Finances

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S. V. Lyashenko,
Master of economics, Donetsk, Ukraine

MODELING THE INTERACTION AMONG THE UKRAINIAN AND FOREIGN STOCK MARKETS

Problem statement. Stock market is a major source of funding for corporations in the world economy. Stock indices and their dynamics are designed to assess the state of the stock market which makes this study topical.

The analysis of stock indexes interdependence is crucial. Indexes of emerging markets such as Ukrainian are very sensitive to changes in global indices, therefore estimation of such dependency is very important.

Ukrainian scientists started to research the problem thoroughly only a few years ago. Y. Makogon and V. Lyashenko thoroughly investigated the stock indices and ratings; V. Kucherenko characterized the PFTS; O. Mozgoviy defined the relationship between the stock indexes and indicators of economic development of Ukraine. There is an interesting work on autocorrelation analysis and study of dependency of stock indices and industries in M. Alyeksyenkova's paper, Borovikova's research on the stock indices behavior, Polyuhovich's analytical papers and analysis of the stock indices quality by Belarusian scientist A. Belzetskiy.

The purpose of this paper is to build a model of interaction of Ukrainian and foreign stock markets and interpretation of the model.

There are different mathematical models to show the interaction of stock indexes. We are interested in finding such a model that will represent the interaction of selected indices in the long and short term.

Correlation is a relationship where the effect of individual factors reveal only an average tendency for the actual data. The simplest type of correlation is the pair correlations, correlation between the two indices [8].

In order to simulate long-term trend dependency average monthly data were collected from the PFTS Index, MICEX and Dow Jones from January 2006 to September 2009.

As can be seen from figures 1 and 2 the nearest form of regression equation is linear.

For the simulation of short-term impact of changes in indices the vector autoregression model is the best fit. Not only does it show the impact of lag values, but it also builds the momentum response function (showing how long each index bears the influence of other index) [9-11].

For modeling of the long-term relationships we need to build two models of correlation of the PFTS index, MICEX and Dow Jones. The equation for these models is as follows:

$$\bar{y} = a_0 + a_1 * x, \qquad (1)$$

where is theoretically calculated value of y;

a_0, a_1 are coefficients.

The sample of input data consists of 45 monthly observations that determine the index dynamics. Options to find the equation using the following formula [12]:

$$a_1 = \frac{\sum (y - y_C)(x - x_C)}{\sum (x - x_C)^2}, \qquad (2)$$

$$a_0 = y_C - a_1 * x_C, \qquad (3)$$

where x_C and y_C are average values of corresponding indices.

The coefficients of equation (influence of Dow Jones on PFTS) are equal:

$a_1 = 0{,}1193$, $a_0 = -729{,}71$.

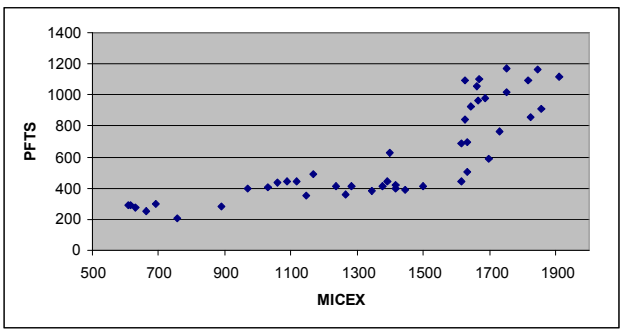

Fig. 1. Diagram spread values PFTS and MICEX (MICEX)

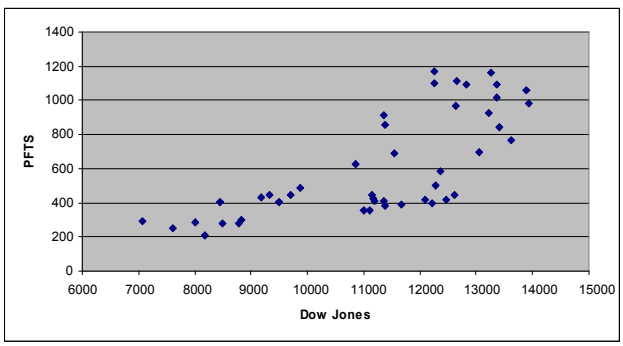

Fig. 2. Spread chart of PFTS and Dow Jones

The model is as follows:

$$\bar{y} = 0{,}1193 * \text{x} - 729{,}71 \ , \qquad (4)$$

That means that for 10 points change in Dow Jones PFTS changes for 1.1 point.

In the second case (MICEX on PFTS):

$$a_1 = 0{,}646 \ , \ a_0 = -274{,}4 \ ,$$

$$\bar{y} = 0{,}646 * \text{x} - 274{,}4 \ , \qquad (5)$$

That means that for 10 points change in MICEX PFTS changes for 6.4 point.

The obtained regression equation describes the dependence of the PFTS index on Dow Jones, and PFTS index on MICEX. Calculated values $\bar{y}$ are found according to this equation are listed in Appendix B. The correctness of regression equation parameters calculation can be tested by comparing the total amounts of differences between actual and calculated amounts. In our case, these amounts equal to zero.

To determine the strength of a linear correlation linear correlation coefficient is used [13].

Use the following formula to calculate the linear correlation coefficient:

$$\text{r} = \frac{\mathbb{M}[XY] - \mathbb{M}X \cdot \mathbb{M}Y}{\sqrt{(\mathbb{M}[X^2] - (\mathbb{M}X)^2)} \cdot \sqrt{(\mathbb{M}[Y^2] - (\mathbb{M}Y)^2)}} \ , \qquad (6)$$

where MX is the mean of X,

MY is the mean of Y.

Linear correlation coefficient equals to $r_{dow} = 0{,}73$ for PFTS and DOW and $r_{micex} = 0{,}81$ for PFTS and MICEX.

Value of coefficient is greater than 0.6, which proves strong relationship between values.

In order to determine how well the model is consistent with data seize coefficient determination (R2), which is equal to:

$$R^2 = \frac{\sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2} \ , \qquad (5)$$

where $\bar{y}$ is the average value of y;

$\hat{y}_i$ — calculated value of y;

y_i — actual value of y.

The next values for models were obtained: $R_{dow}^2 = 0{,}53$ and $R_{micex}^2 = 0{,}66$, which shows that there is a strong and mean correlation between the observations.

To check the reliability of correlation coefficient Student's criterion (t-criterion) is used:

$$t = \frac{|r|\sqrt{(n-k)}}{\sqrt{1-r^2}} \ , \qquad (6)$$

where *r is a value of correlation coefficient,*

n is a number of observations,

k is a number of regressors,

t is a value of Student's criteria.

Student's criteria is equal to t_{dow} =7,09 t_{micex}=9,1 respectively. Critical value of Student's criteria confidence level α=5% and degree of freedom equal to 43 is $t = 2.02$. Actual values are greater than the critical value. Therefore one can conclude that linear coefficient of correlation is statistically reliable with probability of 95%.

The reliability coefficient of determination is tested using Fisher's criterion:

$$F = \frac{R^2}{1-R^2} \times \frac{k_2}{k_1} \ , \qquad (7)$$

where k_1, k_2 are degrees of freedom.

$$k_1 = 2 - 1 = 1$$

$$k_2 = 45 - 2 = 43$$

$$F_{dow} = \frac{0{,}53}{1-0{,}53} \times \frac{43}{1} = 48{,}5$$

$$F_{micex} = \frac{0{,}66}{1-0{,}66} \times \frac{43}{1} = 83{,}5$$

Critical value of F-distribution for significance level α=5% and the respective degrees of freedom equal to 4.06. Observation value of the Fisher criterion is more than critical therefore one can conclude about the statistical reliability of coefficient of determination with probability 95%.

After checking the adequacy, accuracy and reliability of the designed models (regression equation), they can be used for the analysis and forecasting.

The equations of dependence between the PFTS, MICEX and Dow Jones we got during calculations, show that 1 point change of MICEX index has a greater impact on the PFTS, than 1 point change in the Dow Jones, but 1% of the MICEX approximately equals to 11.3 points, while 1 % of Dow Jones equals to 112 points that is almost 10 times more. It means, that MICEX index changed by 1% would cause change in PFTS by 7.15 points and Dow Jones changed by 1% would cause change in PFTS by 13.44 points. Thus, the impact of the Dow Jones is more significant.

$$\bar{y}_{pfts} = 0{,}646 * \text{x}_{\text{micex}} - 274{,}4 \ , \qquad (8)$$

$$\bar{y}_{pfts} = 0{,}1193 * \text{x}_{\text{dow}} - 729{,}71 \ , \qquad (9)$$

Values of coefficients are greater than 0, which

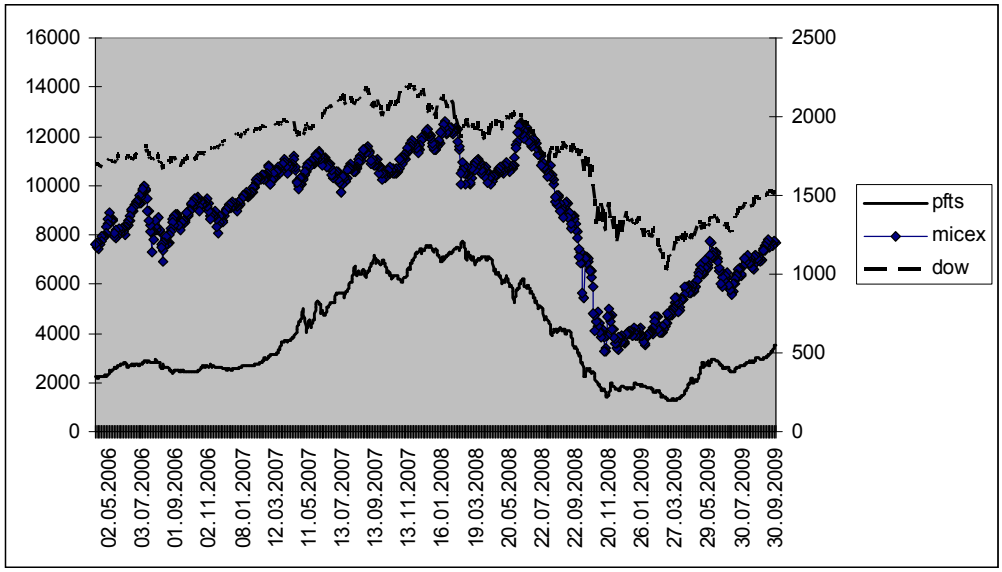

Fig. 3. Dynamics of the PFTS, MICEX and Dow Jones (left scale)

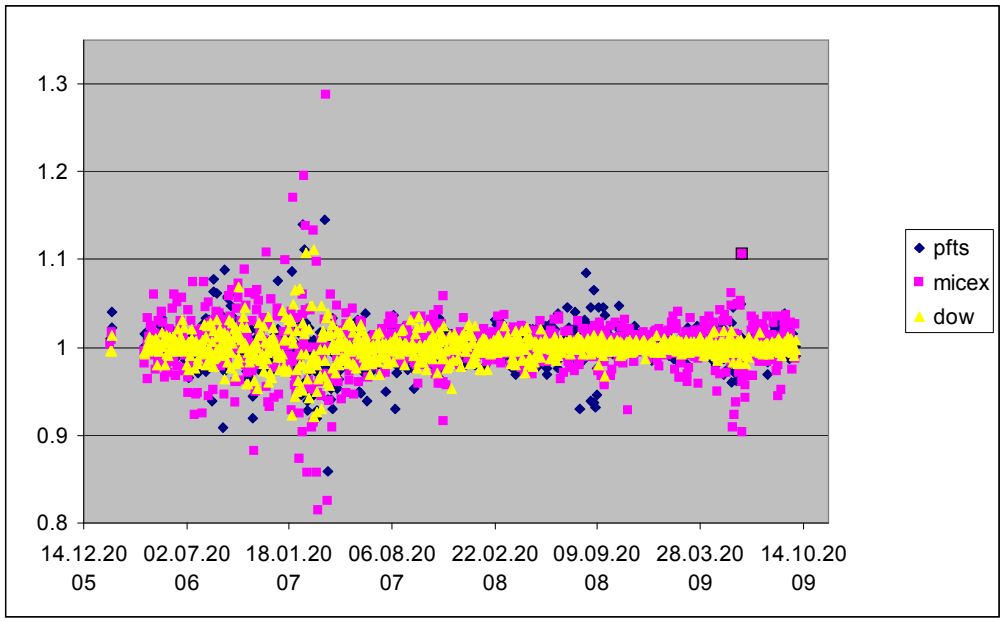

Fig. 4. Dynamics of chain growth rates of PFTS (pfts), MICEX (micex) and Dow Jones (dow)

means that if the stock markets of Russia and the United States will grow the Ukrainian market will also grow. This may be an additional proof that Ukraine and its capital market gradually integrate into the international economy.

On the other hand, the correlation coefficient $r_{micex} = 0{,}81 > r_{dow} = 0{,}73$, which means that ties between Ukrainian and Russian indices is stronger.

For modeling of the short-term relationships the daily values of PFTS, MICEX, Dow Jones indices from January 2006 to September 2009 (total 879 observations) will be used to build vector autoregression model (Figure 3).

Observations that were incomplete were excluded from the sample (for instance, holidays).

As was already mentioned, a number of indices values are not fixed, so the VAR model will analyze profitability (growth rate) of the relevant indices (Figure 4).

The optimal number of lag variables obtained on the basis of the Schwarz information criterion is 2. Thus, the VAR model is:

$$\begin{aligned} R_t^{pfts} &= \alpha_{10} + \alpha_{11} R_{t-1}^{pfts} + \alpha_{12} R_{t-2}^{pfts} + \alpha_{13} R_{t-1}^{dow} + \alpha_{14} R_{t-2}^{dow} + \alpha_{15} R_{t-1}^{micexi} + \alpha_{16} R_{t-2}^{micexi} \\ R_t^{dow} &= \alpha_{20} + \alpha_{21} R_{t-1}^{pfts} + \alpha_{22} R_{t-2}^{pfts} + \alpha_{23} R_{t-1}^{rtsi} + \alpha_{24} R_{t-2}^{rtsi} + \alpha_{25} R_{t-1}^{micexi} + \alpha_{26} R_{t-2}^{micexi} \\ R_t^{micexi} &= \alpha_{30} + \alpha_{31} R_{t-1}^{pfts} + \alpha_{32} R_{t-2}^{pfts} + \alpha_{33} R_{t-1}^{dow} + \alpha_{34} R_{t-2}^{dow} + \alpha_{35} R_{t-1}^{micexi} + \alpha_{36} R_{t-2}^{micexi} \end{aligned}, \quad (10)$$

where $R_t^{pfts}, R_t^{dow}, R_t^{micexi}$ are daily returns of corresponding indices, $\alpha_{ij}, i \in [1,3], j \in [1,6], i, j \in N$ are estimated VAR parameters.

Table 1

Estimation of VAR model parameters[1]

Index		Coefficient	Standard error	z	P>|z|	95% confidence interval	
pfts							
	pfts						
	L1.	0.2712	0.0322	8.42	0.000	0.2081	0.3343
	L2.	0.1073	0.0316	3.4	0.001	0.0454	0.1693
	micex						
	L1.	0.0644	0.0231	2.79	0.005	0.0191	0.1097
	L2.	0.1318	0.0243	5.41	0.000	0.084	0.1796
	dow						
	L1.	0.1118	0.0407	2.75	0.006	0.0321	0.1916
	L2.	0.3135	0.037	8.47	0.000	0.2409	0.3861
micex							
	pfts						
	L1.	0.0105	0.0523	0.2	0.841	-0.0921	0.1132
	L2.	0.0976	0.0514	1.9	0.058	-0.0031	0.1984
	micex						
	L1.	0.0395	0.0375	1.05	0.292	-0.034	0.1132
	L2.	-0.0074	0.0396	-0.19	0.852	-0.0851	0.0702
	dow						
	L1.	0.4394	0.0662	6.64	0.000	0.3096	0.5691
	L2.	0.42054	0.0602	6.98	0.000	0.3025	0.5385
dow							
	pfts						
	L1.	0.0122	0.0028	4.31	0.000	0.0665	0.1774
	L2.	0.0169	0.0027	6.1	0.000	0.1148	0.2237
Index		Coefficient	Standard error	z	P>|z|	95% confidence interval	
	micex						
	L1.	0.227	0.0202	11.19	0.000	0.1872	0.2668
	L2.	-0.0001	0.0214	-0.01	0.993	-0.0421	0.0417
	dow						
	L1.	0.1909	0.0357	5.34	0.000	0.1208	0.2609
	L2.	0.2904	0.0325	8.93	0.000	0.2267	0.3542

The stratum 9.2 allows us not only to identify the impact on the Ukrainian stock market, but also explore the relationship between all the factors.

For the PFTS Index (pfts), which represents the Ukrainian stock market, the most significant factors are the second lag of Dow Jones (Dow) and the first lag of PFTS. Influence of the second lag (and not the first) of Dow can be explained by the fact that the U.S. is in the other hemisphere. The second lag is the value of the previous trading day closing in America and investors" focus on this indicator during the opening of the Ukrainian market. Influence of the first lag of PFTS index can be attributed to a large inertia in the market. Impact of MICEX index (micex) is expressed as positive and significant coefficients, but the second lag has a greater impact than the first. This may be caused by the fact that market players look for a stable tendency of growth.

The results obtained on the MICEX are also interesting. According to the study the coefficients in PFTS and MICEX lags are so small, that these lags do not have a significant impact on the index, but the ratios at Dow Jones lags are very large, which means that during the trading session on MICEX the results of the previous day's trade closing have a great influence.

For the detection of significance of the relationship between the dynamics of yield indices test for Granger causality was used (Table 2).

As you can see from the table, the impact of all selected variables is significant. Only PFTS on MICEX impact is characterized by lower significance χ^2 statistics which is significant at the level of significance less than 90.2%).

On impulse response function shows the dynamic

[1] L1 corresponds to the first lag, L2 — to the second, the data was generated by Stratum 9.2.

Table 2

Results of the test for χ^2 for Granger causality

Index	Exception	χ^2	df	Prob > χ^2
pfts	micex	33.716	2	0.000
pfts	dow	93.797	2	0.000
pfts	ALL	340.42	4	0.000
micex	pfts	4.6413	2	0.098
micex	dow	118.47	2	0.000
micex	ALL	291.82	4	0.000
dow	pfts	89.633	2	0.000
dow	micex	127.31	2	0.000
dow	ALL	227.89	4	0.000

response of variable for a single shock of the other variables. As there may be correlation between shocks, this feature is not characterized by dynamic changes in one variable by another shock, other things being equal. To overcome this shortcoming we did orthogonalization of shocks and construct orthogonal impulse response function, which is used for Holetskiy expansion [14].

Let us build orthogonal impulse response functions for the PFTS Index, Dow Jones and the MICEX, and the cumulative orthogonal impulse response functions in order to identify not only the impact of the shock of one variable on another, but to draw conclusions about the overall long-term nature of such influence. Dark color on the figures shows 95% confidence intervals for the orthogonal impulse response functions. The timeframe is 15 trading days.

Charts of impulse response functions confirm our conclusions about the VAR coefficients. Thus, the yield of the Dow Jones affects itself (Figure 5), the impact is reduced for two days and then completely disappears.

Impulses of MICEX indexes yield (Figure 6) and PFTS (Figure 7) have little impact.

Impact of the Dow Jones index impulse on MICEX was not as significant as the coefficients in our model (Figure 8).

The biggest impact on the MICEX profitability has the momentum of the previous value of the index yield (Figure 9)

Impulses of returns of index PFTS on MICEX was not significant (Figure 10)

Both pulse lags of Dow Jones (Figure 11) have a small impact. It also disagrees with the coefficients that we obtained in the VAR model. However, this can be explained by the fact that usually the Dow Jones fluctuations are small (less than 1%), while PFTS and MICEX are very significant (2-4%).

Finally, the strongest impact on the PFTS index is caused by the previous value and the MICEX PFTS index (figures 12 and 13).

Construction of the graphs of cumulative impulse response function for the PFTS index (figures 14-16) confirms our assumption.

Thus, in Figure 3.12, you can see that the yield of

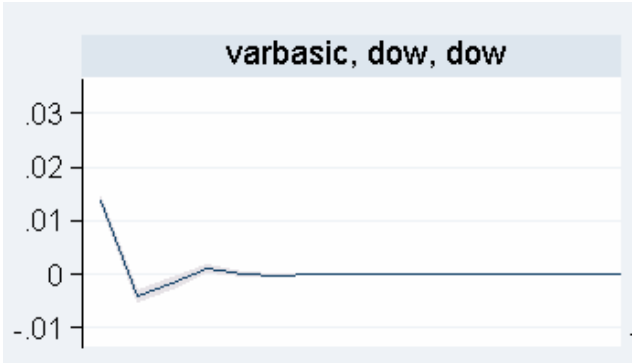

Fig. 5. The orthogonal impulse response function of the Dow Jones by the Dow Jones

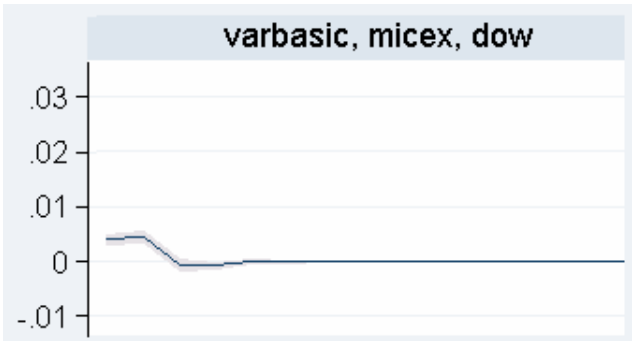

Fig. 6. The orthogonal impulse response function of the Dow Jones by the MICEX

Dow Jones index has almost impalpable effect on the PFTS. Moreover, zero is included in the confidence interval, which means that this dependence is statistically insignificant.

Long-term impact of the momentum returns and the MICEX index itself on the PFTS index is significant and substantial (Fig. 15-16). The growth of the MICEX is a prerequisite for further growth of the PFTS index, and yield reduction has opposite effect.

Thus, the vector autoregression equation daily yield of the PFTS Index, Dow Jones, MICEX was found

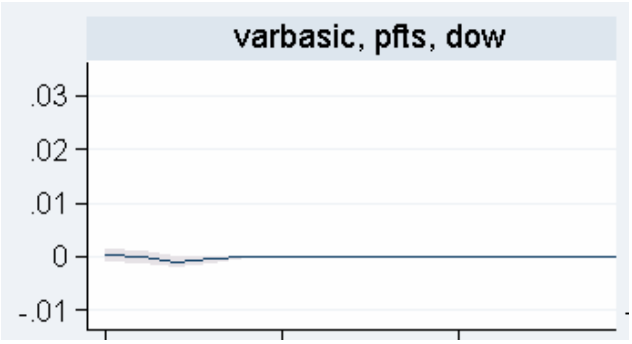

Fig. 7. The orthogonal impulse response function of the Dow Jones index by the PFTS

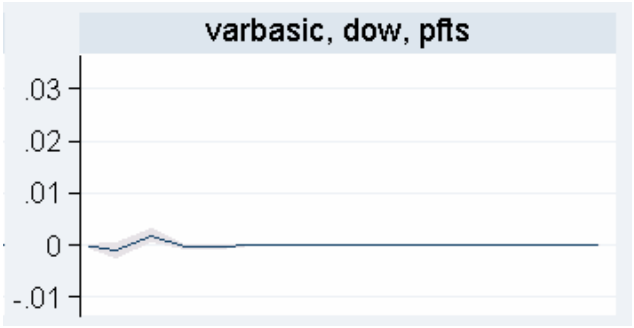

Fig. 11. The orthogonal impulse response function of the PFTS index by Dow Jones

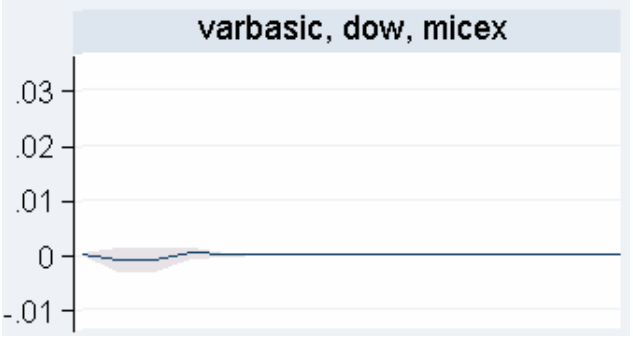

Fig. 8. The orthogonal impulse response function of the MICEX by the Dow Jones

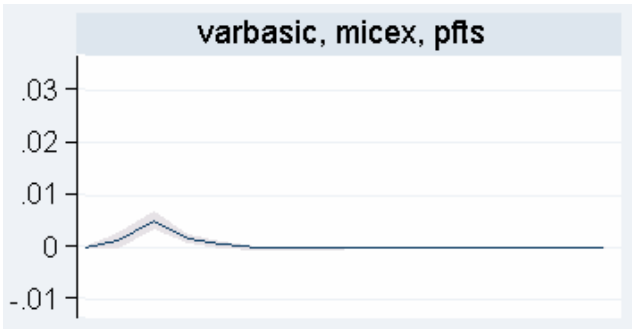

Fig. 12. The orthogonal impulse response function of the PFTS from the MICEX index

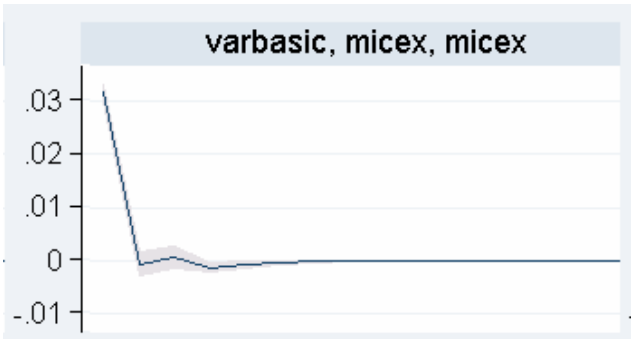

Fig. 9. The orthogonal impulse response function of the MICEX by the MICEX

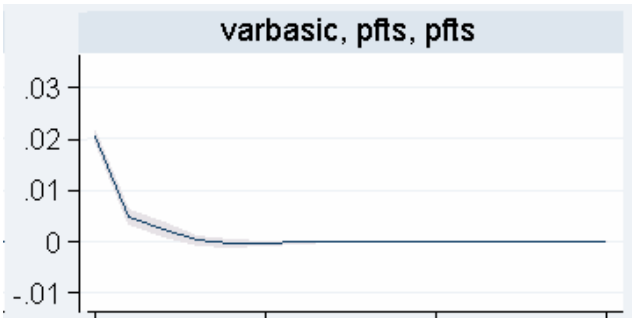

Fig. 13. The orthogonal impulse response function of the PFTS index by PFTS Index

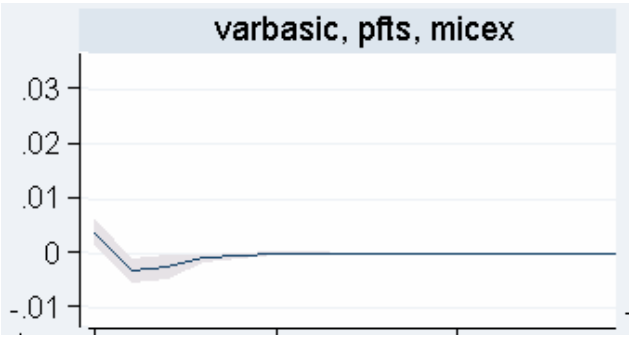

Fig. 10. The orthogonal impulse response function of the index PFTS by the MICEX index

and the following model for the PFTS index was built (formula 3.11)

$$R_t^{pfts} = 0{,}271R_{t-1}^{pfts} + 0{,}107R_{t-2}^{pfts} + 0{,}111R_{t-1}^{dow} + \\ + 0{,}313R_{t-2}^{dow} + 0{,}064R_{t-1}^{micexi} + 0{,}131R_{t-2}^{micexi} \qquad (11)$$

Modeling of the long-term and short-term interdependence of PFTS Index, Dow Jones and MICEX has allowed us to identify the coefficients of regression equations and vector autoregression and assess the significance of these factors and reliability of the models.

The equations of regression of MICEX index (12) and Dow Jones (13) on PFTS index show that the monthly change of MICEX by 1% would change PFTS

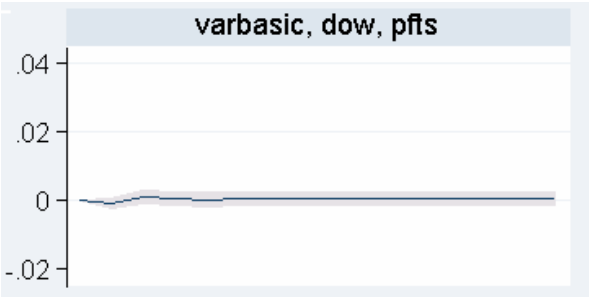

Fig. 14. The cumulative orthogonal impulse response function of the PFTS index from Dow Jones

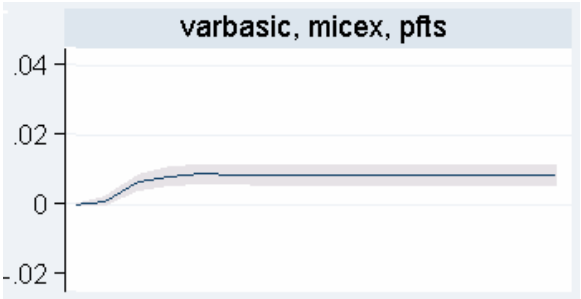

Fig. 15. The cumulative orthogonal impulse response function of the PFTS index from the MICEX index

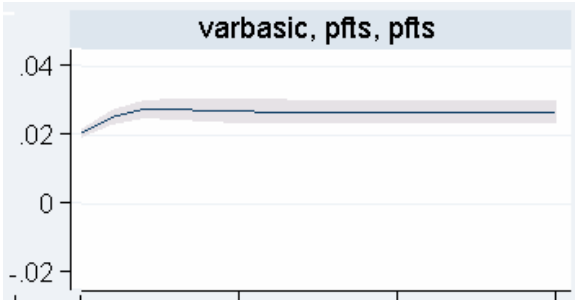

Fig. 16. The cumulative orthogonal impulse response function of the PFTS index from PFTS.

by 7 points, and changes in the Dow Jones by 1% would change PFTS by almost 13.5 points. Thus, the impact of the Dow Jones on PFTS is more significant.

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Lyashenko S. V. Modeling the interaction among the Ukrainian and foreign stock markets

The interaction between Ukrainian stock market PFTS index, Russian stock market MICEX index, and Dow Jones (the United States of America) in the short- and long-term horizon was investigated in the study.

Key words: stock market, indices, regression, vector autoregression, return.

Ляшенко С. В. Моделювання взаємодії українських і закордонних фондових ринків

У статті розглянуто взаємодію між українським індексом фондового ринку ПФТС, російським індексом ММВБ і Dow Jones (Сполучені Штати Америки) в коротко-та довгостроковій перспективі.

Ключові слова: фондовий ринок, індекси, регресія, векторна авторегресія, дохідність.

Ляшенко С. В. Моделирование взаимодействия украинских и зарубежных фондовых рынков

В статье рассмотрено взаимодействие между украинским индексом фондового рынка ПФТС, российским индексом ММВБ и Dow Jones (США) в кратко-и долгосрочной перспективе.

Ключевые слова: фондовый рынок, индексы, регрессия, векторная авторегрессия, доходность.

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