FORECASTING THE STAGE OF THE STOCK MARKET

Chernova N. Filip S.

Stock market is a complex big system that acts in conditions of nonstationary environment. To fully describe the current state of this system the variety of indicators should be taken into account. Those indicators may be classified according to the different criteria: by the sphere of origin (economic, social, political, geographical etc.); in relation to the analyzed system (external, internal); by degree of aggregation (initial, integral) and so on. Thus, the state of the market is determined as a point in multidimensional space: $S = (S_1, S_2, \ldots S_n)$. Large dimension of the original set of indicators makes it difficult to define a clear set of disjoint classes of market states. That is why often the final list of indicators includes only stock prices, volumes and stock market indexes.

Let's define two basic stages for a stock market – trend market and flat market.

Flat stage is determined as such state when the market in neither an uptrend nor a downtrend. That is, the securities in a flat market are relatively constant in price, at least for a certain period of time. A flat market is sometimes associated with low trading volume.

Trend market is characterized by the fact that it shows the movement of prices in one clearly defined direction. There are two types of trend market – Bull and Bear.

Bull market is characterized by a gradual increase in prices over a certain period of time. It means the market has more buyers than sellers. It is most common when the economy is growing, unemployment is low and inflation is somewhat tame.

A bear market is when the price falls over time. A bear market occurs when the major indices continue to go lower over time. They will hit new lows. More important, their highs will be lower than before as well. Bear markets are marked by low levels of investor confidence and high levels of pessimism. As investors continue to lose confidence in stocks, they may begin to sell securities as a hedge against potential losses. This behavior can trigger further declines in stock prices, which in turn may impact trading volume. After trading activity hits a trough, it may begin to increase again as speculators venture back into the market to capitalize on lower prices. If stocks begin to gain momentum through reinvestment, a bear market can shift into a bull market.

In this way the main aim of the research is to construct a set of hidden markov models which describe the changes in the state of the stock market according to the price movements in the given set of financial instruments. Then the forecast of the state will be obtained for each model. These forecasts will form the resulting forecast for the hole market.

The following model will be constructed for each instrument:

$$\lambda = (P, B, w), \quad (1)$$

$P = \{p_{ij}\}_{l \times l}$ – matrix which describes transition probabilities for trend and flat markets;

$B = \{b_{ij}\}_{l \times k}$ – matrix which describes probabilities of observing the price from a certain range in the appropriate state of the market;

w – vector of initial probabilities.

To construct the model (1) means to obtain the estimates of its components – P, B and w. The appropriate procedures are discussed below.

Step 1. Matrix P evaluation.

The initial time series X_t of a stock are transformed into normalized ones:

$$r_t = \frac{x_{t+s} - x_t}{x_t} \qquad (2)$$

According to the above definitions of trend markets and flat market for each time period t the stage of the market is determined as follows:

$$z_t = \begin{cases} -1, & r_t < -0{,}01 \\ 0, & r_t \in [-0{,}01; 0{,}01], \\ 1 & r_t > 0{,}01 \end{cases} \qquad (3)$$

where "-1" states for "Bear market", "0" states for "Flat market", "+1" states for "Bull market".

Step 2. Matrix *B* evaluation.

Let's determine b_{ij} as probability of price movement by the value *j* in the state *i*. To calculate elements b_{ij} the three intervals for price movements are used (the intervals' bounds depend on the standard deviation(sd) of the initial time series:

interval 1 (low movements): $[-1sd;+1sd]$;

interval 2 (medium movements): $[-2sd;-1sd]$ or $[+1sd;+2sd]$;

interval 3 (high movements): $[-\infty;-2sd]$ or $[+2sd;+\infty]$.

Step 3. Vector *w* evaluation.

The vector components are determined according to (3).

The implementation results are presented below.

The hidden markov models are constructed for time series which describe the daily closing prices of stocks of some well-known companies for time period 2016-2017.

Let's consider the results obtained for Johnson & Johnson Company. To estimate the elements of matrix B the following values of parameter s were taken: s=5, s=10, s=20.

The corresponding graphs for stock price dynamics and for market stage changes are presented on the fig. 1 – fig. 3.

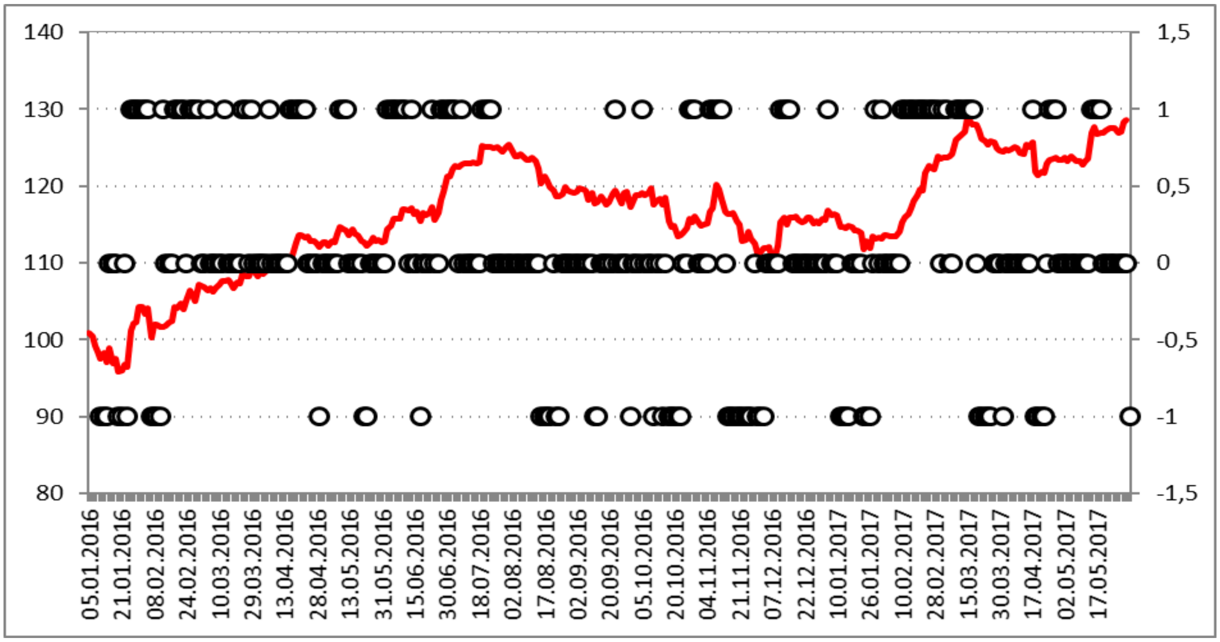

Fig. 1. Stock price and market stage movements (s = 5)

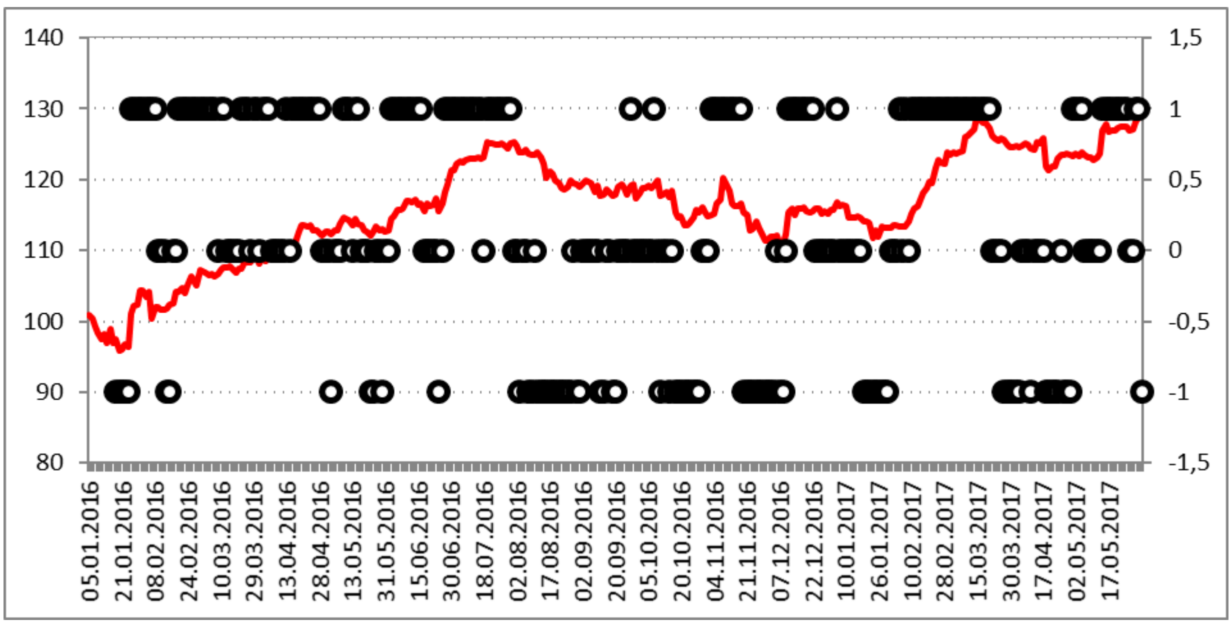

Fig. 2. Stock price and market stage movements (s = 10)

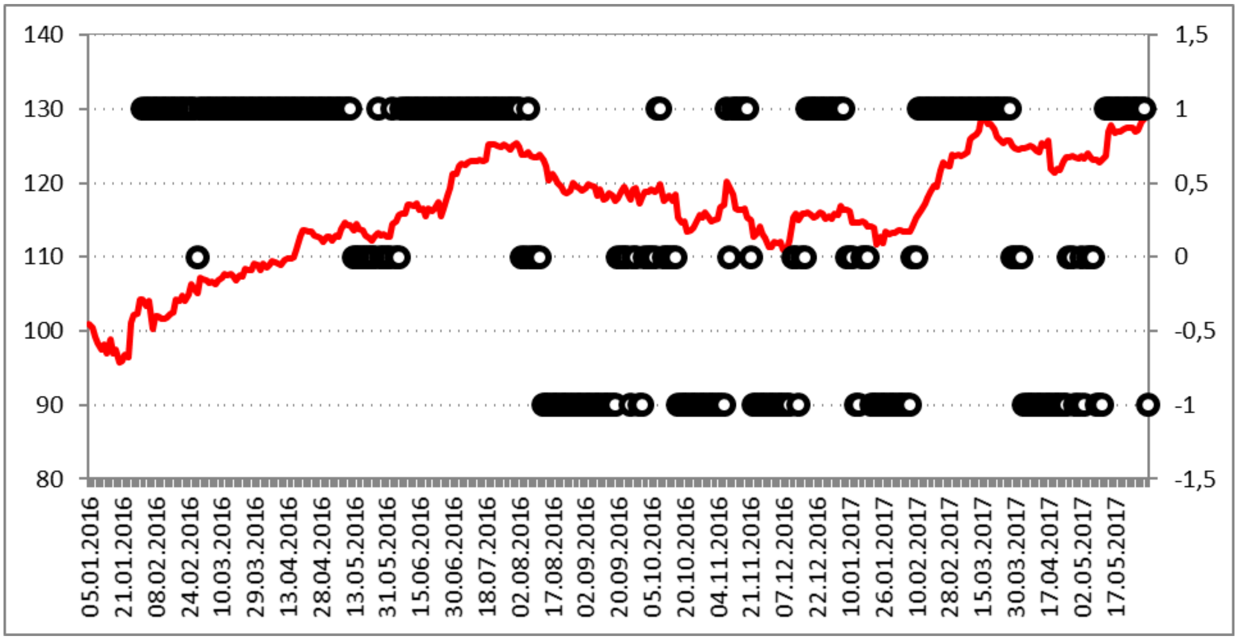

Fig. 3. Stock price and market stage movements (s = 20)

The results obtained for s=20 will be used for the next calculations.

The table below shows the transition probabilities between trend and flat markets. The probability of a delay is 0,87; 0,65 and 0,93 respectively for “BULL”, “FLAT” and “BEAR” markets.

Table 1

Transition probabilities (Johnson & Johnson)

	BEAR	FLAT	BULL
BEAR	0,87	0,11	0,02
FLAT	0,20	0,65	0,15
BULL	0,01	0,06	0,93

The matrix is ergodic, so we can obtain the final probabilities of states, which are presented in the Table 2.

Table 2

Final probabilities (Johnson & Johnson)

BEAR	0,311356	0,182508	0,506137
FLAT	0,311355	0,182508	0,506137
BULL	0,311355	0,182508	0,506137

Thus in long perspective approximately 50% of time the market is bullish, 31% of time the market is bearish, the last 18% of time refers to flat state of the market.

The calculated probabilities of observing the price from a certain interval in the appropriate state of the market are presented in the Table 3.

Table 3

Matrix B (Johnson & Johnson)

	Low	Medium	High
BEAR	0,49	0,41	0,11
FLAT	0,55	0,40	0,05
BULL	0,58	0,32	0,10

The resulting model was used to determine market states during one week in 2018. The initial set of normalized observations looks like: r_t = (Low, Medium, Medium, Medium, Medium). As the result, the following sequence of hidden states were estimated using Viterbi algorithm: (FLAT, FLAT, FLAT, BEAR, BEAR).

Let's consider the results obtained for Hewlett-Packard Company.

The matrix B was estimated for s=20. The corresponding graphs for stock price dynamics and for market stage changes are presented on the fig. 4.

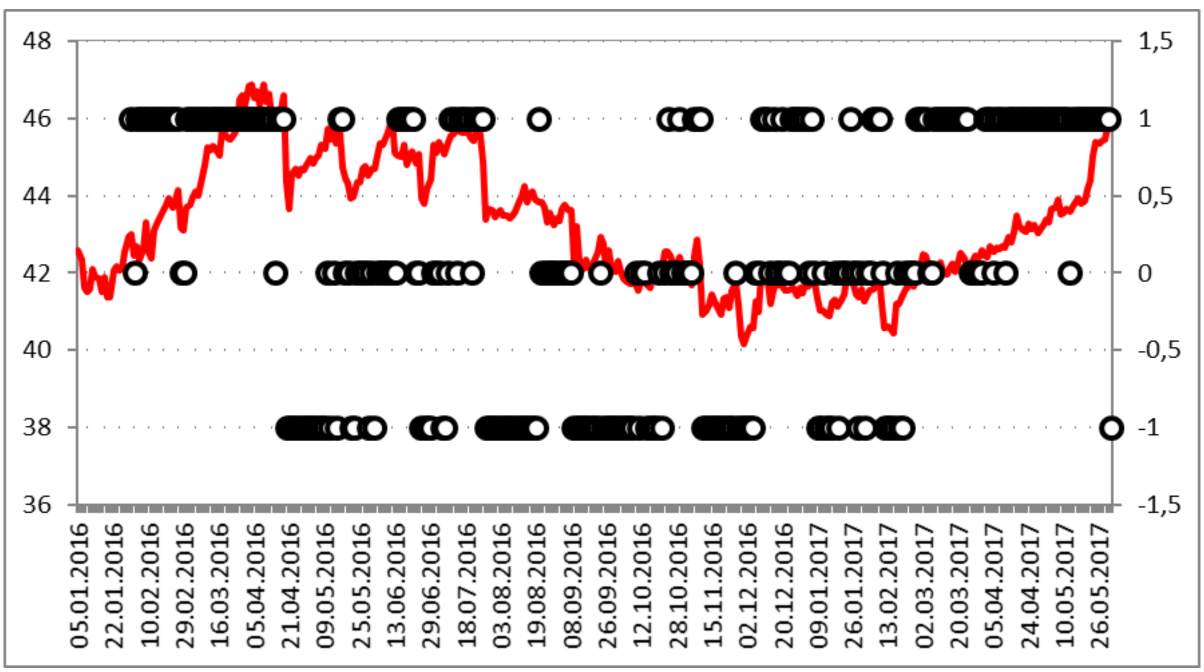

Fig. 4. Stock price and market stage movements (s = 20)

As a result of calculations the following matrix P was obtained (Table 4).

Table 4

Transition probabilities (Hewlett-Packard)

	BEAR	FLAT	BULL
BEAR	0,83	0,16	0,01
FLAT	0,24	0,40	0,36
BULL	0,03	0,03	0,94

The analysis of the matrix P allows to conclude that the probability of a delay in the "bull market" is 83%, while the similar probability of keeping the bear market next day is higher and equal to 94 %. The lowest probability of a day delay is for the flat stage. If the market is in the flat, the probability of maintaining this condition on the next day is only 40%, while the probability of leaving this state is 60% (herewith the probability of a transition to the bear market is more (36%) than to the bullish (24 %)). The resulting matrix is ergodic. The final probabilities are presented in the Table. 5.

Table 5.

Final probabilities (Hewlett-Packard)

BEAR	0,247843	0,100953	0,651203
FLAT	0,247843	0,100953	0,651203
BULL	0,247843	0,100953	0,651203

Thus, in the stationary regime 25% of the total time the market will be bearish, 65% of the time the market will be bullish, and 10% the market will be in flat stage.

The estimates of matrix B are presented in the Table 6.

Table 6

Matrix B (Hewlett-Packard)

	Low	Medium	High
BEAR	0,49	0,41	0,11
FLAT	0,55	0,40	0,05
BULL	0,58	0,32	0,10

The resulting model was used to determine market states during one week in

2018. The initial set of normalized observations looks like: r_t = (Low, Medium, Medium, Medium, Low). As the result, the following sequence of hidden states were estimated using Viterbi algorithm: (FLAT, FLAT, FLAT, BEAR, BEAR).

Let's consider the application results for the stock prices of IBM Company.

To determine the matrix of transition probabilities, the same value for the parameter s are considered, as in the previous cases. The resulting graphs are presented on the Fig. 5. Table 7 contains the matrix of transition probabilities.

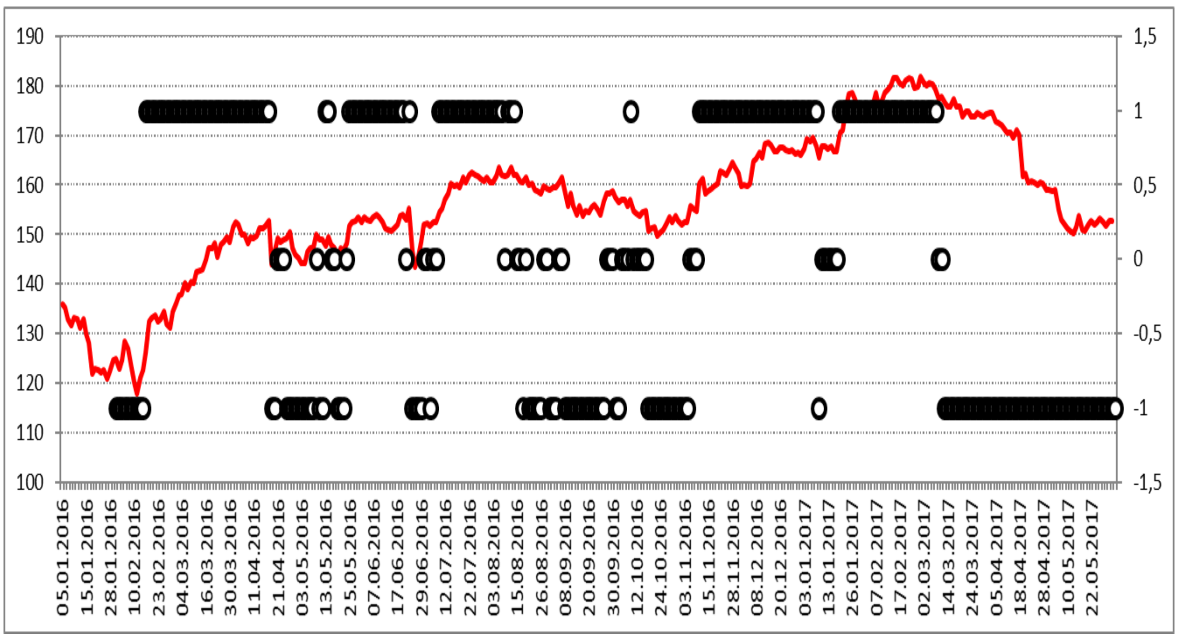

Fig. 5. Stock price and market stage movements (s = 20)

Table 7

Transition probabilities (IBM)

	BEAR	FLAT	BULL
BEAR	0,89	0,09	0,02
FLAT	0,26	0,57	0,17
BULL	0,02	0,04	0,94

The matrix P allows to conclude that the probability of a delay in the bull market is approximately 89%, while the similar probability of preserving the bears market is lower and equals 94%. If the market is in the flate stage, the probability of maintaining this state the next day is rather high (about 57%). The probability of escaping from this state is 43%, with the probability of transition to the bear market less (17%) than to the bullish (26%).

Table 8.

Final probabilities (IBM)

BEAR	0,386228	0,125749	0,488024
FLAT	0,386228	0,125749	0,488024
BULL	0,386228	0,125749	0,488024

Thus in about 38% of cases the market will be in the bear stage, in about 49% - in the bull stage, the last 13% will be flat.

The estimates of matrix B are presented in the Table 9.

Table 9

Matrix B (IBM)

	Low	Medium	High
BEAR	0,49	0,40	0,12
FLAT	0,60	0,31	0,10
BULL	0,51	0,42	0,07

The resulting model was used to estimate market stages in 2018. The initial set of observations per working week was of the form (Medium, Low, Low, Medium, Low). Using the Viterbi algorithm, the sequence of states (FLET, FLET, BEAR, FLET, BEAR) is obtained.

Let’s consider the results for Adobe Inc. The dinamics of stock prices and appropriate market stages are shown on the Fig. 6. The resulting one-step transition probabilities are presented in the Table 10.

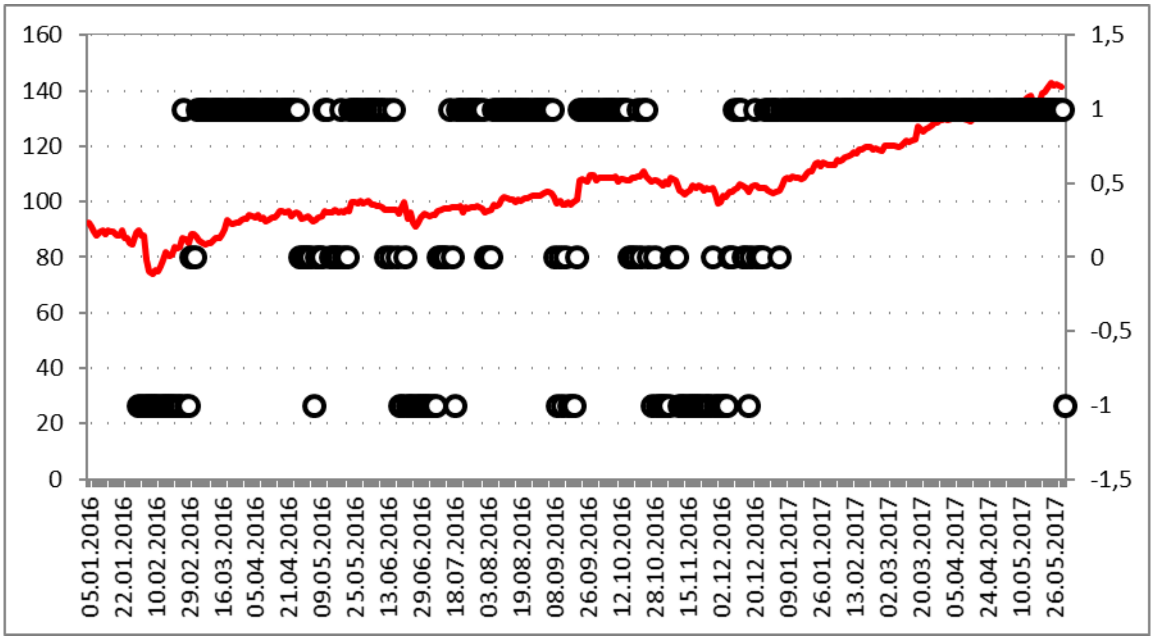

Fig. 6. Stock price and market stage movements (s = 20)

Table 10

Transition probabilities (Adobe)

	BEAR	FLAT	BULL
BEAR	0,77	0,19	0,03
FLAT	0,24	0,47	0,29
BULL	0,01	0,07	0,92

As it shown in the matrix the probability of a delay is the highest for the bullish stage (92%), while the similar probabilities of preserving the bear market is lower and equals 77 %. The lowest probability of one step delay is determined for the flat stage (47%). The probabilities of escaping from the flat stage are approximately the same for the cases of bulish and bearish stages.

Table 11.

Final probabilities (Adobe)

BEAR	0,185629	0,152695	0,661677
FLAT	0,185629	0,152695	0,661677

BULL	0,185629	0,152695	0,661677

The matrix of final probabilities allows to conclude that the bull stage is the one of the most common occurrence. Its final probability is about 66%. the other two stages have approximately equal values (18,5% and 15,2%)

The calculated probabilities of observing the price from a certain interval in the certain stage are presented in the Table 12.

Table 12

Matrix B (Adobe)

	Low	Medium	High
BEAR	0,29	0,27	0,45
FLAT	0,55	0,29	0,16
BULL	0,68	0,19	0,13

The initial set of observations for agiven week was of the form (Medium, High, Medium, High, High). The resulting sequence of stages are the following - (FLET, FLET, FLET, BULL, BULL)

Final results for all four models are shown in the Table 13.

Table 13

Results of the diagnostics of the market stage

Model	Period 1	Period 2	Period 3	Period 4	Period 5
Johnson & Johnson	FLAT	FLAT	FLAT	BEAR	BEAR
Hewlett-Packard	FLAT	FLAT	FLAT	BEAR	BEAR
IBM	FLAT	FLAT	BEAR	FLAT	BEAR
Adobe	FLAT	FLAT	FLAT	BULL	BULL

Due to the fact that stocks are traded on the same market, we may draw a conclusion about the state of the whole market as a weighted sum of the results obtained for all individual models. Future researches should be concerned to including more initial models that describe not only stocks but also other types of financial instruments.