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A study on prediction model estimation of financial assets (exchange rate, KOSPI index, interest rate)

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ABSTRACT

In this study, financial assets such as exchange rate, KOSPI index, and interest rate (3-year government bond) were predicted using the vector error correction model used in various financial markets. For this purpose, time series data from February 2000 to January 2021 provided by the Bank of Korea were used. To estimate the prediction model, the stability of the time series variables was confirmed by the ADF test, the causal relationship between the time series variables by the Granger causality test, and the cointegration relationship between the time series variables by the cointegration test. In addition, the prediction model was estimated by identifying the model based on the minimum information criterion based on AICC statistics, and the validity of the model was confirmed by the significance test of the cross-correlation matrix and the multivariate Portmanteau test. As the result of forecasting with the estimated prediction model, the exchange rate was predicted to rise steadily, the KOSPI index was predicted to fall, but remain in the mid-3,000 range, and the interest rate (3-year government bond) was predicted to decline.

1. Introduction

The world economy is rebounding rapidly as the impact of the corona shock was deep. The world economy has rebounded from the second half of 2020, which experienced a sharp recession in the second quarter of 2020 and even already recovered in the first quarter of 2021 as much as the production level before the corona shock. The world overcame the fear of a Great Depression-level crisis as large-scale stimulus measures and quantitative easing prevented the collapse of the financial system, and online consumption replaced that of face-to-face. Meanwhile, in the first half of 2021, the domestic economy is showing a solid recovery trend as export growth is solid thanks to the global economic improvement, and facility investment expands due to the boom in semiconductors. Meanwhile, in the first half of 2021, the domestic economy is showing a solid recovery trend as export growth is solid thanks to the global economic improvement, and facility investment expands due to the boom in semiconductors. In the second half of the year, the domestic economy is expected to show a growth rate exceeding 4% (3.9% per annum) as exports continue to increase and the recovery of domestic demand improves. In particular, consumption growth is expanding on the back of accelerated vaccination, easing of quarantine measures, and delayed demand, and construction investment is highly likely to show signs of recovery given improvement in leading indicators and policy factors. Thus, in the second half of the year, the contribution of domestic demand to growth is expected to exceed that of exports, driving economic growth. Inflationary pressure will increase this year due to the rapid recovery of global demand and supply disruptions, but the trend of global inflation will gradually ease as demand growth slows and supply capacity is filled after next year.

Central banks in developed countries will continue their monetary easing stance for the time being, and in the case of the US, quantitative easing is expected to decrease in the second half of next year, and interest rates are expected to rise in the second half of 2023. In the domestic financial market, stock prices are highly volatile due to rising long-term interest rates in major countries, while the exchange rate is expected to rise due to the strong global dollar, and the interest rate on government bonds is expected to rise mainly in mid- to long-term bonds due to concerns about rising global interest rates

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and the burden of supply and demand for government bonds.

In the second half of the year, market interest rates are expected to continue rising, mainly on short-term bonds, given the possibility of a base rate hike focused on concerns about the domestic economic recovery and financial imbalance amid the Fed's full-fledged discussion of tapering. Upward pressure on the won/dollar exchange rate, despite sound internal fundamentals, is likely to gradually emerge due to the Fed's discussion on the normalization of monetary policy and the resulting strong dollar. Korea's financial market has been greatly affected by the inflow and outflow of foreign capital since its opening. When foreign capital flows into the stock market, it affects stock yield and exchange rate, and when it moves from the stock market to the bond market, the bond yield and stock yield are affected. As such, the correlation between financial markets has become closer, and uncertainty in one market can directly affect the stability of another financial market, thereby causing uncertainty in the overall financial market. Existing domestic and foreign studies on financial assets such as exchange rates, stock indices, and interest rates are as follows. Fleming et al. (1998) analyzed the correlation between stocks, bonds, and interest rates using data from January 1983 to August 1995, and presented that the three variables were highly correlated. Darbar and Deb (1999) analyzed the correlation between stock prices, interest rates, exchange rates, and raw material prices in the United States from March 1984 to December 1993 and suggested that volatility transitions between markets existed. Baig and Goldfain (1998) examined the relationship between the call rate and the won/dollar rate in four Asian countries that suffered from the foreign exchange crisis from 1997 to May 1998 and found that a positive relationship existed between the call rate and the exchange rate. Park and An (2009) analyzed the factors using the VAR model to investigate the relationship between the long-term rent price and the interest rate. Kim and Park (2012) analyzed the correlation between mortgage loans and macroeconomics (including interest rates) and said that there is a concern that mortgage loans affect interest rates, leading to aggravation of financial costs and delinquency. Lee and Chun (2016) attempted to predict the KOSPI index using the DL-GARCH model that integrated the GARCH model and deep learning and Li et al. (2014) predicted the stock market with SVR along with stock-related social data. It is not easy to accurately predict financial time series data because the trend and volatility are not constant compared to other time series data. In this study, however, using the financial time series data of exchange rate, stock index (KOSPI index), and interest rate (3-year government bond), the vector error correction model, which is used as an empirical analysis method in various financial markets, is applied to estimate and test the prediction model.

2. Theoretical background

The vector error correction model is a model that can be applied to variables having a cointegration relationship, in other words when the linear combination of individually nonstationary time series variables becomes a stable process. In particular, the vector error correction model is widely used in various financial markets because it is useful for simultaneously understanding the long-run equilibrium relationship and the short-run dynamic relationship of variables. The vector error correction model is as follows (Engle and Granger, 1987).

$$\nabla Z_t = \delta(t) + \Pi Z_{t-1} + \sum_{i=1}^{p-1} \Phi_i \nabla Z_{t-i} + \varepsilon_t \quad (1)$$

where, $\nabla Z_t = Z_t - Z_{t-1}$, $\Pi = \alpha\beta'$, α and β are k × r matrices respectively, Φ_i is k × k matrix, and $\delta(t) = \delta_0 + \delta_1 t$ which denotes the deterministic trend, where δ_0 and δ_1 are k × 1 constant vectors.

The cointegration test is a test that determines the number of columns that are linearly independent of $\Pi = \alpha\beta'$, that is, the value of the cointegration coefficient r. When constructing the VECM (p) model from the VAR(p) model, various considerations can be made depending on the decisive factors included in the model. The cointegration test used in this study, where δ_0 is not restrictive and $\delta_1 = 0$, is as follows (Harbo et al., 1998; Johansen, 1995).

$$Z_t = \delta_0 + \alpha\beta' Z_{t-1} + \sum_{i=1}^{p-1} \Phi_i \nabla Z_{t-i} + \varepsilon_t \quad (2)$$

The hypotheses for the cointegration test are as follows.

$$H_0: r = 1 \quad vs. \quad H_1: r > 1 \quad (3)$$

where, r=rank(Π) is the number of cointegration relations.

The Granger causality test is a test to determine whether one variable can be used as a predictor in predicting another variable. In terms of the stationary time series Z_t and X_t, using the following two autoregressive models, it is defined as follows (Granger, 1980).

$$\begin{aligned} Z_t &= \sum_{i=1}^{m} \alpha_i Z_{t-i} + \sum_{i=1}^{m} \beta_i X_{t-i} + \varepsilon_{1t} \\ X_t &= \sum_{i=1}^{m} \gamma_i X_{t-i} + \sum_{i=1}^{m} \delta_i Z_{t-i} + \varepsilon_{2t} \end{aligned} \quad (4)$$

where, The error terms $\varepsilon_{1t}, \varepsilon_{2t}$ are independent of each other and assume equal variances

The multivariate Portmanteau test used in this study is defined as follows, a statistic that tests whether correlation remains in the residuals after fitting a vector time series model (Hosking, 1980).

$$Q(k) = n^2 \sum_{k=1}^{K} (n-k)^{-1} tr\{\widehat{\rho_k}(e) \widehat{\sum_\varepsilon^{-1}} [\widehat{\rho_k}(e)]'\} \quad (5)$$

where, $\widehat{\rho_k}(e)$ is the k lag sample cross autocorrelation matrix of the residual time series vector e_t, $\widehat{\sum_\varepsilon}$ is the estimator of $\sum_\varepsilon$, which is the covariance matrix of the multivariate white noise process, n is the size of the time series data, k is the appropriate lag, l is the number of univariate time series constituting the multivariate time series.

3. Results

The data used in this study are data from February 2000 to January 2021 provided by the Bank of Korea Economic Statistics System, and time series data of three financial assets were used: exchange rate, KOSPI index, and interest rate (3-year government bond). In other words, the vector time series data $Z_t(z_{1,t}, z_{2,t}, z_{3,t})$ composed of $Z_{1,t} = Exchange\ Rate$, $Z_{2,t} = KOSPI\ Index$, and $Z_{3,t} = Interest\ Rate$(3-year government bond) was predicted by applying the vector error correction model.

The trend of the exchange rate decreased in 2002, rose in 2008, fell again in 2009, and has been continuing stable since 2010. The trend of the KOSPI index has continued to rise while repeating upward and downward trends from February 2000 to January 2021. Contrary to the KOSPI index, the trend interest rate shows a downward trend while repeating upward and downward movements. Fig. 1 shows the exchange rate, KOSPI index, and Interest rate trend.

Table 1 shows the results of the ADF-unit root test of the original variable and the first-order difference time series variables to test the stability of the variables used in this study. Since the p-values of the Tau statistics of the original time series variables of the exchange rate, KOSPI index, and interest rates are all greater than the significance level of 0.05, it is confirmed that the time series is a non-stationary time series with a unit root. And as a result of testing the first-order difference variables, it is confirmed that the p-values of the Tau statistics are all less than the significance level of 0.05, so there is no unit root. Therefore, it can be seen that each time series variable follows $I(1)$.

Table 2 shows the results of the Granger causality test for the first-order difference variables of the exchange rate, KOSPI, and interest rates. According to Table 2, for Test1, Test2, and Test3, since the p-values of the chi-square statistics are all less than the significance level of 0.05, it is found that each variable has a two-way linear dependency relationship (causal relationship) that is affected by the past values of itself and the other two time series variables, respectively.

Table 1: Unit root test

Original Variable	Type	Tau	Pr<Tau
	Zero Mean	-0.23	0.6037
Exchange_Rate	Single Mean	-2.49	0.1197
	Trend	-2.50	0.3277
	Zero Mean	1.43	0.9619
KOSPI_Index	Single Mean	-0.25	0.9283
	Trend	-2.76	0.2142
	Zero Mean	-1.53	0.1105
Interest_Rate	Single Mean	-0.87	0.3072
	Trend	-0.72	0.3845
First Difference Variable	Type	Tau	Pr<Tau
	Zero Mean	-8.12	<.0001
Exchange_Rate	Single Mean	-8.10	<.0001
	Trend	-8.09	<.0001
	Zero Mean	-7.08	<.0001
KOSPI_Index	Single Mean	-7.26	<.0001
	Trend	-7.27	<.0001
	Zero Mean	-8.54	<.0001
Interest_Rate	Single Mean	-8.78	<.0001
	Trend	<.0001	<.0001

Table 2: Granger causality test

Test	DF	Chi-Square	Pr>ChiSq
1	6	20.50	0.0023
2	6	14.71	0.0226
3	6	24.59	0.0004

Since exchange rate, KOSPI index, and interest rates shown in the unit root test follow the process (1), we tested whether cointegration relationships exist between unstable time series variables. Table 3 shows the results of the cointegration test using the Johansen trace statistic. According to Table 3, since the trace test statistic of 11.6148 for $H_0: m = 1.\ vs.\ H_1: m > 1$ is smaller than the critical value of 15.34 at the significance level of 5%, H_0 is adopted. Therefore, since it is $\mathrm{m} = \mathrm{rank}(\Pi) = 1$, it shows that a cointegration relationship exists between the three variables. This indicates that there is a significant long-term relationship between exchange rates, the KOSPI index, and interest rates.

Table 3: Cointegration test

H0: Rank=r	H1: Rank>r	Eigenvalue	Trace	5% Critical Value	Drift in ECM	Drift in Process
0	0	0.0679	29.1156	29.38	Constant	Linear
1	1	0.0448	11.6148	15.34		
2	2	0.0009	0.2120	3.84		

Therefore, the estimation of a long-term parameter (β) and error correction coefficient (α) are shown in Table 4, and the cointegration equation is as follows:

$$W_t = \beta' Z_t = Z_{1,t} - 27.90450 Z_{2,t} - 11833.31650 Z_{3,t} \quad (6)$$

For model identification, a minimum information criterion based on the corrected Akaike information criterion (AICC) statistics were used, and the results are shown in Table 5. In Table 5, the model with the smallest AICC value is the VECM (3) model with AICC=11.517664 and p=3 as follows:

$$\nabla Z_t = \delta_0 + \alpha\beta' Z_{t-1} + \Phi_1 \nabla Z_{t-1} + \Phi_2 \nabla Z_{t-2} + \varepsilon_t \quad (7)$$

And the parameter estimation results are presented in Table 6. The prediction model estimated using Table 4 and Table 6 is as follows:

Table 4: Estimation of long-term parameter (β) and error correction coefficient (α)

β and α	Variable	1	2	3
β	Exchange_ rate	1.00000	1.00000	1.00000
	KOSPI_ Index	-27.90450	0.05849	0.39722
	Interest_ Rate	-11833.31650	38.62710	32.55993
α	Exchange_ Rate	-0.00033	-0.03349	-0.00142
	KOSPI_ Index	0.00127	0.01205	-0.00616
	Interest_ Rate	0.00000	-0.00032	0.00001

$$\nabla Z_t = \begin{bmatrix} -29.292 \\ 118.231 \\ 0.140 \end{bmatrix} + \begin{bmatrix} -0.000 & -0.033 \\ 0.001 & 0.012 \\ 0.000 & -0.000 \end{bmatrix} \begin{bmatrix} 1 & -27.904 & -11833.316 \\ 1 & 0.058 & 38.627 \end{bmatrix} \begin{bmatrix} Z_{1,t-1} \\ Z_{2,t-2} \\ Z_{3,t-3} \end{bmatrix} + \begin{bmatrix} 0.387 & -0.015 & -4.417 \\ 0.121 & 0.296 & 4.147 \\ -0.000 & 0.000 & 0.348 \end{bmatrix} \nabla Z_{t-1} + \begin{bmatrix} -0.268 & -0.029 & -23.796 \\ -0.071 & -0.103 & 40.064 \\ -0.000 & 0.000 & -0.138 \end{bmatrix} \nabla Z_{t-2} \quad (8)$$

Table 5: Model identification

Minimum Information Criterion Based on AICC	
Lag	MA0
AR0	22.018690
AR1	11.923704
AR2	11.616459
AR3	11.517664

In schematic representation, which is the result of testing the significance of the cross-correlation matrix (CCM) for the residual time series vector obtained after fitting the estimated prediction model, it was found that there was no auto-correlation and cross-correlation at time lag 1 or more. And as shown in the multivariate Portmanteau test result (Table 7), the p values of the chi-square statistics are larger than the significance level ($\alpha = 0.05$). This means that auto-correlation and cross-correlation no longer exist in the residual time series vector.

Fig. 1: Exchange rate, KOSPI index, and interest rate trend

Table 6: Parameter estimation

Equation	Parameter	Estimate	Variable
D_Exchange_ Rate	CONST1	-29.29214	1
	AR1_1_1	-0.00033	Exchange_Rate(t-1)
	AR1_1_2	0.00927	KOSPI_Index(t-1)
	AR1_1_3	3.93247	Interest_Rate(t-1)
	AR2_1_1	0.38745	D_Exchange_Rate(t-1)
	AR2_1_2	-0.01508	D_KOSPI_Index(t-1)
	AR2_1_3	-4.41700	D_Interest_Rate(t-1)
	AR3_1_1	-0.26844	D_Exchange_Rate(t-2)
	AR3_1_2	-0.02963	D_KOSPI_Index(t-2)
	AR3_1_3	-23.79609	D_Interest_Rate(t-2)
D_KOSPI_ Index	CONST2	118.23172	1
	AR1_2_1	0.00127	Exchange_Rate(t-1)
	AR1_2_2	-0.03530	KOSPI_Index(t-1)
	AR1_2_3	-14.96930	Interest_Rate(t-1)
	AR2_2_1	0.12137	D_Exchange_Rate(t-1)
	AR2_2_2	0.29645	D_KOSPI_Index(t-1)
	AR2_2_3	4.14761	D_Interest_Rate(t-1)
	AR3_2_1	-0.07149	D_Exchange_Rate(t-2)
	AR3_2_2	-0.10398	D_KOSPI_Index(t-2)
	AR3_2_3	40.06480	D_Interest_Rate(t-2)
D_Interest_ Rate	CONST3	0.14074	1
	AR1_3_1	0.00000	Exchange_Rate(t-1)
	AR1_3_2	-0.00006	KOSPI_Index(t-1)
	AR1_3_3	-0.02344	Interest_Rate(t-1)
	AR2_3_1	-0.00020	D_Exchange_Rate(t-1)
	AR2_3_2	0.00032	D_KOSPI_Index(t-1)
	AR2_3_3	0.34832	D_Interest_Rate(t-1)
	AR3_3_1	-0.00086	D_Exchange_Rate(t-2)
	AR3_3_2	0.00039	D_KOSPI_Index(t-2)
	AR3_3_3	-0.13803	D_Interest_Rate(t-2)

Therefore, it can be said that the VECM (3) model presented in this study is suitable. The forecast values after 1-lag and multi-lag of the fitted period, and the prediction interval under the 95% confidence level of the exchange rate, KOSPI index, and interest rates are presented in Fig. 2, Fig. 3, and

Fig. 4, respectively. And, the predicted values for 12 months are presented in detail (Table 8).

Table 7: Multivariate portmanteau test for the residual time series vector

Up To Lag	Chi-Square	Pr > ChiSq
4	20.30	0.2431
5	27.38	0.3125
6	42.67	0.1614
7	54.78	0.1411
8	60.25	0.1672
9	66.74	0.2523
10	78.42	0.2416

According to Fig. 2, the exchange rate is expected to rise steadily. According to Fig. 3 and Table 8, the KOSPI index is expected to decline steadily but maintain the mid-3,000 level. And according to Fig. 4, the interest rate is expected to continue to decline steadily.

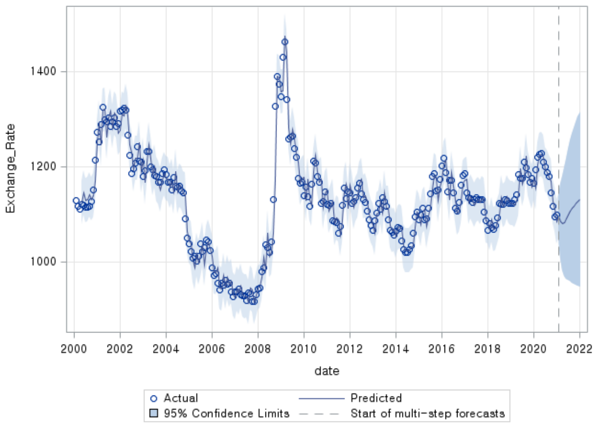

Fig. 2: Exchange rate prediction by VECM (3) model

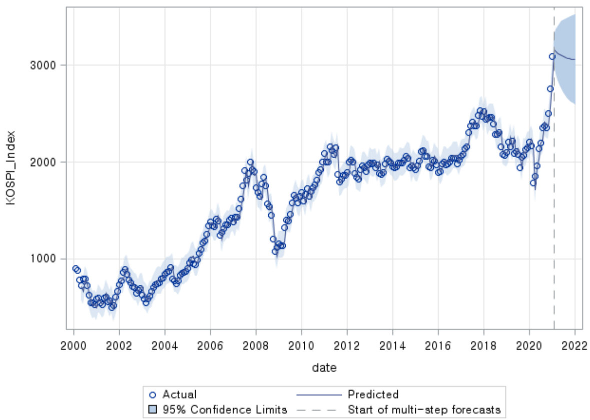

Fig. 3: KOSPI index prediction by VECM (3) model

4. Conclusion

The time series variables used in this study are the won-dollar exchange rate representing the domestic foreign exchange market, the KOSPI index representing the stock market, and the 3-year government bond yield representing the mid- to long-term interest rate of the bond market. The vector error correction model was applied as a research model, the prediction model was estimated by applying the Granger causality test, the cointegration test, and the multivariate Portmanteau test, and then the prediction values were presented after testing the goodness of fit of the model.

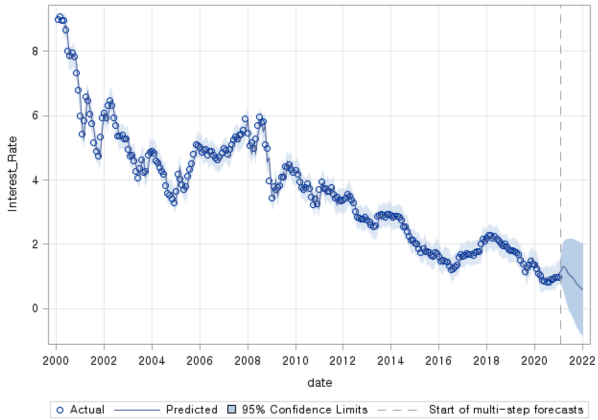

Fig. 4: Interest rate (3-year government bond) prediction by VECM (3) model

Table 8: 12-month forecasts

Time	Exchange rate Forecast	KOSPI index Forecast	Interest rate Forecast
FEB 21	1094.41	3160.00	1.14704
MAR 21	1084.91	3137.57	1.29739
APR 21	1080.09	3119.57	1.28969
MAY 21	1082.51	3112.83	1.20116
JUN 21	1089.89	3104.40	1.10859
JUL 21	1098.44	3092.83	1.02499
AUG 21	1105.82	3081.83	0.94154
SEP 21	1111.87	3073.11	0.85770
OCT 21	1117.26	3066.51	0.77836
NOV 21	1122.26	3061.74	0.70572
DEC 21	1126.73	3058.76	0.63882
JAN 22	1130.54	3057.49	0.57645

The estimated vector error correction model has theoretically secured the validity of the model, and the prediction results of exchange rates, KOSPI, and interest rates are as follows. The exchange rate is expected to rise steadily, the KOSPI index is expected to decline steadily, but remain in the mid-3,000 range, and the interest rate is expected to continue to decline steadily. It appears that the causal relationship between major macroeconomic indicators, such as exchange rates, stock indices, and interest rates presented in this study will be of great help to not only government policymakers, but also investors participating in the financial and capital markets to establish investment strategies and risk management strategies. The ability to predict the price change of financial assets in the financial market is expected to play a very important role in establishing asset management strategies in the underlying asset and derivatives markets. In addition, the prediction model proposed in this study can be used as a basic tool to predict macroeconomic indicators, and it is judged that it can provide useful information for real economy forecasts and monetary policy establishment of governments and financial institutions.

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Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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