

P-adic modeling of the RTS Index dynamics depending on the timeframes

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Modeling for dynamics of the financial assets today:

- Actual and necessary, because there is active increase in trading volumes (in the picture - the RTS Index trading volumes at the Moscow exchange*).
- 2. The dynamics of financial assets is a stochastic process (time series), which were studied using economic, econometric, statistical methods and methods of interdisciplinary sciences (such as econophysics).
- 3. Modern financial markets are a complex, open, dynamic and multi-agent systems.
- 4. The possibility of constructing the forecast for income.





Purpose of the report

• Application the *p*-adic modeling and forecasting technique to the dynamics of the RTS Index for different timeframes.

Tasks of the report:

1. To describe the formation of econophysics as a special direction in economic science.

2. To consider one of the most important properties of the value of profitability - scale invariance (scaling principle).

3. To offer the *p*-adic modeling technique for dynamics of the financial assets.

4. To construct the model and the forecast depending on the timeframes for the RTS Index.



Development of econophysics

 Middle of the 1990th - emergence of econophysics (this is studying of economic processes on the basis of use of fundamental laws of the nature and physical theories).

o1997 - Workshop on Econophysics in Hungary (it was organized by Imre Kondor and Janos Curtis).

 Formation of econophysics is connected with receipt to economy of large physicists, such as Philip Anderson (The Nobel prize of physics in 1977), Per Bak, Harry Eugene Stanley and many other scientists.

• The *p*-adic analysis is the modern methods of econophysics.



Formation of the *p*-adic analysis

Year	Group of scientists	Institute	Novelty	Application
1897	K. Hensel	Marburg university (Germany)	<i>P</i> -adic numbers	Application in the theory of numbers, the general algebra
1980th	V. S. Vladimirov and group of I.V Volovich	Department of mathematical physics in Mathematical institute of V. A. Steklov (Moscow, Russia)	The mathematical instrument of the <i>p</i> -adic numbers	Application of <i>p</i> - adic numbers in mathematics and physics
Since 2000th	V. M. Zharkov	Natural science institute of PSU (Perm, Russia)	Adele theory of the stock market	Application of <i>p</i> - adic numbers in economy



The scaling principle

In 1965 B. Mandelbrot found that financial ranks have property of scale invariance or self-similarity (fractality). Scale invariance of financial assets means that the character of their dynamics does not depend on in what scale to consider them: hours, days or months.

• Formula of the value of profitability for indexes of the stock exchange on the basis of the principle of scaling:

$$R(\Delta t) = lnY(t) - lnY(t - \Delta t)$$

where

- R the value of profitability,
- Y price series.



P-adic analysis

P-adic number is a prime number:

 $p \in \{2, 3, 5, 7, 11, 13, \ldots\}$

P-adic numbers are presented in a canonical form:

 $0. a_0 a_1 a_2 \dots,$ where $a_i = \{0, 1, \dots, p-1\}$ and $x = a_0 + a_1 p + a_2 p^2 + \cdots$



P-adic analysis

Let's define on Q (the field of rational numbers) the following map $|\cdot|_p$:

$$|x|_{p} = \begin{cases} \frac{1}{p^{ord_{px}}}, & \text{if } x \neq 0; \\ 0, & \text{if } x = 0. \end{cases}$$

Degree $ord_p x$ shows how many times p enters in decomposition of number x on simple factors.

The norm is called non-Archimedean if the inequality is always performed:

$$||x + y|| \le max(||x||, ||y||)$$

Thus, $|\cdot|_p$ is a non-Archimedean norm in the field of Q.



P-adic modeling technique

- 1. Choice of the *p*-adic number (p = 2, p = 3). The *p*-adic number is used for the description of the corrective and impulse waves.
- 2. Conversion numbers in the *p*-adic number system. Any *p*-adic number has a record, when conversion from an integer *x* on the basis *p*:

 $0.a_0a_1a_2\dots a_i\dots$

where $a_i \in \{0, 1, ..., p-1\}$,

 $x(p) = a_0 + a_1 p^{\beta_1} + a_2 p^{2 \cdot \beta_2} + \cdots, \beta_1, \beta_2, \dots \in [0, 2] - \text{dimension of } p \text{-adic number.}$

- 3. Creation of piecewise and linear approximation of wave patterns with the use of *p*-adic mapping: $\hat{y}_t = y(x) = a + b \cdot x(p)$
- 4. Evaluation of the p-adic model finding the sum of squared differences between the input and the model data:

$$S^2 = \sum (y_t - \hat{y}_t)^2 \to min$$



ПЕРМСКИЙ ГОСУДАРСТВЕННЫЙ НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИ УНИВЕРСИТЕТ ЭКОНОМИЧЕСКИЙ ФАКУЛЬТЕТ

Purpose of the *p*-adic research

 to show that the financial ranks have scale invariance property for dynamics of the RTS Index, which is chosen in months, weeks, days and hours;

oto define the main types of *p*-adic forecasts;

oto draw conclusions on the received models and their forecasts.





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The input data for creation of RTSI models

	RTS Index (monthly)	RTS Index (weekly)	RTS Index (daily)	RTS Index (by the hour)		
Modeling period	Jan 2009 - Aug 2015	15.12.2014 - 20.06.2016	11.05.2016 - 29.07.2016	04.08.2016 (10:00) - 16.08.2016 (17:00)		
Forecasting period	Sept 2015 – Sept 2016	27.06.2016 - 19.09.2016	30.07.2016 - 11.08.2016	16.08.2016 (18:00) - 18.08.2016 (12:00)		
Timeframe	month	week	day	hour		
Quantity of the modeling points	80					
Quantity of forecasting points	13					



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The value of the profitability of the RTSI by months, weeks, days, hours





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The value of the profitability of the RTSI by months, weeks, days, hours



—Input data in months —Input data in weeks —Input data in days —Input data in hours



Types of the *p*-adic forecasts

- 1. The **optimistical** scenario, when the tilt angle of impulse waves is steeper than the corrective. The scenario represents the ascending ("bull") trend.
- 2. The **pessimistic** scenario, when the tilt angle of corrective waves is steeper than the impulse. The scenario represents the descending ("bear") trend.
- 3. The **average** scenario, when the forecast reflects the general (average) trend of the development model based on the input data.
- 4. The scenario of the **continuing development** shows the possible fluctuation of future values, if the dynamics of the last known points will not change.



The *p*-adic forecasts of the RTSI by weeks

1100 1000 900			Minimum error of one of forecasts	The forecast
3 8 8 0 1 1 1 1 1 1 1 1 1 1		RTSI (monthly)	1002,2	The average scenario
600 - 500 - 400 -	106.16 101.16 01.16 201.16 108.16 208.16 208.16 208.16 209.16 209.16	RTSI (weekly)	275,7	The scenario of the continuing development
Ŷ	 	RTSI (daily)	310,8	The scenario of the continuing development
	 The p-adic pessimistic scenario The p-adic average scenario The p-adic scenario of the continuing development 	RTSI (by the hour)	387,3	The scenario of the continuing development



Conclusions

Daily data on rates of financial assets are the most optimum for *p*-adic researches. The conclusion is received on the basis of error estimation of the models and the forecasts.

The forecast of the RTS index fluctuations in the majority of cases (in three of four models) correlates most strongly with the scenario of the continuing development.

□*P*-adic numbers are factors of *p*-adic model. They aren't checked for a multicollinearity, heteroscedasticity and autocorrelation in the residuals.

The predicted values of the stock exchange indexes, share prices and quotations of currencies deviate from the real values, but truly transfer character and trend changes.

There is a relatively high accuracy of the model and the forecast for a small amount approximating points.





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THANK YOU FOR YOUR ATTENTION! Have you any questions?