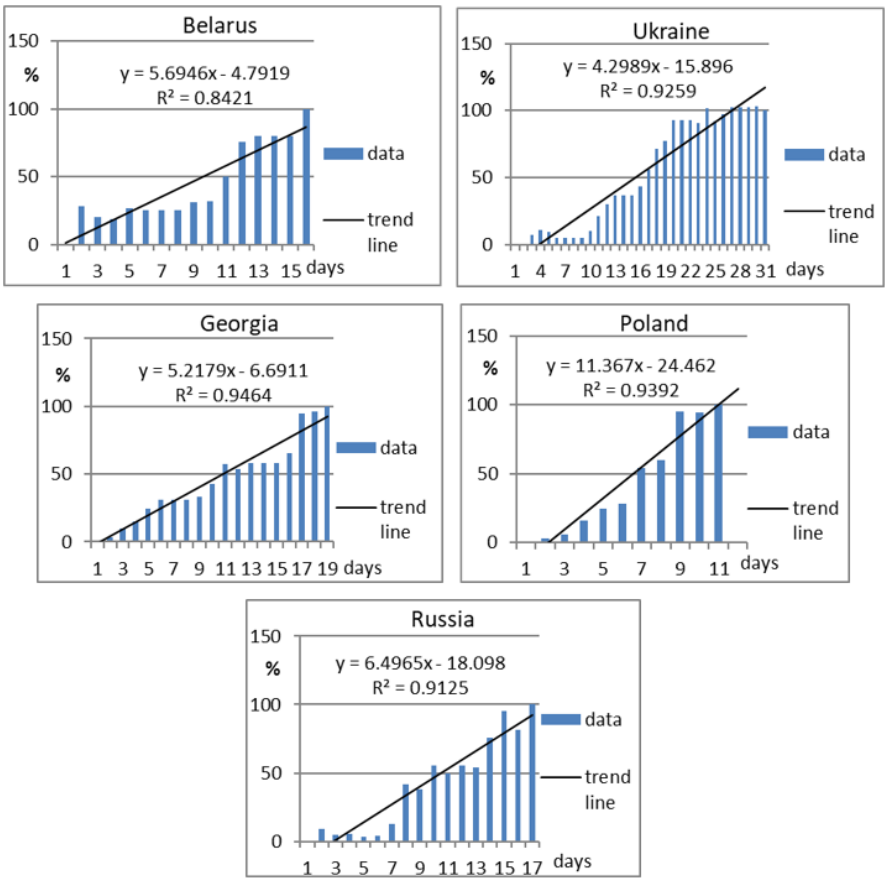

Figure 1: Comparison of the period and velocity of reaching the maximum exchange rate (time needed to stabilize FX market) during COVID-19 Pandemic Crisis

Source: calculated by the authors on the basis of the central banks' data on the exchange rates value [2, 22, 23, 24, 25]

Comparison of the exchange rate extremum achievement velocity calculated as the growth rates between the minimum and maximum exchange rate values during COVID-19 Pandemic Crisis demonstrates **Figure 2**.

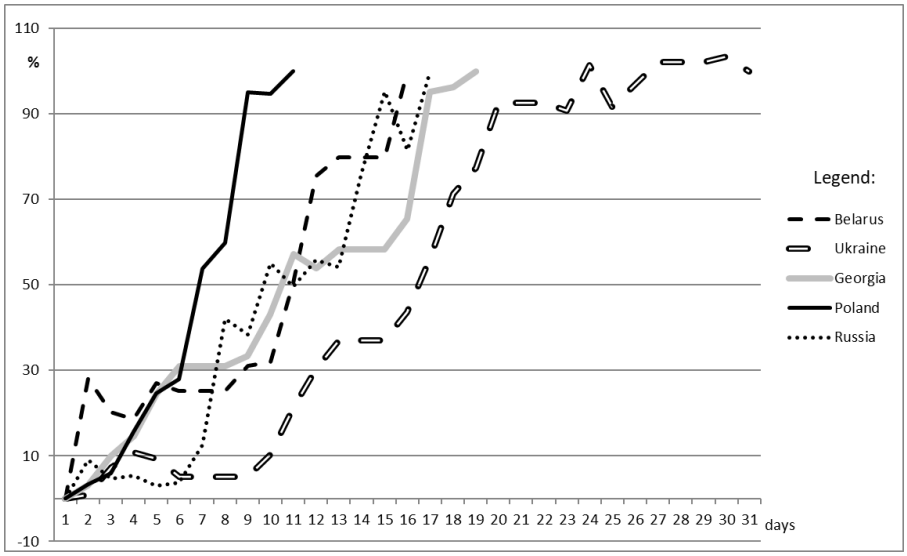

Figure 2: Comparison of the exchange rate extremum achievement velocity calculated as the growth rates between the minimum and maximum exchange rate overshooting during COVID-19 Pandemic Crisis

Source: calculated by the authors on the basis of the central banks' data on the exchange rates value [2, 22, 23, 24, 25]

The Polish FX market reaches its peak in uniform steps in the dynamics of the exchange rate. The Georgian FX market for the first 6 days develops similarly to the Polish FX market, but then, thanks to the central bank's intervention, the growth rate is temporarily reduced (formed 5-day plateau), but the market was stabilized only at the third plateau, which occurred 19 days after the beginning of exchange rate overshooting. The FX markets of Russia and Ukraine have the same tendency to reach the peak, the difference is the velocity of its achievement, which in Ukraine is 2 times lower than in Russia. However, minor exchange rate fluctuations at the beginning of the crisis (in Russia - 5 days, in Ukraine - 10 days) are further accompanied by a sharp rise in the exchange rate (in Russia - 10 days, in Ukraine - 20 days) until it reaches an extreme. No plateaus in exchange rate fluctuations, as observed in Georgia, neither in Ukraine nor in Russia do not occur.

Belarus currency market reacts differently to COVID-19 Pandemic Crisis, because from the list of countries we are analyzing, it is the only country that has not implemented quarantine and lockdown. Therefore, there was a sharp rise in the exchange rate in the first 2 days of the crisis (because the society reacts in panic to the actions of public authorities, which are different from the actions of neighboring and leading countries), the next 10 days of exchange rate fluctuations were more "smooth" other analyzed countries, but from 10 to 16 days of the crisis, the exchange rate sharply reaches peak values.

Differences in the exchange rate dynamics during COVID-19 Pandemic Crisis, as well as in the time required to stabilize FX market due to the following factors:

- level of FX market development - the more developed the market, the faster it is possible to "quench" exchange rate overshooting and stabilize the market;
- level of confidence in the central bank's measures aimed at stabilizing FX market - the higher is the confidence in the central bank's actions, the faster it is possible to "quench" the panic in FX market and stabilize the exchange rate fluctuations;
- level of effectiveness of the central bank's measures aimed at stabilizing FX market - the more diversified, innovative and objective are the measures, the faster it is possible to stabilize FX market.

If we analyze the parameters formed in **Figure 1** trend lines, we can see that the more time is spent on reaching the peak values of the exchange rate in crisis periods, the smaller is the elasticity of the exchange rate growth rate, and vice versa.

5. Big Data Analysis and detection of links and patterns of exchange rate fluctuations during COVID-19 Pandemic Crisis

It is advisable to use statistical methods of Data Mining as part of Big Data Analysis to further study the patterns of FX market volatility during financial crisis. The methods include: preliminary analysis of statistics nature, identification of links and patterns, multidimensional statistical analysis, dynamic models and forecast based on time series:

$$MDSt = \langle MS_1, MS_2, MS_3, MS_4 \rangle, \quad (1)$$

where MS_1 – descriptive analysis and description of initial data;
MS_2 – links analysis (correlation, regression, factor, variance);
MS_3 – multidimensional statistical analysis (component, discriminant, multidimensional regression, canonical correlations);
MS_4 – time series analysis (dynamic models and forecasting) [18].

In Table 1 there are shown the indicators, that characterize the exchange rates dynamics during COVID-19 Pandemic Crisis.

Table 1

Indicators, that characterize the exchange rates dynamics during COVID-19 Pandemic Crisis

Indicators	Belarus	Ukraine	Georgia	Poland	Russia
Duration of panic (share of the year),%	4.44	8.61	5.28	3.06	4.72
One-day step (velocity) of reaching the exchange rates extremum during panic,%	6.25	3.23	5.26	9.09	5.88

Source: calculated by the authors on the basis of the central banks' data on the exchange rates value [2, 22, 23, 24, 25]

The longer is the panic in FX market, the slower is the exchange rate velocity of reaching the extreme. From the economic view point, regardless of the crisis causes, the longer it lasts, the worse its consequences for the country's economy as a whole. Therefore, the priority during crisis exchange rates overshooting is to minimize the duration of panic and minimize the time spent on FX market stabilizing.

The trends identification results for the exchange rates time series during the COVID-19 Pandemic Crisis (based on F-statistics) are shown in Table 2.

Table 2

Trends identification results for the exchange rates time series during the COVID-19 Pandemic Crisis (based on F-statistics)

Indicators	100 USD exchange rate	Growth index	Growth rate
F-table$_1$		0.269	
F-table$_2$		3.7168	
F-value (Belarus / Ukraine)	144.7728	0.172635	5.792566
F-value (Belarus / Georgia)	3.282838	1.257844	1.257844
F-value (Belarus / Poland)	2.449983	1.907184	1.907184
F-value (Belarus / Russia)	1,969.631	1.810524	1.810524
F-value (Ukraine / Georgia)	44.0999	4.605154	4.605154
F-value (Ukraine / Poland)	59.09136	3.037235	3.037235
F-value (Ukraine / Russia)	13.60498	10.48758	10.48758
F-value (Georgia / Poland)	1.339943	1.516233	1.516233
F-value (Georgia / Russia)	599.9782	2.277357	2.277357
F-value (Poland / Russia)	803.9367	3.453004	3.453004

Note: if F-table$_1$< F-value < F-table$_2$, then there are identical trends in time series

Source: calculated by the authors on the basis of the central banks' data on the exchange rates value [2, 22, 23, 24, 25]

In Table 2 there are highlighted those combinations for which the presence of identical trends in time series was detected. The calculations results have shown that COVID-19 Pandemic Crisis has provoked identical trends in FX markets of Belarus and Georgia, Belarus and Poland, Georgia and Poland. The similarity with the Russian FX market is only partial in Belarus, Georgia and Poland - identical trends can be observed not so much in terms of absolute exchange rates, but in terms of growth index and growth rate. Have to note that Ukrainian FX market volatility does not have similar trends with FX markets of Belarus, Georgia and Russia. There is only a similarity in terms of growth index and growth rate with the Polish FX market.

The discrepancies in the exchange rate change trends during COVID-19 Pandemic Crisis primarily indicate the impossibility of applying in Ukraine those FX market regulating measures, which are used in crisis times in the analyzed countries, because the nature and causes of exchange rate overshooting are different, so the effectiveness of activities will vary. Also, the identified patterns indicate different FX markets development levels and mechanisms for their regulation. In this case, overcoming the negative impact of the crisis on exchange rate dynamics and FX market state at all, Ukraine must take into account the characteristics and current state of FX market, society mentality, previous experience and expected results from market intervention.

6. Big Data Analysis for identification links and patterns of exchange rate fluctuations during the financial crises of 2008, 2015, 2020 in Ukraine

It is important for Ukraine to reduce the time spent on FX market stabilizing during the crisis. The main problem of Ukraine is the high FX market volatility due to exchange rate shocks. However, changes in the monetary policy of the National Bank of Ukraine allowed to minimize exchange rate fluctuations during COVID-19 Pandemic Crisis in 2020, relatively quickly (as for Ukraine) to stabilize the FX market and "calm" panic among the society, and the overall growth of the exchange rate compared to previous financial crises. In addition, new approach to the exchange rate calculation had the positive impact on the Ukrainian FX market stabilization after COVID-19 Pandemic Crisis, as since

2015 Ukraine has switched to a floating exchange rate regime. During the crises in 2008 and in 2015, there was a fixed exchange rate regime, which "collapsed" under the pressure of crisis phenomena and events, which had significant negative consequences for the economy and formed the growing society distrust to the national currency and the actions of the National Bank of Ukraine.

The exchange rate dynamics (**Figure 3**) makes it possible to see that balancing the FX market during the crisis is absolutely necessary, and the value of the exchange rate primarily reflects the state of Ukraine's economy in the certain time period.

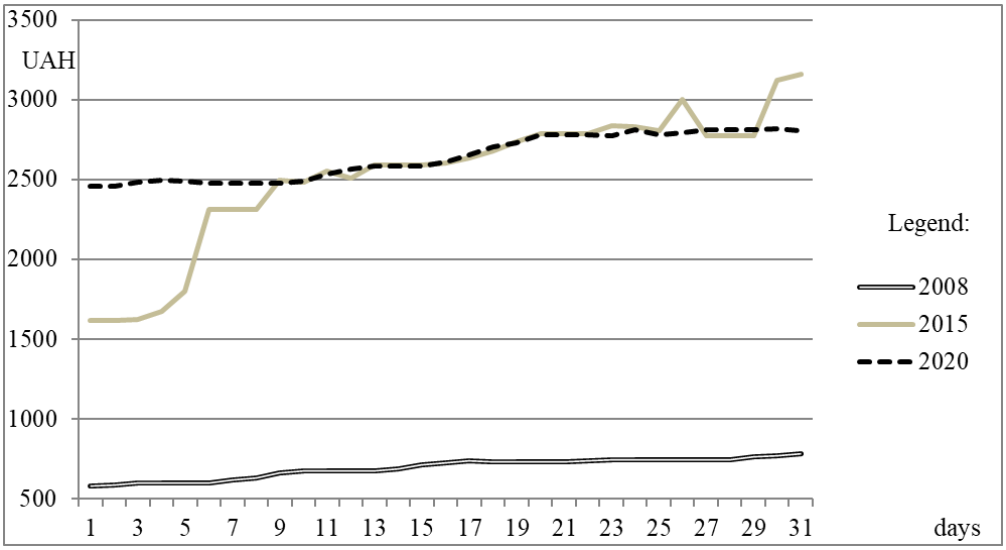

Figure 3: Dynamics of the exchange rate UAH per 100 USD during the crises of 2008, 2015 and 2020
Source: based on the data of the National Bank of Ukraine [25]

In the case where there is the discrepancy between the fixed exchange rate and the real effective exchange rate, there has been the significant change in the exchange rate with negative consequences for the economy (typical for both 2008 and 2015 financial crisis in Ukraine). In 2020, when the exchange rate in Ukraine is determined on the supply and demand balancing basis and is not subject to administrative influence, the change in the exchange rate was relatively insignificant. This change was observed in almost all countries and the main difference in the response of FX markets to COVID-19 Pandemic Crisis was the period of FX market stabilization.

UAH/USD exchange rate dynamics analysis results during the financial crises in 2008, 2015 and 2020 are presented in Table 3.

The maximum and minimum values in each of the time series are different, but this is neither a cause nor a consequence of the financial crisis - it primarily characterizes the state of the Ukrainian FX market and financial system at the time of entry into the vase of significant exchange rate overshooting. Therefore, there is no economic reason to compare the time series of these absolute indicators.

Dynamics indicators were calculated for the time series: variation range, growth index, growth rate (both per period and per 1 day). Comparing the values of average growth rates in different crisis periods, we see that the most rapidly changing exchange rates were during the crisis of 2015 (the average growth rate was 3.0857% per day). COVID-19 Pandemic Crisis is characterized by a significant margin of financial strength of Ukraine before its beginning, as well as new approaches of the National Bank of Ukraine to currency regulation. These allowed to obtain the exchange rate average daily growth rate at 0.4598%, which is 2.5% lower than during the crisis of 2008, when the FX market was 100% controlled and the exchange rate was fixed.

If the coefficient of variation is less than 33%, then the sample is homogeneity. The calculation results showed that the formed samples are homogeneous and it is inexpedient to apply the time series analysis methods only for the growth rate. Oscillation coefficient shows the fluctuations of the time series extreme values around the average values. The biggest exchange rate fluctuations were in 2015 (the oscillation coefficient is 0.6133). It is almost 2 times bigger than in 2008. And in 2020 such fluctuations were 4.5 times smaller than in 2015 and 2 times smaller than in 2008.

Table 3

Indicators, that characterize the exchange rates dynamics during COVID-19 Pandemic Crisis

Indicators	2008, Global Financial Crisis			2015, Military Conflict Crisis			2020, COVID-19 Pandemic Crisis		
	100 USD exchange rate	Growth index	Growth rate	100 USD exchange rate	Growth index	Growth rate	100 USD exchange rate	Growth index	Growth rate
Maximum, UAH	786.48	1.0500	4.9959	3,161.41	1.2850	28.5049	2,818.30	1.0200	2.0045
Minimum, UAH	579.39	0.9972	-0.2777	1,614.70	0.9251	-7.4876	2,456.10	0.9879	-1.2087
Variation range, UAH	207.09	0.0527	5.2737	1546.71	0.3599	35.9926	362.20	0.0321	3.2132
Average deviation, UAH	55.73	0.0108	1.0817	321.63	0.0354	3.5419	131.04	0.0064	0.6368
General dispersion	3,938.19	0.0002	1.6819	180,702.35	0.0035	35.4611	19,565.80	0.0001	0.5763
Sample dispersion	4,069.47	0.0002	1.7399	186,725.76	0.0037	36.6839	20,217.99	0.0001	0.5962
General standard deviation	62.76	0.0130	1.2969	425.09	0.0595	5.9549	139.88	0.0076	0.7591
Sample standard deviation	63.79	0.0132	1.3191	432.12	0.0606	6.0567	142.19	0.0077	0.7721
Mid-arithmetic	694.49	1.0103	1.0321	2,521.95	1.0242	2.4198	2,641.23	1.0045	0.4480
Coefficient of variation	**9.1855**	**1.3056**	**127.8056**	**17.1343**	**5.9136**	**250.2997**	**5.3835**	**0.7687**	**172.3531**
Oscillation coefficient	0.2982	0.0522	5.1097	0.6133	0.3514	14.8743	0.1371	0.0320	7.1727
Average growth index	1.0102			1.0226			1.0045		
Average growth rate, %	1.0238			2.2625			0.4451		
Average daily growth rate, %	1.1530			3.0857			0.4598		

Source: calculated by the authors on the bases of the National Bank of Ukraine data [25]

In other words, it can be argued that the FX market overcame the crisis in 2020 with a slight devaluation of the Ukrainian hryvnia and minimal negative consequences for the Ukrainian economy as a whole.

UAH/USD exchange rate time series comparing results during the financial crises in 2008, 2015 and 2020 (based on F-statistics) are presented in Table 4.

The Fisher's F-test values, calculated to compare the UAH/USD exchange rate time series trends during the crises in 2008, 2015 and 2020, showed that there are no similarities between these series. At the same time, no similarities were found either for the absolute values, or for the growth index, or for the growth rate. The results show that the nature and causes of the crises were different, which led to different imbalances in the Ukrainian FX market. Also the reason of the received results is various mechanisms of FX market regulation in the periods of the analyzed crises. Due to such calculation results, it is impractical and economically incorrect to compare the National Bank of Ukraine actions their effectiveness during each of these crises.

The results of trends identification in UAH/USD exchange rate time series during the crises in 2008, 2015 and 2020 (based on Student's t-test) are presented in Table 5.

Table 4

UAH/USD exchange rate time series comparing results during the financial crises in 2008, 2015 and 2020 (based on F-statistics)

Indicators	100 USD exchange rate	Growth index	Growth rate
F-table$_1$		0.4760	
F-table$_2$		2.1010	
F-value (2015 / 2008)	44.4044	21.0837	21.0837
F-value (2020 / 2008)	4.8080	2.9186	2.9186
F-value (2015 / 2020)	9.2356	61.5345	61.5345

Note: if F-table$_1$< F-value < F-table$_2$, then there are identical trends in time series
Source: calculated by the authors on the bases of the National Bank of Ukraine data [25]

Table 5

Results of trends identification in UAH/USD exchange rate time series during the crises in 2008, 2015 and 2020 (based on Student's t-test)

Indicators	2008, Global Financial Crisis			2015, Military Conflict Crisis			2020, COVID-19 Pandemic Crisis		
	100 USD exchang e rate	Growth index	Growth rate	100 USD exchang e rate	Growth index	Growth rate	100 USD exchange rate	Growth index	Growth rate
μ					5.99				
σ_1					1.882				
σ_2					2.447				
M	20	8	8	19	9	18	16	9	9
t-table	**2.04**	**2.05**	**2.05**	**2.04**	**2.05**	**2.05**	**2.04**	**2.05**	**2.05**
t-value$_1$	7.444	1.068	1.068	6.913	1.599	6.382	5.319	1.599	1.599
t-value$_2$	4.908	-2.448	-2.448	3.682	-2.039	1.639	3.273	-2.039	-2.039
Trend	+	-	-	+	-	-	+	-	-

Note: if t-table < t-value1 and t-table < t-value2, then there are identical trends in time series
Note: "+" - a trend is available, "-" - a trend is absent.
Source: calculated by the authors on the bases of the National Bank of Ukraine data [25]

The obtained results allow us to confirm that there is a clear trend - a tendency to increase in the exchange rate time series. However, if we form time series based on the growth rate or growth index, we see that they do not show trends, so on their basis it is impossible to predict changes in exchange rates, including decisions to regulate the FX market during the crisis, based on the results of such time series analysis.

7. Conclusions

Summarizing the results of the exchange rates time series research, we can draw the following conclusions:

- Big Data Analysis allows to identify trends in unstructured and poorly structured data;
- as information on exchange rates fluctuations is formed often and in detail (at least 2 times per day in terms of a significant number of currencies for each FX market), processing it with Big Data Analysis allows to structure information, identify trends, analyze dynamics and form a decision tree on the impact on FX market and its regulation;
- all studied FX markets respond to financial crises with high exchange rate volatility which can be described as panic with a tendency to increase and overshooting;
- in all analyzed countries COVID-19 caused panic in FX markets, which is characterized by exchange rate volatility with more than 2% per day growth rate;
- the dynamics of different FX markets during panic shocks is similar to each other (unlike the dynamics of the Ukrainian FX market);

- the reaction of the Ukrainian FX market to the crises in 2008, 2015 and 2020 was the same - the growth of the exchange rate, but the time series showed that the change in the exchange rate was different in dynamics and velocity;
- the application of measures to regulate the Ukrainian FX market should be based on the exchange rates absolute values analysis, because time series based on growth indices and growth rates do not reflect the trend of change in the FX market;
- crises in different countries, provoked by identical causes, have different nature of course and reaction, including on the part of the exchange rate and the FX market, therefore, measures to overcome them should be different;
- implementation of foreign experience in overcoming the crisis should take into account the presence of similarities in time series trends, as well as the state and features of the FX market in the pre-crisis period.

The hypothesis formed at the beginning of the study was proved. The research results further confirmed the need for a thorough analysis of exchange rate overshooting in FX market during financial crises. Exchange rate fluctuations are the first indicator of the financial crisis in the country and the crisis factors are not the indicators that determine the presence or absence of exchange rate fluctuations. In order to successfully overcome the crisis, it is necessary to balance the FX market as soon as possible and set exchange rate fluctuations to regulatory values that do not threaten the country's financial stability. The use of the formed hypothesis will allow in the future to optimize the time spent on FX market studying, to harmonize Data Analysis approaches, as well as to more clearly draw conclusions about the links between market indicators.

The possibilities of using Big Data Analysis during financial crises to research the exchange rate fluctuations in panic were tested on the basis of real data on exchange rate fluctuations during financial crises for the sample of countries (Ukraine, Georgia, Poland, Russia, Belarus), as well as for Ukraine in different time periods. It is proved that Big Data Analysis makes it possible to structure large amounts of unstructured data, to form conclusions about the existence of links between phenomena due to various factors. In further research, it is advisable to focus on forming information models for analyzing financial shocks in FX market, taking into account the main factors of the crisis, as well as developing practical measures to balance the FX market based on these models with minimal administrative interventions in market mechanisms.

8. References

[1] D. Alaminos, F. Aguilar-Vijande, J. R. Sánchez-Serrano, Neural Networks for Estimating Speculative Attacks Models, Entropy 1 (2021) 106. URL: https://doi.org/10.3390/e23010106.

[2] Bank of Russia, FX market data. URL: https://www.cbr.ru.

[3] F. Benguria, A. M. Taylor, After The Panic: Are Financial Crises Demand Or Supply Shocks? Evidence from International Trade, National Bureau of Economic Research, Working Paper 25790 (2019). URL: http://www.nber.org/papers/w25790.

[4] M. Cavallo, K. Kisselev, F. Perri, N. Roubini, Exchange rate overshooting and the costs of floating, Federal Reserve Bank of San Francisco, Working paper series 2005-07 (2005). URL: http://www.frbsf.org/publications/economics/papers/2005/wp05-07bk.pdf.

[5] T. Daniëls, Rationalised panics: The consequences of strategic uncertainty during financial crises, Amsterdam, Thela Thesis, 2009.

[6] S. C. W. Eijffinger, B. Karataş, Together or apart? The relationship between currency and banking crises, Journal of Banking & Finance (2020) 105631. URL: https://doi.org/10.1016/j.jbankfin.2019.105631.

[7] L. Einav, J. Levin, The Data Revolution and Economic Analysis (2013). URL: http://www.nber.org/chapters/c12942.pdf.

[8] C. Eom, T. Kaizoj, J. W. Park, E. Scalas, Realized FX Volatility: Statistical Properties and Applications, Journal of Derivatives and Quantitative Studies 1 (2018) 1-25. URL: https://doi.org/10.1108/jdqs-01-2018-b0001.

[9] Exchange rate fluctuations. URL: https://www.adb.org/sites/default/files/linked-documents/47100-004-sd-08.pdf.

[10] J. A. Frenkel, C. A. Rodriquez, Exchange Rate Dynamics and The Overshooting Hypothesis, National Bureau of Economic Research, Working Paper 832 (1982). URL: https://www.jstor.org/stable/3866942?seq=1.
[11] V. Gadepally, J. Kepner, Big Data Dimensional Analysis (2014). URL: https://arxiv.org/pdf/1408.0517v1.pdf.
[12] J. S. Hodges, Compare and contrast the current financial crisis with that which started the Great Depression, EC248. URL: https://www1.essex.ac.uk/economics/documents/eesj/hodges.pdf.
[13] S. Kim, S. H. Kim, Financial Panic and Exchange Rate Overshooting during Currency Crises, International Economic Journal 1 (2007) 71-89. URL: https://doi.org/10.1080/10168730601180929.
[14] C. P. Kindleberger, R. Z. Aliber, Manias, Panics, and Crashes: A History of Financial Crises, Fifth Edition, Published by John Wiley & Sons, Inc., Hoboken, New Jersey, 2005.
[15] E. Kohlscheen, F. H. Avalos, and A.Schrimpf, When the Walk is not Random: Commodity Prices and Exchange Rates, Bank for International Settlements, 2016. URL: www.bis.org.
[16] Š. Lyócsa, T. Plíhal, T. Výrost, FX market volatility modelling: Can we use low-frequency data?, Finance Research Letters (2020) 101776. URL: https://doi.org/10.1016/j.frl.2020.101776.
[17] V. Lytvyn, V. Vysotska, A. Rzheuskyi, Technology for the psychological portraits formation of social networks users for the IT specialists recruitment based on Big Five, NLP and Big Data Analysis, CEUR Workshop Proceedings 2392 (2019) 147–171.
[18] V. Lytvyn, V. Vysotska, O. Veres, Ontology of big data analytics, MEST Journal 6 (2018) 41-60.
[19] V. Lytvyn, V. Vysotska, O. Veres, I. Rishnyak, H. Rishnyak, Classification Methods of Text Documents Using Ontology Based Approach. Advances in Intelligent Systems and Computing, Springer International Publishing, (2017) 229-240. URL: DOI: 10.1007/978-3-319-45991-2_15.
[20] B. Marr, Big Data: Using SMART Big Data, Analytics and Metrics to Make Better Decisions and Improve Performance, John Wiley & Sons Ltd, 2015. 256 p.
[21] V. Mayer-Schonberger, K. Cukier, Big Data: A Revolution That Will Transform How We Live, Work, and Think, John Murray Publishers, UK, 2013. 256 p.
[22] Narodowy Bank Polski, FX market data. URL: https://www.nbp.pl.
[23] National Bank of Georgia, FX market data. URL: https://www.nbg.gov.ge.
[24] National Bank of the Republic of Belarus, FX market data. URL: http://nbrb.by.
[25] National Bank of Ukraine, FX market data. URL: https://bank.gov.ua.
[26] Z. Rudenko, The financial crisis in Ukraine in 2014-2015: causes and tools of regulation, Scientific Bulletin of NLTU of Ukraine 7 (2015) 216-221. URL: https://doi.org/10.15421/40250733.
[27] N. Shakhovska, O. Veres, Y. Bolubash, L. Bychkovska-Lipinska, Data space architecture for Big Data managering, Xth International Scientific and Technical Conference "Computer Sciences and Information Technologies" (CSIT'2015) (2015) 184-187. DOI: 10.1109/STC-CSIT.2015.7325461.
[28] N. Tak, A. Gök, Dating currency crises and designing early warning systems: Meta-possibilistic fuzzy index functions, International Journal of Finance & Economics (2020). URL: https://doi.org/10.1002/ijfe.2350 ·
[29] P. Turner, External shocks, the exchange rate and macroprudential policy, Bank for International Settlements, Papers 86 (2016). URL: www.bis.org.
[30] O. Veres, N. Shakhovska, Elements of the formal model big date, XI International Conference on Perspective Technologies and Methods in MEMS Design (MEMSTECH'2015) (2015) 81-83.
[31] O. Veres, P. Ilchuk, O. Kots, Application of data mining to exchange rate influence identification, CEUR Workshop Proceedings, 4th International Conference on Computational Linguistics and Intelligent Systems (COLINS 2020) 2604 (2020) 1117-1126.
[32] T. Visyna, V. Visyn, T. Polianska, Theoretical foundations of currency crises, Economic sciences, Series "Regional Economy", 17(67) (2020) 33-39. URL: https://doi.org/10.36910/2707-6296-2020-17(67)-4.
[33] V. Vysotska, V. Lytvyn, V. Danylyk, S. Vyshemyrska, M. Luchkevych, I. Lurie, Detecting items with the biggest weight based on neural network and machine learning methods, Communications in Computer and Information Science 1158 (2020) 383–396.
[34] H. Yilmazkuday, Welfare costs of bilateral currency crises: The role of international trade, International Finance (2020). URL: https://doi.org/10.1111/infi.12385.