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MARKOV CHAIN MODEL FOR PREDICTING THE STOCK PRICE OF PAPER AND PAPER PRODUCTS INDUSTRY

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ABSTRACT: Markov chains, which are a stochastic process, are a method for analyzing the current behavior of variables to predict their future behavior. With stochastic analysis, it is possible to make decisions in stock markets and make predictions about the future. In this study, with the help of Markov chains, the stock prices of the companies traded in the paper and paper products industry in BIST were predicted. In order to realize the purpose of this study, the closing prices of the seven companies traded in the BIST for the period 01.06.2022-31.05.2023 were used. While it was concluded that six stocks would likely decrease in the long term, it was concluded that the stock of TEZOL company would increase in the long term. When the expected stock returns of the companies are examined, it was determined that VIKING is the company with the highest expected stock return, while KARTN is the company with the lowest expected stock return.

Keywords: Markov chain, stock, paper and paper products

KAĞIT VE KAĞIT ÜRÜNLERİ SEKTÖRÜNÜN HİSSE FİYATININ TAHMİN EDİLMESİNE YÖNELİK MARKOV ZİNCİR MODELİ

ÖZET: Stokastik bir süreç olan Markov zincirleri, gelecekteki davranışları tahmin etmek için değişkenlerin mevcut davranışlarını analiz eden bir yöntemdir. Stokastik analiz ile hisse senedi piyasalarında kararlar almak ve geleceğe yönelik tahminlerde bulunmak mümkündür. Bu çalışmada Markov zincirleri yardımıyla BIST'te kağıt ve kağıt ürünleri sektöründe işlem gören şirketlerin hisse senedi fiyatları tahmin edilmiştir. Bu çalışmanın amacını gerçekleştirmek için BİST'te işlem gören yedi şirketin 01.06.2022-31.05.2023 dönemine ait kapanış fiyatları kullanılmıştır. Altı hissenin uzun vadede düşüşe geçeceği sonucuna

varılırken, TEZOL firmasının hissesinin uzun vadede artacağı sonucuna varıldı. Şirketlerin beklenen hisse senedi getirileri incelendiğinde, hisse senedi getirisi en yüksek olan firmanın VIKING olduğu belirlenirken, hisse senedi getirisi en düşük firmanın ise KARTN olduğu belirlenmiştir.

Anahtar kelimeler: Markov zinciri, hisse senedi, kağıt ve kağıt ürünleri

INTRODUCTION

Stock markets, which are one of the few markets where perfect competition conditions are dominant, are structures in the nature of organized capital markets where millions of buyers and sellers trade at constantly changing prices and lead to the spread of capital to the base. In these markets, where many investors evaluate their assets to provide higher returns, the right decisions should be made so that the scarce financial resources can be directed to the right areas. In addition, it is extremely important to make the right decision for managers who want to maximize company values.

Making predictions on stocks under the influence of many different parameters and choosing the right stock are initially carried out with traditional methods and market experiences. Today, with modern prediction methods, it is possible to take stronger decisions and reduce the amount of possible losses. Fundamental analysis, technical analysis and quantitative methods are used in decision-making processes for the future of stocks.

Fundamental analysis was developed by Graham-Dod and is the oldest and most widely used method for estimating the price of a stock (Fettahoğlu, 2003; Birgili, 2013). The purpose of fundamental analysis is to find the closest real value of the stock according to certain market conditions and to make an investment decision by comparing this value with the market value (Karslı, 2004; Çoşkun, 2010). In the fundamental analysis, the analysis of stocks is carried out in three stages: economy analysis, sector analysis and firm analysis (Afşar & Afşar, 2010).

Technical analysis is defined as a method based on statistical methods, which is used to predict the trend and trend changes expressed by the price charts of today, by using the graphical models created by the price movements of the past years (Karslı, 2004). As the definition suggests, the most important analysis tool of technical analysis is charts. Technical analysts are also called "chartists" because a large part of technical analysis is chart analysis (Tomakin, 2007). Unlike fundamental analysts, technical analysts try to predict the price of stocks rather than their value (Yakın, 2002). There is a lot of debate about whether technical analysis is a scientific method of analysis. In order to understand technical analysis, first of all, the “Dow theory” of Charles Dow, who is accepted as the founder of technical analysis, should be examined (Bilgili, 2013). The Dow Theory is the starting point of the technical analysis approach. Dow Theory was developed by Charles Dow between 1900 and 1902. Dow has been called the grandfather of technical analysis (Tomakin, 2007). According to Dow Theory, the evolution of stock market prices over time is a function of earnings from the stock and stocks depend on equilibrium prices that speculators cannot manipulate. The Great Crisis was predicted using the Dow Theory. Today, various forms of Dow Theory exist and are in use and form the basis of many techniques used by technical analysts (Akca, 2005).

In recent years, especially the complex structure of the problems and the presence of a large number of variables that will affect the estimation have led to the foreground of quantitative methods. Quantitative methods are methods based on mathematical modeling developed by processing data on the subject. These methods are categorized in two classes as statistical methods and operations methods (Kocatepe & Yıldız, 2016). Statistical methods include various statistical methods that collect, classify, analyze and interpret data. Operations methods are advanced techniques, and management uses them in decision making and solving complex problems. Markov chains, which form the basis of the research, are included in operations research methods. (İlarslan, 2014).

In this study, Markov Chains method, which is one of the quantitative techniques, was used to predict the future prices of the stocks of companies in the paper and paper products industry traded in Borsa Istanbul (BIST).

Literature Research

Öz (2009) developed a Markov chain model to estimate the exchange value of the ISE 100 index and obtained successful results. Idolor (2010) tried to predict the future price movements of eight stocks traded in the Nigerian Stock Exchange using the Markov chain method. For this purpose, daily data between 2005 and 2008 were used. It was learned that the Markov chains model does not give a precise result in predicting price movements in the short run. Vasanthi et al. (2011) applied the Markov chain model to the indices of various stock markets around the world, and the results of trend prediction using Markov chain analysis were compared with the results obtained from traditional trend prediction methods. One, three, and five-year data were used for trend predictions. The Markov model often outperformed traditional trend prediction methods. Using the daily data of the stocks of five companies within the scope of the Dow Jones industrial index, Doubleday & Esunge (2011) tried to predict future prices with Markov chains. They said that the Markov chain can be used to predict the stock price. D'Amico & Petroni (2012) researched stock price movements in the Italian Stock Exchange and analyzed daily price changes using Markov chains. It was determined that the Markov chain will be an alternative to the existing statistical methods. The research conducted by Svoboda & Lukas (2012) was related to predicting the stock index trend of Prague stock market PX by using Markov chain analysis. İlarsan (2014) performed an application for predicting stock price movements with Markov chain analysis. It has been emphasized that the predictability of stock price changes with the Markov chain is high. Özdemir & Demireli (2014) created Markov chains for daily price changes of stocks traded in the BIST Technology Index and calculated probabilities for transitions between states. In addition, they determined which stocks expect higher returns. Karaca & Alp (2017) investigated the long-term relationship between gold and stock prices with the help of Markov chains method and they found that there is no obvious unidirectional relationship between gold prices and the BIST 100 index. Huang et al. (2017) analyzed the movement of stock prices of Taiwanese company HTC with a regular Markov chain and an absorbing Markov chain. As a result of the study, empirical findings on when HTC stock prices will increase after a decrease were presented to investors. Fitriyanto & Lestari (2018) aimed to predict PT HM Sampoerna stock prices using the Markov chain model. They concluded that PT HM Sampoerna's share prices will increase by 9% and 40% and decrease by 46% and 5%. Petkovic et al. (2018) analyzed the returns on the Belgrade stock exchange with the Markov chain model. Sarıyer et al. (2018) tried to predict the stock price movements of thirteen companies in the automotive industry with the help of the Markov chain model. Yavuz

(2019) predicted the KATLM-KAT50 participation indices with the help of a Markov chain model. To achieve this aim, 520-day closing values were used for KATLM, whereas 514-day closing values were used for KATN50. It was concluded that the Markov chain is an accurate and powerful method for prediction. It was also found that the Markov chain has very low error rates. Lakshmi & Manoj (2020) applied a Markov chain model for compare the performance of five stocks in Oil and Gas Sector in India. Yenisu (2020) tried to provide investors with information about the possible future returns of stocks with the help of the Markov chain method. For this, daily closing data of 10 stocks with the highest trading volume among BIST 100 companies were used. As a result of the study, he pointed out the difference in the long-term expected returns of stocks. Ayo & Uwabor (2021) investigated the stock price movements of seven oil and gas companies quoted on the Nigerian Stock Exchange with a Markov model. For this, daily closing share prices of companies from April 2017 to January 2020 were used. Anuthrika & Thanusika (2021) tried to predict the stock prices of five Canadian banks, and Markov chain was used as the method. As a result of the analysis, they determined that all banks have a high chance of getting earnings and each of the five banks has a high chance of getting small increment. Dar et al. (2022) aimed to forecast Tata Consultancy Services Limited share prices in the Indian stock market using a Markov chain.

MATERIALS AND METHODS

In the estimation process performed by using one-year data (01.06.2022-31.05.2023) of seven companies traded in the paper and paper products industry in Borsa Istanbul, the closing prices of the relevant companies' stocks were obtained on a daily basis. Stock closing prices are obtained from isyatirim.com.tr website (URL-1, 2023). The companies within the scope of the analysis are given below:

Alkim Paper Industry and Trade Inc. (ALKA)
Kaplamin Packaging Industry and Trade Inc. (KAPLM)
Kartonsan Karton Industry and Trade Inc. (KARTN)
Konya Paper Industry and Trade Inc. (KONKA)
Mondi Tire Kutsan Paper and Packaging Industry Inc. (MNDTR)
Europap Tezol Paper Industry and Trade Inc. (TEZOL)
Viking Paper and Cellulose Inc. (VIKING)

In the research, Markov chain was used as a method. Markov chains are often used as a decision-making tool in probabilistic situations such as financial return, brand preference, stocking level (Yenisu, 2020). Markov Chains are a stochastic model used in decision making under uncertainty and this method was developed by the Russian mathematician Andrei A. Markov in the early 1900s (Ross, 2014; Karaca & Alp, 2017). The state space in the Markov chain goes through a process of random transition from one state to another, and the probability distribution of the next state can only be determined by the current state and the events before it (Gu & Feng, 2022). The most fundamental feature of the Markov chain is that the occurrence of any future event depends solely on the current state (Padi et al., 2022).

In a Markov chain, the state transition probabilities are denoted by pij, which represents the probability of going from state i to state j (Ross, 2014; Kallah-Dadagu et al., 2022).

Mathematically, a Markov Chain model can be expressed as follows (Winston & Goldberg, 2004; Manasseh et al., 2022):

$$p_{ij} = P\{X_{n+1} = j | X_n = i\} \quad (1)$$

A matrix representation of the state transition probabilities is shown as below and i and j represent rows and columns, respectively. It should be $0 \leq p_{ij} \leq 1$ for all elements of the P matrix and $\sum_j p_{ij} = 1$ for each row (Winston & Goldberg, 2004; Manasseh et al., 2022).

$$p_{ij} = \begin{vmatrix} p_{11} & p_{12} & p_{13} & \dots & p_{1j} \\ p_{21} & p_{22} & p_{23} & \dots & p_{2j} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ p_{i1} & p_{i2} & p_{i3} & \dots & p_{ij} \end{vmatrix}$$

The probability of going from state i to state j after n steps is called transition probability with n steps and is denoted by p_{ij}^n. The Chapman-Kolmogorov equation is used to calculate the n-step transition probabilities. The n-step transition probabilities matrix consists of the product of two ((lxn) and (nxn)) dimensional matrices (İlarslan, 2014; Taha, 2017).

$$P_{ij}^n = P(X_{n+m} = j | X_m = i) = P(X_n = j | X_0 = i) \quad i, j \in S \quad (2)$$

$$P^n = P^{n+1} * P = P^n \quad (3)$$

If all the states of the chain are interconnected and non-periodic, the chain is called ergodic (long-term). For a given transition matrix P, the chain has a stable distribution if the vector π exists such that the following equation is true (Kostandinova et al., 2021):

$$\pi = \pi P \quad (4)$$

The stationary vector π can be thought of as the long-run distribution of an arbitrary variable. The vector π can be obtained as an arbitrary row from the matrix of the following boundary transition (Kostandinova et al., 2021):

$$\lim_{n \to \infty} P^n = \begin{vmatrix} \pi_1 & \pi_2 & \dots & \pi_m \\ \pi_1 & \pi_2 & \dots & \pi_m \\ \vdots & \vdots & \vdots & \vdots \\ \pi_1 & \pi_2 & \dots & \pi_m \end{vmatrix}$$

RESULTS

The stock prices of seven companies traded in the paper and paper products industry in Borsa Istanbul may increase, decrease or constant compared to the previous situation. There is a transition from any of these three states to any of these three states. In the study, 247 transitions were calculated for a company. As a result of the calculations, the transition matrix in Table 1 was created.

Table 1. Transition matrices of seven stocks

ALKA	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	66	2	56	124

Constant (j=2)	2	0	2	4
Increase (j=3)	55	2	62	119
KAPLM	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	84	3	49	136
Constant (j=2)	3	0	2	5
Increase (j=3)	48	2	56	106
KARTN	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	60	1	62	123
Constant (j=2)	3	0	0	3
Increase (j=3)	61	2	58	121
KONKA	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	73	3	57	133
Constant (j=2)	2	1	2	5
Increase (j=3)	58	0	51	109
MNDTR	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	77	0	55	132
Constant (j=2)	1	0	1	2
Increase (j=3)	55	2	56	113
TEZOL	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	57	1	56	114
Constant (j=2)	2	0	2	4
Increase (j=3)	55	4	70	129
VIKING	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	72	3	51	126
Constant (j=2)	4	0	3	7
Increase (j=3)	51	4	59	114

When Table 1 is examined, there is a decrease in 124 of the stock prices, an increase in 119 of them and no increase-decrease in 4 of them for ALKA company. There is a decrease in 136 of the stock prices, an increase in 106 of them and no increase-decrease in 5 of them for KAPLM company. There is a decrease in 123 of the stock prices, an increase in 121 of them and no increase-decrease in 3 of them for KARTN company. There is a decrease in 133 of the stock prices, an increase in 109 of them and no increase-decrease in 5 of them for KONKA company. There is a decrease in 132 of the stock prices, an increase in 113 of them and no increase-decrease in 2 of them for MNDTR company. There is an increase in 129 of the stock prices, a decrease in 114 of them and no increase-decrease in 4 of them for TEZOL company. There is a decrease in 126 of the stock prices, an increase in 114 of them and no increase-decrease in 7 of them for VIKING company. Using the data in the transition matrix, the transition probabilities were obtained and the transition probabilities matrix was created. The transition probabilities are found by dividing the value in each row of the transition matrix by the total value in that row. The transition probabilities matrix for seven stocks is given in Table 2.

Table 2. Transition probability matrices of seven stocks

ALKA	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	0.532	0.016	0.452	1.000
Constant (j=2)	0.500	0.000	0.500	1.000
Increase (j=3)	0.462	0.017	0.521	1.000
KAPLM	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	0.618	0.022	0.360	1.000
Constant (j=2)	0.600	0.000	0.400	1.000
Increase (j=3)	0.453	0.019	0.528	1.000
KARTN	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	0.488	0.008	0.504	1.000
Constant (j=2)	1.000	0.000	0.000	1.000
Increase (j=3)	0.504	0.017	0.479	1.000

KONKA	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	0.549	0.023	0.429	1.000
Constant (j=2)	0.400	0.200	0.400	1.000
Increase (j=3)	0.532	0.000	0.468	1.000
MNDTR	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	0.583	0.000	0.417	1.000
Constant (j=2)	0.500	0.000	0.500	1.000
Increase (j=3)	0.487	0.018	0.496	1.000
TEZOL	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	0.500	0.009	0.491	1.000
Constant (j=2)	0.500	0.000	0.500	1.000
Increase (j=3)	0.426	0.031	0.543	1.000
VIKING	Decrease (j=1)	Constant (j=2)	Increase (j=3)	Total
Decrease (j=1)	0.571	0.024	0.405	1.000
Constant (j=2)	0.571	0.000	0.429	1.000
Increase (j=3)	0.447	0.035	0.518	1.000

While the stock of ALKA company increased on May 31, 2023 compared to May 30, 2023, it has been concluded that the stock return of ALKA company on June 01, 2023 will increase with 52.1% probability, decrease with 46.2% probability and be no increase-decrease with 1.7% probability.

While the stock of KAPLM company increased on May 31, 2023 compared to May 30, 2023, it has been concluded that the stock return of KAPLM company on June 01, 2023 will increase with 52.8% probability, decrease with 45.3% probability and be no increase-decrease with 1.9% probability.

While the stock of KARTN company decreased on May 31, 2023 compared to May 30, 2023, it has been concluded that the stock return of KARTN company on June 01, 2023 will increase with 50.4% probability, decrease with 48.8% probability and be no increase-decrease with 0.8% probability.

While the stock of KONKA company increased on May 31, 2023 compared to May 30, 2023, it has been concluded that the stock return of KONKA company on June 01, 2023 will decrease with 53.2% probability and decrease with 46.8% probability.

While the stock of MNDTR company decreased on May 31, 2023 compared to May 30, 2023, it has been concluded that the stock return of MNDTR company on June 01, 2023 will decrease with 58.3% probability and increase with 41.7% probability.

While the stock of TEZOL company has neither decreased nor increased on May 31, 2023 compared to May 30, 2023, it has been concluded that the stock return of TEZOL company on June 01, 2023 will decrease with 50% probability and increase with 50% probability.

While the stock of VIKING company decreased on May 31, 2023 compared to May 30, 2023, it has been concluded that the stock return of VIKING company on June 01, 2023 will decrease with 57.1% probability, increase with 40.5% probability and be no increase-decrease with 2.4% probability. In Table 3, long-term stability-state probability values of stocks are given.

Table 3. Stability-state probabilities of stocks

	Decrease (j=1)	Constant (j=2)	Increase (j=3)

ALKA	0.497	0.016	0.486
KAPLM	0.546	0.020	0.434
KARTN	0.501	0.012	0.485
KONKA	0.540	0.015	0.446
MNDTR	0.539	0.008	0.454
TEZOL	0.462	0.020	0.518
VIKING	0.514	0.028	0.457

In the long-term, stability-state probability values of stocks of the companies are as follows: ALKA's stock value will decrease with 49.7% probability, increase with 48.6% probability and be no increase-decrease with 1.6% probability. KAPLM's stock value will decrease with 54.6% probability, increase with 43.4% probability and be no increase-decrease with 2% probability. KARTN's stock value will decrease with 50.1% probability, increase with 48.5% probability and be no increase-decrease with 1.2% probability. KONKA's stock value will decrease with 54% probability, increase with 44.6% probability and be no increase-decrease with 1.5% probability. MNDTR's stock value will decrease with 53.9% probability, increase with 45.4% probability and be no increase-decrease with 0.8% probability. TEZOL's stock value will increase with 51.8% probability, increase with 46.2% probability and be no increase-decrease with 2% probability. VIKING's stock value will decrease with 51.4% probability, increase with 45.7% probability and be no increase-decrease with 2.8% probability.

The daily expected return of the stock was obtained by multiplying the values obtained from the average of the percent stock price change rates with the probabilities of stability-state vector. While obtaining the daily expected return of the stock, it is assumed that all 1000 TL is invested in a stock. Table 4 shows the expected returns of stocks in the long-term.

Table 4. Exchange rates and expected returns of stocks

Stock code	Change (%)		Value (TL)		Prediction of stock
	Decrease	Increase	Decrease	Increase	
ALKA	2.774	3.707	972.26	1037.07	1003.229
KAPLM	3.097	4.598	969.03	1045.98	1003.046
KARTN	2.150	2.202	978.50	1022.02	997.908
KONKA	2.702	3.732	972.98	1037.32	1003.054
MNDTR	2.364	2.480	976.36	1024.80	999.517
TEZOL	2.224	2.903	977.76	1029.03	1004.763
VIKING	3.602	5.807	963.98	1058.07	1007.024

When the calculated expected stock returns are examined, it is seen that the values are close to each other. VIKING is the company with the highest expected return of the stock. This company is followed by TEZOL and ALKA. KARTN is the company with the lowest expected return on the stock.

CONCLUSION

Stocks are under the influence of many parameters and are constantly changing. Various technical, fundamental and quantitative methods are used to predict future stock movements. One of the quantitative methods is Markov chains. In this study, the future prices of stocks of companies in the paper and paper products industry are predicted by Markov chains. According to the findings, we can say that on June 1, 2023, ALKA, KAPLM, KARTN stocks will increase with a high probability, and KONKA, MNDTR and VIKING stocks will

decrease with a high probability. The probability of decrease and increase of TEZOL stock is equal (50%). In the long term, a decrease of more than 50% probability is expected in the values of KAPLM, KARTN, KONKA, MNDTR, VIKING stocks, while an increase of more than 50% in the value of TEZOL stock is expected. Although the probability of decrease and increase of ALKA stock in the long term is close to each other, a decrease is expected in ALKA stock. For any of the stocks within the scope of the study, the probability of no decrease-increase in daily change was not high in the long term. When the percentage change rates are analyzed, it is seen that the rate of increase in stock prices is higher than the rate of decrease for all companies' stocks. When the expected stock returns of the companies are examined, it has been determined that the stock values of companies are close to each other.

In this study, only paper and paper products companies traded in Istanbul stock exchange in Turkey are focused. The Markov chain can also be applied to different sectors and countries. With the hidden Markov chain, which also takes into account the variables affecting the stock market, stock estimates of paper and paper products companies can be made and the results can be compared. In addition, the use of Markov chains together with artificial neural networks will reduce the margin of error in cases where the estimation error is determined. Therefore, stock predictions can be made by integrating Markov chains and artificial neural networks.

AUTHOR CONTRIBUTIONS

Nadir Ersen: Choosing the study subject, conducting the study, obtaining the data, making the analysis, interpreting the data, writing the article. **İlker Akyüz**: Data interpretation and analysis, writing the article. **Kadri Cemil Akyüz:** Review of the study.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ETHICS COMMITTEE APPROVAL

This study does not require any ethics committee approval.

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