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Forecasting SASX-10 Index Using Multiple Regression Based on Principal Component Analysis

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Abstract

In this paper we forecast SASX-10 Index (SArajevo Stock Exchange Index 10) by using multiple regression based on Principal Component Analysis scores (PCAS). In order to forecast stock market index SASX-10, as dependent variable, we use multiple regression and various macroeconomic indicators as independent variables to investigate indicators that significantly affect the performance of stocks actively traded on the Bosnia and Herzegovina (B & H) financial market.

Initially, the sample of study covered 17 macroeconomic factors as independent variables but we chosen in our model 9 statistically significant factors as independent variables ($p < 0.05$).

After that, we have used multiple regression based on PCA scores to establish a meaningful relationship among various explanatory variables identified through the empirical analysis considering the available research studies. This paper provides an econometric analysis of the valuation SASX-10 Index.

Principal Component Analysis was used to reduce large number of explanatory variables and we have taken into consideration the multicollinearity problem among different independent variables.

The main objective of this study was to forecast the value for SASX-10 Index using a multivariate statistical approach, Principal Component Analysis, to classify predictor variables according to interrelationships and to predict SASX-10 Index. For this purpose, PCA scores of 9 macroeconomic indicators were used as independent variables in multiple linear regression model for prediction of SASX-10 Index.

We have got some relationships of macroeconomic indicators with the SASX-10 market index. The result shows that the empirical characteristics of the SASX-10 Index are determined by the CPI, BIRS Index, SASX-10_{t-1} Index, CROBX10 Index, ATX Index, FTSE Italian STAR Index, SBITOP Index, KM/HRK and M1. Finally, we create four models with their loss function. After that, we compare loss function of all created forecasting models and the model Forecast 1 has a minimum of all loss function.

As it can be seen, 81.10% of variation in SASX-10 can be explained by explanatory variables. Accordingly, we forecast SASX-10 Index closed price for the period 01/12/2014 through 31/12/2014 by using four models.

Key words: Forecasting; SASX-10 index; Multiple regression analysis; Principal component analysis

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INTRODUCTION

Stock market forecasting research offers many challenges and opportunities forecasting either the level (value) of future market prices or the direction of market price movement. The stock market indices are primarily used for the analysis of historical trends in the capital markets. They are very important indicators of market movements in economy.

Generally, the related literature shows that in developed countries there are various traditional stock valuation models such as DCFM (The discounted cash flow model), CAPM (The capital asset pricing model), APT (The arbitrage pricing model) and other. But, all of these models are based on the concept of market equilibrium and the existence of a perfect market. Thus, these models are not appropriate for undeveloped market such is B & H.

Dezsi and Fat (2012) noticed three main approaches arise in describing the relationships between markets: a) The first group of studies measures stock market integration by using a single criterion (the law of one price); b) The second group of studies measures stock market integration by using impact of barriers to capital mobility; c) The third group of studies measures stock market integration by comparing the mutual risk factors in asset returns.

Also, they noticed four distinctive techniques to explore and capture the relations between stock market indices: a) The correlation coefficient; b) The co-integration vectors; c) The univariate and multivariate general autoregressive conditional heteroscedasticity models (the variance-covariance structure); d) The factor analysis.

The objective of this study is to identify and explain the relationship between SASX-10 Index prices and macroeconomic indicators by using multiple regression based on principal component analysis. SASX-10 is the main stock index on the Sarajevo Stock Exchange. It depicts the price movement of the top 10 issuers on the Sarajevo Stock Exchange ranked by market capitalization and frequency of trading.

In order to mitigate the problem of multicollinearity and to explore the relations among the independent variables we are using PCA scores (PCAS). The new variables from the PCAS become appropriate to use as predictors in a regression equation since they optimize spatial patterns and remove possible complications caused by multicollinearity.

1. LITERATURE REVIEW

In the previous papers, researchers have used many different factors to forecast the stock market index. According to available literature most researchers found significant relationship between stock market indices (returns) and different macroeconomic/ microeconomic factors such as other stock exchange indices, money supply, industrial production, interest rates, inflation, exchange rates, oil prices, crude oil prices, gold prices, food prices inflation, FDI, foreign exchange reserve, producer price index, industrial production index, cash reserve ratio, nominal EPS and DPS, T-bill rates, CD rates, Current Assets/Current Liabilities, Bond index and so on (Mukherjee & Naka, 1995; Okon, 2012; Maysami, Howe, & Hamzah, 2000; Nishat & Shaheen, 2004; Al-Tamimi, Alwan, & Abdel Rahman, 2011; Çagli, Halac, & Taskin, 2010; Khumyoo, 2000; Chaereon - Kithuttakorn, 2005; Rimcharoen, Sutivong, & Chongstitvatana, 2005; Sutheebanjard & Premchaiswadi, 2009; Chaigusin, Chirathamjaree, & Clayden, 2008; Dezsi & Fat, 2012; Abugri, 2008; Lam, 2004; Ghosh, 2008; Ghosh, Bandyopadhyay, & Choudhuri, 2011; Islam, Watanapalachaikul, & Billington, 2004; Sopipan, Kanjanavajee, & Sattayatham, 2012). These factors are identified as independent variables and are given in Table 1.

Table 1
Impact Factor in the Previous Research Papers

Researchers / Impact factors	Khumyoo (2000)	Chaereon -Kithuttakorn (2005)	Rimcharoen et al. (2005)	Sutheebanjard & Premchaiswadi (2009)	Chaigusin et al. (2008)	Dezsi & Fat (2012)	Abugri (2008)	Lam (2004)[1]	Ghosh (2008)	Ghosh et al. (2011)	Islam et al. (2004)	Sopipan et al. (2012)[2]
Nasdaq Index		x										
Dow Jones Index	x	x	x	x	x							x
Nikkei 225 Index	x		x	x	x	x			x			x
S&P 500 Index		x				x			x			x
Hang Seng Index	x		x	x	x	x						x
Straits Times Industrial Index	x											x
PX Index						x						
DAX30 Index						x						x
CAC40 Index						x						
BUX Index						x						
BSE100 Index						x						
WIG Index						x						
BET Index						x						
SAX16 Index						x						
FTSE100 Index						x						x
Exchange Rates	x				x		x	x	x	x	x	x

To be continued

Continued

Impact factors \ Researchers	Khumyoo (2000)	Chaereon -Kithuttakorn (2005)	Rimcharoen et al. (2005)	Sutheebanjard & Premchaiswadi (2009)	Chaigusin et al. (2008)	Dezsi & Fat (2012)	Abugri (2008)	Lam (2004)[1]	Ghosh (2008)	Ghosh et al. (2011)	Islam et al. (2004)	Sopipan et al. (2012)[2]
Crude oil price								x	x			
Oil price	x									x		x
Gold prices					x					x		x
MLR – Minimum Loan Rates				x	x							
Nominal DPS								x				
Nominal EPS								x				
T-bill rates							x				x	
CD rates												
Producer Price Index												
Money supply M1							x					
Consumer Price Index - CPI								x			x	
Industrial Production Index							x					
MSCI World Index							x					
Interest rates							x	x		x	x	
Current Assets/ Current Liabilities								x				
Bond Index									x			
Cash reserve ratio										x		
Food prices inflation										x		
FDI										x		
Foreign exchange reserve										x		
Market capitalization											x	
P/E ratio											x	

Sopipan et al. (2012) showed that using the principal components scores in multiple regression analysis for predicting SET 50 Index is more appropriate than using the original explanatory variables data. There has been no research on this topic in B&H. Therefore, there is a need to develop a suitable approach to identify key macroeconomic factors and predict movement of stock market index SASX-10.

2. DATA AND METHODOLOGY

2.1 Data

The statistical data sets used in this paper are dependent variable, which is the daily closed prices of SASX-10 Index at time t (SASX-10_t), and the explanatory independent variables at time t-1:

- SASX-10_{t-1}: Sarajevo Stock Exchange Index 10.
- CPI_{t-1}: Consumer Prices Index.
- $BIRS_{t-1}$: BIRS Index (The stock index of the Banja Luka Stock Exchange.
- $CROBX10_{t-1}$: The stock index of the Zagreb Stock Exchange.
- ATX_{t-1}: The stock market index of the Vienna Stock Exchange.
- $FTSEI_{t-1}$: The stock market index of the Milano Stock Exchange.
- $SBITOP_{t-1}$: The Slovenian capital market benchmark Index.
- HRK_{t-1}: The Currency Exchange Rate in KM for one currency of Croatia.
- $M1_{t-1}$: Money supply M1.

All data are observed in the period 04/01/2011 through 28/11/2014 (961 observations). The data set is collected from the Central banks, Stock Exchanges and Annual Statistical Reports of considered countries. According to Foreign Direct Investments and Volume of trade exchange B&H, we are chosen market stock indices of Croatia, Slovenia, Austria and Italy such as indicators of movement economy considered countries.

2.2 Methodology

Multiple linear regression (MLR) is a method used to model the linear relationship between a dependent variable and many independent variables. The MLR model can be written as:

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \ldots + \beta_k X_{kt} + \varepsilon_t$$

where:

$Y_t -$ Dependent variable

$X_{1t}, X_{2t}, X_{3t}, \ldots, X_{kt} -$ Independent variables in the time t ($t = 1, 2, 3, \ldots, T$)

$\beta_1, \beta_2, \beta_3, \ldots, \beta_k -$ Coefficient of predictors

$\beta_0 -$ Regression constant

$\varepsilon_t -$ Error term

$k -$ Total number of predictors.

A multiple regression with PCA model consists of expressing the Y_t as a function of the principal component scores as independent variables. The MLR model based on principal component scores can be written as:

$$Y_t = \alpha_0 + \alpha_1 PCAS_{1t} + \alpha_2 PCAS_{2t} + \ldots + \alpha_k PCAS_{kt} + \varepsilon_t$$

where:

$Y_t -$ Dependent variable

$PCAS_{1t}, PCAS_{2t}, \ldots, PCAS_{kt} -$ Principal component in the time t ($t = 1, 2, 3, \ldots, T$)

$\alpha_1, \alpha_2, \alpha_3, \ldots, \alpha_k -$ Coefficient of predictors (PCASs)

$\alpha_0 -$ Regression constant

$\varepsilon_t -$ Error term

$k -$ Total number of predictors (PCASs).

The criteria used for evaluation of forecast are as follows: Root Mean Square Error (RMSE), Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE).

3. EMPIRICAL RESULTS

Descriptive statistics of SASX-10 and explanatory variables are given in Table 2. Correlation matrix is given in Table 3. As it can be seen, high correlation coefficients were found between SASX-10 and other explanatory variables with a high significance ($p < 0.01$). Also high correlation coefficients were found between explanatory variables with high significance ($p < 0.01$) which show that there was a multicollinearity problem.

Multiple regression analysis based on raw data (Forecast 1) also shows that there was a multicollinearity problem with the variance inflation factor (VIF) in Table 2 (VIF >= 5.0). Once of the approaches to avoid this problem is using principal component analysis. Hence, principal component analysis has been completed based on all explanatory variables. The overall results of the PCA are shown in Table 4 and Table 5.

Table 2
Descriptive Statistics

Variables	Mean	St. Dev.	Min	Max	VIF
SASX-10t	829.1088	135.3332	663.55	1199.85	///
$FTSEI_{t-1}$	13231.09	3326.845	8987.76	20007.4	13.09
$SBITOP_{t-1}$	785.2711	174.3776	501.27	1127.23	11.68
$M1_{t-1}$	6345.214	370.9163	5814.978	7278.37	9.60
$BIRS_{t-1}$	838.2496	114.6857	694.38	1220.96	6.53
SASX-10t-1	829.04	135.2386	663.55	1199.85	5.13
ATX_{t-1}	2338.075	277.5432	1652.79	3000.33	3.61
HRK_{t-1}	0.259547	0.002673	0.25531	0.26591	2.84
$CROBX10_{t-1}$	1041.248	86.33103	880.30	1282.84	2.58
CPI_{t-1}	104.9988	1.027615	102.70	106.80	2.40

Table 3
Correlation Matrix of SASX-10 and Explanatory Variables

Variables	$SASX\text{-}10_t$	$BIRS_{t-1}$	$CROBX10_{t-1}$	$SASX\text{-}10_{t-1}$	$SBITOP_{t-1}$	ATX_{t-1}	$M1_{t-1}$	CPI_{t-1}	$FTSEI_{t-1}$	HRK_{t-1}
$SASX\text{-}10_t$	1.0000									
$BIRS_{t-1}$	0.8598**	1.0000								
$CROBX10_{t-1}$	0.6280**	0.6702**	1.0000							
$SASX\text{-}10_{t-1}$	0.8576**	0.8604**	0.7113**	1.0000						
$SBITOP_{t-1}$	-0.1789**	-0.1983**	-0.3706**	-0.1846**	1.0000					
ATX_{t-1}	0.4357**	0.5682**	0.3055**	0.4303**	0.2362**	1.0000				
$M1_{t-1}$	0.0892**	-0.0114	-0.1476**	0.0850**	0.7917**	-0.0115	1.0000			
CPI_{t-1}	-0.6023**	-0.6027**	-0.4888**	-0.6045**	0.2975**	-0.2284**	0.0330	1.0000		
$FTSEI_{t-1}$	0.2087**	0.2217**	-0.0904**	0.2035**	0.8412**	0.3890**	0.8437**	-0.0800**	1.0000	
HRK_{t-1}	0.2895**	0.3279**	0.4504**	0.2893**	-0.6585**	0.1146**	-0.6572**	-0.4458**	-0.5370**	1.0000
Kaiser-Meyer-Olkin Measure of Sampling Adequacy								0.720		
Bartlett's Test of					Chi-square			8448.755		
					df			36		
Sphericity					*p*-value			0.000		

Note. **Correlation is significant at the 0.01 level (2-tailed).

Firstly, the results of Bartlett's sphericity test are shown in Table 3. The null hypothesis in this test is that the correlation matrix is an identity matrix which was used to verify the applicability of PCA. The value of Bartlett's sphericity test for the SASX-10 index was 8448.755 which implied that the PCA is applicable to our data sets ($p < 0.000$). Overall Kaiser's measure of sampling adequacy was 0.720 which indicated that sample sizes were enough to apply the PCA.

Table 4
Eigenvalues for PCASs

Factor	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	3.76708	41.86	41.86
2	3.01788	33.53	75.39
3	0.85116	9.46	84.85
4	0.55971	6.22	91.06
5	0.34200	3.80	94.86
6	0.23388	2.60	97.46
7	0.12304	1.37	98.83
8	0.05908	0.66	99.49
9	0.04617	0.051	100.00

According to the results of PCA (Table 4), there are two principal components out of nine (PCAS1, PCAS2) with eigenvalues greater than 1 which were selected for multiple regression analysis (Forecast 2).

Thus, the first of two principal components provides an adequate summary of the data for most purposes. Only first two principal components, explaining 75.39% of the total variation, should be sufficient for almost any application (Table 4).

According to the results of the correlation matrix of SASX-10 and PCASs (see Table 5), out of nine principal components there are six principal components (PCAS2-6 and PCAS8, $p <= 0.01$) with correlations between SASX-10 and PCASs not zero which were selected for multiple regression analysis (Forecast 3). Finally, we selected all PCASs to forecast SASX-10 for multiple regression analysis (Forecast 4).

Table 5
Correlation Matrix of SASX-10 and PCASs

Components	SASX-10$_t$	PCAS1	PCAS2	PCAS3	PCAS4	PCAS5	PCAS6	PCAS7	PCAS8	PCAS9
SASX-10$_t$	1.000									
PCAS1	0.056	1.000								
PCAS2	0.791**	0.000	1.000							
PCAS3	0.184**	0.000	0.000	1.000						
PCAS4	-0.273**	0.000	0.000	0.000	1.000					
PCAS5	0.212**	0.000	0.000	0.000	0.000	1.000				
PCAS6	0.099**	0.000	0.000	0.000	0.000	0.000	1.000			
PCAS7	0.071*	0.000	0.000	0.000	0.000	0.000	0.000	1.000		
PCAS8	-0.091**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	
PCAS9	-0.080*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

Note. **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

In this study we used two different approaches to predict value of SASX-10. One approach was employed using explanatory variables in multiple regression analysis. Second approach was employed using principal component scores in multiple regression analysis. As it can be seen from Panels A-E, 81.10% of variation in SASX-10 can be explained by explanatory variables (Panel A.: Model Forecast 1), 62.8% of variation in SASX-10 can be explained by the first two PCAS (Panel B.: Model Forecast 2), 79.7% of variation in SASX-10 can be explained by the PCAS2-6 and PCAS8 (Panel C.: Model Forecast 3) and 81.10% of variation in SASX-10 can be explained by all PCASs (Panel D.: Model Forecast 4).

For the Forecasts 1-4 predicted SASX-10 values were obtained for the following models:

Model Forecast 1:

$$SASX10_t = \begin{bmatrix} -1429.36 + 0.578 BIRS_{t-1} - 0.096 CROBX10_{t-1} + \\ +0.364 SASX10_{t-1} - 0.137 SBITOP_{t-1} + \\ +0.052 ATX_{t-1} + 0.135 M1_{t-1} - 2.588 CPI_{t-1} - \\ -0.006 FTSEI_{t-1} + 4029.244 HRK_{t-1} \end{bmatrix}$$

Model Forecast 2:

$$SASX10_t = 828.604 + 7.606 PCS_1 + 107.023 PCS_2$$

Model Forecast 3:

$$SASX10_t = \begin{bmatrix} 828.604 + 107.023 PCS_2 + 24.925 PCS_3 - \\ -36.881 PCS_4 + 28.635 PCS_5 + \\ +13.454 PCS_6 - 12.370 PCS_8 \end{bmatrix}$$

Model Forecast 4:

$$SASX10_t = \begin{bmatrix} 828.604 + 7.606 PCS_1 + 107.023 PCS_2 + \\ +24.925 PCS_3 - 36.881 PCS_4 + \\ +28.635 PCS_5 + 13.454 PCS_6 + 9.595 PCS_7 - \\ -12.370 PCS_8 - 10.781 PCS_9 \end{bmatrix}$$

In Panel E we forecast the SASX-10 Index closed price for the period 01/12/2014 through 31/12/2014 by four models. We compare loss function and the loss function for the model Forecast 1 which explained by explanatory variables have minimum of all MSE, MAE and MAPE. Figure 1 displays the SASX-10 Index closed prices and four models are used for forecast.

Panel A
Multiple Regression Model Based on Explanatory Variables (Forecast 1)

Model	b	St. Error	*t*	Sig.
(Const.)	-1429.36	509.368	-2.806	0.005
BIRS$_{t-1}$	0.578	0.043	13.601	0.000
CROBX10$_{t-1}$	-0.096	0.036	-2.696	0.007
SASX-10$_{t-1}$	0.364	0.032	11.422	0.000
SBITOP$_{t-1}$	-0.137	0.037	-3.734	0.000
ATX$_{t-1}$	0.052	0.013	3.998	0.000
M1$_{t-1}$	0.135	0.016	8.511	0.000
CPI$_{t-1}$	2.588	2.540	-1.019	0.039
FTSEI$_{t-1}$	-0.006	0.002	-2.871	0.004
HRK$_{t-1}$	4029.244	1192.287	3.379	0.001
RMSE=59.110		R^2=0.811	DW=2.148	

Panel B
Multiple Regression Model Based on First Two PCAS

Model	b	St. Error	t	Sig.
(Const.)	828.604	2.664	311.059	0.000
PCAS1	7.606	2.665	2.854	0.004
PCAS2	107.023	2.665	40.156	0.000
RMSE=82.578		R^2=0.628	DW=1.565	

Panel C
Multiple Regression Model Based on Correlation PCAS

Model	b	St. Error	t	Sig.
(Const.)	828.604	1.976	419.417	0.000
PCAS2	107.023	1.977	54.144	0.000
PCAS3	24.925	1.977	12.610	0.000
PCAS4	-36.881	1.977	-18.659	0.000
PCAS5	28.635	1.977	14.487	0.000
PCAS6	13.454	1.977	6.806	0.000
PCAS8	-12.370	1.977	-6.258	0.000
RMSE=61.244		R^2=0.797	DW=2.407	

Panel D
Multiple Regression Model Based on All PCAS

Model	b	St. Error	*t*	Sig.
(Const.)	828.604	1.907	434.559	0.000
PCAS1	7.606	1.908	3.987	0.000

To be continued

Continued

Model	b	St. Error	*t*	Sig.
PCAS2	107.023	1.908	56.099	0.000
PCAS3	24.925	1.908	13.065	0.000
PCAS4	-36.881	1.908	-19.332	0.000
PCAS5	28.635	1.908	15.010	0.000
PCAS6	13.454	1.908	7.052	0.000
PCAS7	9.595	1.908	5.030	0.000
PCAS8	-12.370	1.908	-6.484	0.000
PCAS9	-10.781	1.908	-5.651	0.000
RMSE=59.110		R^2=0.811	DW=2.148	

Panel E
Loss Function for a Comparison of Out of Sample SASX-10 Index Closed Prices for the Period 01/12/2014 Through 31/12/2014

Model	RMSE	MAE	MAPE
Forecast 1	61.78	6.99	1.74
Forecast 2	114.67	9.97	3.41
Forecast 3	93.37	8.81	2.71
Forecast 4	81.00	8.24	2.32

Graph of SASX-10 Index closed prices and Forecast SASX-10 with MLR for the period 01/12/2014 through 31/12/2014 given on Figure 1.

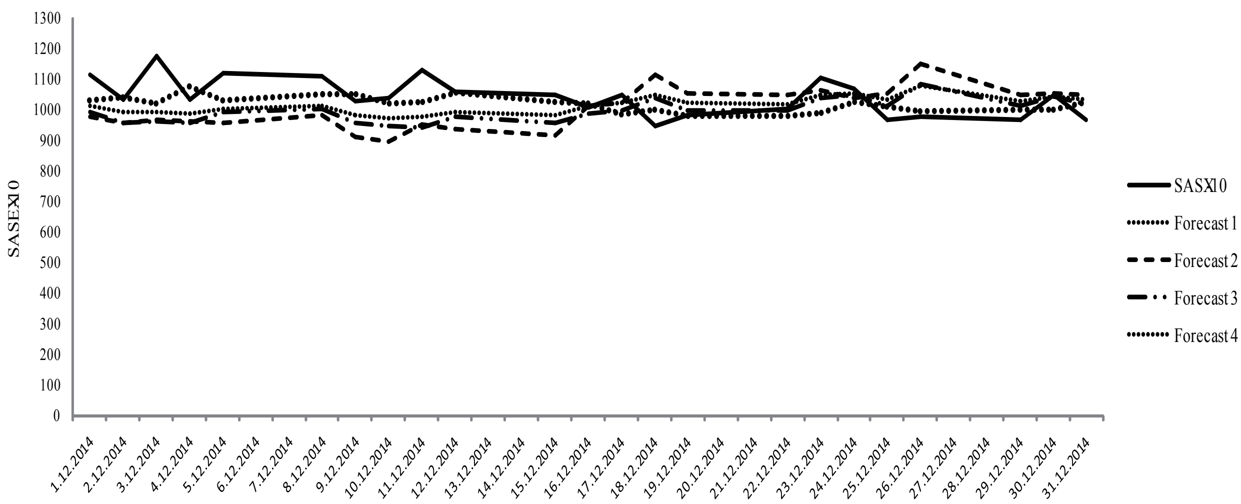

Figure 1
Graph of SASX-10 Index Closed Prices and Forecast SASX-10

Figure 1: Graph of SASX-10 Index closed prices, Forecast SASX-10 with MLR based on explanatory variables (Forecast 1), first two PCASs (Forecast 2), six most closely correlated PCASs (Forecast 3) and all PCASs (Forecast 4) for the period 01/12/2014 through 31/12/2014.

CONCLUSION

Earlier studies showed the relationship between Stock market Index and various factors i.e. other stock market indices, foreign exchange rates, gold prices, minimum loan rates, money supply, interest rates, inflation, producer price index, industrial production index, consumer price indices and many others. Results of this study showed that regression models estimating SASX-10 Index can be used using other stock market indices, foreign exchange rates, money supply and consumer price index. Initial regression model covered 17 macroeconomic factors as independent variables, but we chosen in our model 9 statistically significant factors as independent variables ($p < 0.05$).

In model Forecast 1, when the raw data of the study were used for the regression analysis for forecast SASX-10 Index, a multicolinearity problem existed (VIF > 5.0) and some indirect effects on the SASX-10 Index become inevitable. In this case, we used the principal component analysis to both reduce the number of variables and to get rid of the multicolinearity problem. When the PCA was completed on the explanatory variables and the principal component scores (PCASs) were included in the multiple regression analysis as predictor variables instead of original predictor values, that problem diminished.

Results of PCA showed that for Bartlett's sphericity test and Kaiser's measure of sampling adequacy indicated that sample sizes are enough to apply the PCA.

According to the results of nine principal components there are two principal components with eigenvalue greater than 1 which were selected for multiple regression analysis (Forecast 2). If only the first two PCASs are selected, this can explain 75.39% of the total variation. According to the results of correlation matrix of SASX-10 and PCASs there are six principal components with coefficient correlations not zero which were selected for multiple regression analysis (Forecast 3). Finally, we selected all PCASs to forecast SASX-10 for multiple regression analysis (Forecast 4).

In this study, three approaches were employed in using principal component scores in multiple regression analysis. As it can be seen 81.10% of variation in SASX-10 can be explained by explanatory variables, 62.8% of variation in SASX-10 can be explained by the first two PCASs, 79.7% of variation in SASX-10 can be explained by the PCAS2-6 and PCAS8 and 81.10% of variation in SASX-10 can be explained by all PCASs. When we compare loss function, the model Forecast 1 based on explanatory variables has a minimum of all MSE, MAE and MAPE.

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