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A Study on the Estimation of Interest Rate Prediction Model Using VECM

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Abstract
This paper estimates an interest rate prediction model using monthly data on the New Wage Base (NWB) and Balance Standard (BS) of mortgage rate, and KORIBOR provided by the Bank of Korea's Economic Statistics System and the Korea Federation of Banks. The vector error correction (VECM) model was used as a research model, and the model was set up and estimated by performing the Granger Causality Test and Cointegration Test. The Multivariate Portmanteau Test was performed to test the goodness of fit of the model. The causal test results show that there is a bidirectional linear dependency in which each time series variable is affected by the past values of itself and two other time series variables. The model was set up as a vector autoregressive (VAR) model using the Schwarz Bayesian Criterion (SBC) statistic based on the Minimum Information Criterion. Then, as a result of cointegration test using trace statistics, a model with a constant intercept in the error correction term was selected. The prediction model was estimated using the selected model, and as a result of testing the goodness of fit of the prediction model with the multivariate Portmanteau test, the cross-correlation no longer existed because the P-values of the chi-square statistics were all greater than the significance level of 0.05 until the maximum delay of 3 to 12 lags. These results imply that the interest rate prediction model presented in this paper is suitable and, therefore, the predictive value of interest rate could be presented using the model. The results of this paper can be very important for providing useful information for forecasting future real economy and analyzing the effectiveness of monetary policy of government and financialinstitutions.

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1. INTRODUCTION

As the unrest in emerging economies stemming from the ongoing US-China trade disputes and concerns about the hard landing of the Chinese economy overlaps with the effect of US interest rate hikes and develops into a compound shock that affects the global market as a whole, the Korean economy is also expected to enter a low-growth phase where exports, investments, and consumption all decrease. Following the US benchmark rate hike, domestic market interest rate hike is also expected to begin soon as banks will tighten their screening for new housing loans starting next year. In particular, COFIX (Cost of Funds Index), KORIBOR (Korea Inter-bank Offered Rates), and bond yields, which are the bases for commercial banks' mortgage rate decisions, have recently been rising at the same time. KORIBOR (3M), which climbed around 1.55% in October, started to soar in November, and peaked at 1.75% on the first day of

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December. Afterwards, KORIBOR lowered a little, but started rising again by 0.01% point to 1.67% since the US rate hike was decided. Mortgage rates rose gradually to 3.27% in 2017 and 3.45% in August 2018, since falling to 2.91% in 2016. Recently, market interest rate hikes have been picking up. Commercial banks raised their mortgage rates by 0.05~0.11% due to higher market rates, and some banks raised their highest interest rates to 5%. If this persists, mortgage rates are expected to exceed 5% by the end of this year or early next year. The rise in mortgage rates due to the rise in market interest rates is expected to have a major impact on the possibility of insolvent household debt, which is at an all-time high. The ordinary people and self-employed, who are vulnerable to repaying loans due to higher loan interest rates, will likely face a worsening economy by repaying household debts with heavier interest burden and reducing private consumption. In addition, foreign investment funds holding up the domestic stock market are highly likely to escape, and thus, the exports of domestic companies, which are doing well lonely, will be hurt as the foreign exchange market fluctuates. Therefore, the research model on the prediction of interest rates has been actively researched at home and abroad. Lee (2008) proposed that the interest rate rise leads to a decrease in housing prices and a decrease in consumption and production, using the structural vector autoregressive (SVAR) model [1]. Park and An (2009) analyzed the factors using the VAR model to investigate the relationship between the charter price and the interest rate [2]. Kim and Park (2012) analyzed the relationship between mortgage loans and macroeconomics (including interest rates) and said that mortgage loans could affect interest rates and led to financial costs and delinquency [3]. Kim and Kim (2015) analyzed that the decline in interest rates led to the increase in mortgage loans [4]. Ku (2010) studied the prospect of COFIX interest rates and the need for risk management [5]. Hamilton and Kim (2000) estimated the effect on the economic growth rate by dividing the term spread into changes in future short-term rates and changes in period premiums in the United States. He argued for higher predictive power [6]. Hamilton and Kim (2000) estimated the effect on economic growth rates by dividing the term spread into changes in future short-term interest rates and changes in term premiums in the United States, and argued that changes in future short-term interest rates would be more predictive than term premium, in terms of GDP growth rate [6]. Wright (2006) suggested that forecasting power was improved when the Federal Reserve nominal interest rate was added as an explanatory variable when estimating economic forecasting power using term spread [7]. Andrew, Monika, and Min (2006) suggested that short-term interest rates were better at predicting GDP growth rate than term spreads [8]. Kaminska, Meldrum, and Smith (2013) estimated zero-coupon forward rates curves for the United States, the United Kingdom, and Germany [9]. Predicting interest rates is difficult because it is known that volatility is not constant and trends are not easy to identify compared to other time series data. In this study, we predicted the interest rates using the three-dimensional vector error correction model with data on the new wage base and balance standard of mortgage rate, and KORIBOR. This paper is composed of Chapter II research model, Chapter III research results, and Chapter IV conclusions.

2. RESEARCH MODEL

2.1 Vector Error Correction Model

The Vector Error Correction Model (VECM) is a useful model for analyzing relationships between data when nonstationary time series data are co-integrated. Linear combinations of nonstationary time series variables are usually nonstationary. If, however, the linear combination satisfies the stationarity, it is not desirable to differentiate all the time series

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variables because it leads to loss of information. In this case, the vector error correction model defines the cointegration relationship between time series variables and uses the error correction model to explain the relationships between the variables. If there are $r(\leq k)$ linear combination that satisfies the stationarity between k time series variables, it is called a cointegration rank. The p-order vector error correction model, VECM(p), is defined as follows [10].

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

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

2.2Cointegration Test

If $k \times k$ matrix $\Pi = \alpha\beta'$ is a full rank matrix, that is, $\text{rank}(\Pi) = k$, then all time series of Z_t are $I(0)$ stationary time series. If $\text{rank}(\Pi) = 0$ means $\Pi = 0$, meaning that no cointegration vector exists, then all time series $I(1)$ of Z_t are nonstationary time series and are predicted by applying the VAR(p) model to the differenced series. However, if $0 < rank(\Pi) = r < k$, there exist r stationary, independent linear equations, which are predicted by the VECM(p) model. The cointegration test determines the number of columns that are independent of $\Pi = \alpha\beta'$, that is, the value of the cointegration coefficient r. The hypothesis setting for this test is as follows.

$$H_0: r = 1 \quad \text{vs.} \quad H_1: r > 1 \quad (2)$$

Where, $r = \text{rank}(\Pi)$ is the number of cointegration relations.

When constructing a VECM(p) model from a VAR(p) model, there are many considerations depending on the determinants included in the model. The cointegration test used in this study has a constant intercept in the error correction term [11], [12].

$$\nabla Z_t = \alpha(\beta', \beta_0)(Z'_{t-1}, 1)' + \sum_{i=1}^{p-1} \Phi_i \nabla Z_{t-i} + \varepsilon_t \quad (3)$$

The trace statistic for testing the null hypothesis that r cointegration vectors exist is as follows.

$$\lambda_{trace} = -n \sum_{i=r+1}^{k} \log(1 - \lambda_i) \quad (4)$$

Where, n is the number of observations and λ_i is the eigenvalue.

2.3 Granger Causality Test

The Granger causality test is a test for determining whether one variable can be used as a predictor variable in predicting another. The stationary time series Z_t and X_t are defined using two autoregressive models as follows [13].

$$Z_t = \sum_{i=1}^{m} \alpha_i Z_{t-i} + \sum_{i=1}^{m} \beta_i X_{t-i} + \varepsilon_{1t} \quad (5)$$

$$Z_t = \sum_{i=1}^{m} \gamma_i Z_{t-i} + \sum_{i=1}^{m} \delta_i X_{t-i} + \varepsilon_{2t} \quad (6)$$

Where, error term $\varepsilon_{1t}, \varepsilon_{2t}$ are independent of each other and assume equal variances.

In predicting Z in (Equation 5), there is a causal relationship $Z \leftarrow X$ if the prediction power is higher when past values of X are used together than past values of Z are only. Likewise, in predicting X in (Equation 6), there is a causal relationship $X \leftarrow Z$ if the prediction power is higher when past values of Z are used together than past values of X are used only.

The Granger causality test for (Equation 5) performs the hypothesis test on (Equation 7), and the Granger causality test for (Equation 6) performs the hypothesis test on (Equation 8).

$$H_{10}: \beta_i = 0, \text{ for all } (i = 0,1,\cdots,m)$$
$$H_{11}: \beta_i \neq 0, \text{ for at least one } (i = 1,2,\cdots,m) \quad (7)$$

$$H_{20}: \delta_i = 0, \text{ for all } (i = 0,1,\cdots,m)$$
$$H_{21}: \delta_i \neq 0, \text{ for at least one } (i = 1,2,\cdots,m) \quad (8)$$

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2.4 Multivariate Portmanteau Test

The multivariate portmanteau test tests the correlation of residuals after fitting the vector time series model [14].

$$Q(k) = n^2 \sum_{k=1}^{K} (n-k)^{-1} tr\{\hat{\rho}_k(\epsilon)|\hat{\rho}_k(\epsilon)|'\} \approx \chi^2(l^2(K-p-q)) \quad (9)$$

Where, $\hat{\rho}_k(\epsilon)$ is the k -lag sample cross-autocorrelation matrix of the residual time series vector ϵ_t, $\hat{\sum}_\varepsilon$ is the estimator of $\sum_\varepsilon$, the covariance matrix of the multivariate white noise process, nis the size of the time series data, kis the number of univariate time series that make up the multivariate time series.

The hypothesis setting for this test is as follows.

$$H_0: \rho_1(\epsilon) = \rho_2(\epsilon) = \cdots = \rho_K(\epsilon) = 0 \quad (10)$$

H_1: $H_0$is not true

3. RESULT ANALYSIS

3.1 NEB, BS, KORIBOR Interest Rate Changes

The NWB and BS on mortgage rates, and KORIBOR rates are almost same over time (Figure 1).

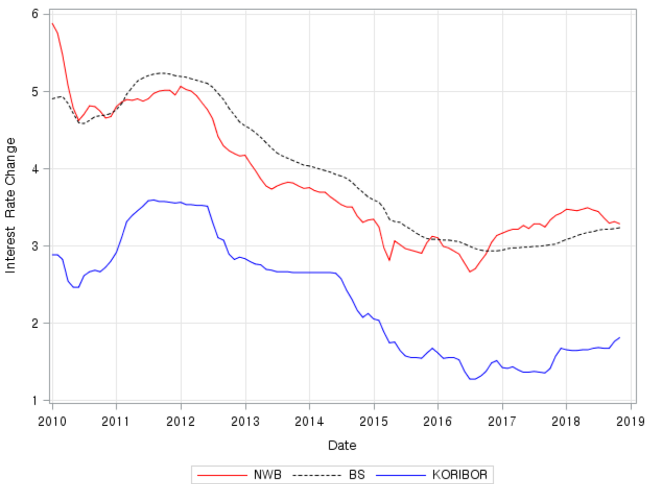

Figure1: NWB, BS, KORIBOP Interest Rate Change

3.2 Unit Root Test

The ADF unit root test was performed to confirm that the NWB, BS, and KORIBOR variables were nonstationary time series. As a result, the p-values of the Tau statistic were all greater than the significance level of 0.05, indicating that unit roots exists (Table 1).

Table 1: Unit Root Test

Augmented Dickey-Fuller Unit Root Tests				
Variable	**Type**	**Tau**	**Pr<Tau**	**Pr>F**
NWB	Zero Mean	-1.74	0.0779	
	Single Mean	-2.29	0.1775	0.1798
	Trend	-2.23	0.4658	0.5033
BS	Zero Mean	-1.37	0.1586	
	Single Mean	-1.30	0.6283	0.6985
	Trend	-1.70	0.7431	0.8389
KORIBOR	Zero Mean	-0.95	0.3009	
	Single Mean	-1.07	0.7268	0.8713
	Trend	-1.76	0.7179	0.8652

In addition, when the same unit root test performed after the first differencing for each time series variable, the p-values of the Tau statistics were all smaller than the significance level of 0.05, indicting that no unit root existed. That is, it can be seen that each time series variable follows I(1) (Table 2).

Table 2: Unit Root Test after First Difference

Augmented Dickey-Fuller Unit Root Tests				
Variable	**Type**	**Tau**	**Pr<Tau**	**Pr>F**
∇NWB	Zero Mean	-5.94	<.0001	
	Single Mean	-6.12	<.0001	0.0010
	Trend	-6.23	<.0001	0.0010

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∇BS	Zero Mean	-3.62	0.0004	
	Single Mean	-3.90	0.0029	0.0010
	Trend	-3.93	0.0142	0.0146
∇KORIBOR	Zero Mean	-5.05	<.0001	
	Single Mean	-5.07	0.0001	0.0010
	Trend	-5.05	0.0004	0.0010

3.3 Granger Causality Test

The Granger causality test for each time series variable after the first differencing showed that the p-values of the chi-square statistic for Test1, Test2, and Test3 were all less than the significance level of 0.05, so that each time series variable had a bidirectional linear dependency that was affected by the past values of itself and two other time series variables respectively (Table 3).

Table 3: Granger Causality Test

Granger-Causality Wald Test			
Test	**DF**	**Chi-Square**	**Pr>ChiSq**
1	4	18.06	0.0012
2	4	45.61	<.0001
3	4	9.55	0.1487

3.4 Model Setup

Some studies have shown that the use of p-2 in the VAR(p) model well describes the dynamic structure of multivariate time series. In this study, however, p was determined by the Schwarz Bayesian Criterion (SBC) statistic based on the Minimum Information Criterion (MINIC). As a result, the VAR(2) model was chosen because it was the smallest with SBC= -19.0521 when p=2 (Table 4).

Table 4:VAR(2) Model

Minimum Information Criterion Based on SBC					
Lag	MA0	MA1	MA2	MA3	MA4
AR 0	-6.3909	-7.0181	-7.1246	-7.2327	-7.3134
AR 1	-17.8325	-18.4572	-18.4837	-18.3557	-18.2869
AR 2	-19.0521	-19.1709	-18.9159	-18.7546	-18.5629
AR 3	-18.8821	-19.0504	-18.7343	-18.5183	-18.2071
AR 4	-18.7206	-18.7664	-18.5032	-18.1837	-18.0261

3.5 Cointegration Test

The result of cointegration test on the case where there was a constant intercept in the error correction term using Johansen's trace statistic (* in Table 5) and on the case where there was a constant intercept in the VECM(p) term and no linear trend (** in Table 5) showed that there existed one cointegration relationship (Table 5). In other words,

Result of (** in Table 5): H_0 was adopted because trace=13.4371<5% Critical Value=15.34 when $H_0: r = 1$ vs. $H_1: r > 1$

Result of (* in Table 5): H_0 was adopted because trace=17.7538<5% Critical Value=19.99 when $H_0: r = 1$ vs. $H_1: r > 1$. Thus, rank=1 [15-17].

Table 5: Cointegration Test

Cointegration Rank Test Using Trace (**)				
H_0: Rank $= r$	H_1: Rank $> r$	Eigenvalue	Trace	5% Critical Value
0	0	0.2051	37.5339	29.38
1	1	0.0966	13.4371	15.34
2	2	0.0261	2.7756	3.84
Cointegration Rank Test Using Trace Under				

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Restriction (*)				
H_0: Rank $= r$	H_1: Rank $> r$	Eigenvalue	Trace	5% Critical Value
0	0	0.2191	43.7226	34.80
1	1	0.0971	17.7538	19.99
2	2	0.0647	7.0235	9.13

And, in the model of (* in Table 5) and (** in Table 5), when rank=1, the p-value of the chi-square statistic is 0.1155, which was greater than the significance level of 0.05. Thus, (* in Table 5) was not rejected. Therefore, we chose $\nabla Z_t = \alpha(\beta', \beta_0)(Z'_{t-1}, 1)' + \sum_{i=1}^{p-1} \Phi_i \nabla Z_{t-i} + \varepsilon_t$, a model with a constant intercept in the error correction term (Table 6).

Table 6:VECM(2) Model Selection

Hypothesis of the Restriction		
Hypothesis	Drift in ECM	Drift in Process
H_0(* in Table 5)	Constant	Constant
H_1(** in Table 5)	Constant	Linear

Hypothesis Test of the Restriction					
Rank	Eigenvalue	Restricted Eigenvalue	DF	Chi-Square	Pr>ChiSq
0	0.2051	0.2191	3	6.19	0.1028
1	0.0966	0.0971	2	4.32	0.1155
2	0.0261	0.0647	1	4.25	0.0393

3.6 Estimation of Prediction Model

The results obtained by fitting the (* in Table 5) model of VECM(2) are as follows (Table 7).

Table 7: Estimation of Prediction Model

Model Parameter Estimation			
Equation	**Parameter**	**Estimate**	**Variable**
∇NWB	CONST1	0.07842	1, EC
	AR1_1_1	-0.09026	NWB(t-1)
	AR1_1_2	0.06627	BS(t-1)
	AR1_1_3	0.00091	KORIBOR(t-1)
	AR2_1_1	0.38923	∇NWB(t-1)
	AR2_1_2	-0.22871	∇BS(t-1)
	AR2_1_3	0.42973	∇KORIBOR(t-1)
∇BS	CONST2	-0.00692	1, EC
	AR1_2_1	0.00797	NWB(t-1)
	AR1_2_2	-0.00585	BS(t-1)
	AR1_2_3	-0.00008	KORIBOR(t-1)
	AR2_2_1	0.09891	∇NWB(t-1)
	AR2_2_2	0.57605	∇BS(t-1)
	AR2_2_3	0.13756	∇KORIBOR(t-1)
∇KOROBOR	CONST3	-0.00386	1, EC
	AR1_3_1	0.00444	NWB(t-1)
	AR1_3_2	-0.00326	BS(t-1)
	AR1_3_3	-0.00004	KORIBOR(t-1)
	AR2_3_1	0.03752	∇NWB(t-1)
	AR2_3_2	-0.08550	∇BS(t-1)
	AR2_3_3	0.57131	∇KORIBOR(t-1)

If the estimated prediction model is formulated using (Table 7), it is as in (Equation 11).

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$$\nabla\hat{Z}_t = \hat{\alpha}(\hat{\beta}', \hat{\beta}_0)(Z'_{t-1}, 1)' + \sum_{i=1}^{p-1} \hat{\Phi}_i \nabla Z_{t-i} + \varepsilon_t$$

$$= \begin{bmatrix} -0.09026 & 0.06627 & 0.00091 & 0.07842 \\ 0.00797 & -0.00585 & -0.00008 & -0.00692 \\ 0.00444 & -0.00326 & -0.00004 & -0.00386 \end{bmatrix} \begin{bmatrix} NWB_{1,t-1} \\ BS_{2,t-1} \\ KORIBOR_{3,t-1} \\ 1 \end{bmatrix} \quad (11)$$

$$+ \begin{bmatrix} 0.38923 & -0.22871 & 0.42973 \\ 0.09891 & 0.57605 & 0.13756 \\ 0.03752 & -0.08550 & 0.57131 \end{bmatrix} \begin{bmatrix} \nabla NWB_{t-1} \\ \nabla BS_{t-1} \\ \nabla KORIBOR_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix}$$

3.7 Goodness-of-Fit Test and Prediction

As the result of the significance test of the cross-correlation matrix for the residual vector in the goodness-of-fit test of the prediction model (Equation 11), it was confirmed that the white noise process was followed up to the time lags 1-12. As a result of the multivariate Portmanteau test, it was confirmed that the cross-correlation no longer existed because the P-values of the chi-square statistics were all greater than the significance level of 0.05 until the maximum delay of 3 to 12 lags (Table 8).

Table 8: Multivariate Portmanteau Test

Portmanteau Test for Cross Correlations of Residuals		
Up to Lag	**Chi-Square**	**Pr > ChiSq**
3	16.64	0.0646
4	21.30	0.2644
5	29.38	0.3428
6	43.87	0.1725
7	56.89	0.1101
8	63.39	0.1790
9	68.95	0.2831
10	79.26	0.2608
11	88.23	0.2729
12	102.42	0.1748

Using the VECM(2) forecasting model (Equation 11), under the 95% confidence level, between January 2010 and November 2018, forecasts and the forecast intervals after the first lag based on the NWB of mortgage rates are shown in (Figure 2), the BS in (Figure 3), and the KORIBOR in (Figure 4)].

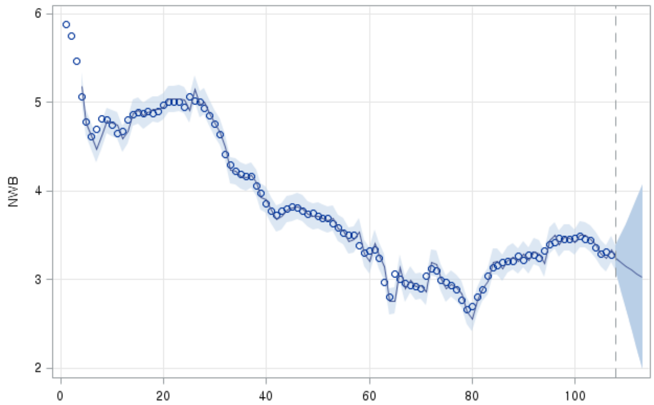

Figure2: Forecasts and Forecast Intervals of NWB Rates

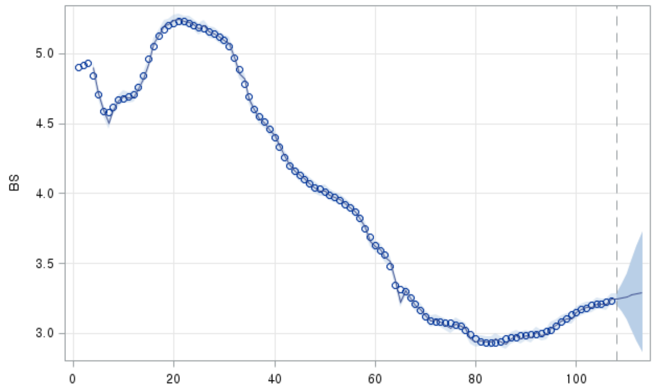

Figure3: Forecasts and Forecast Intervals of BS Rates

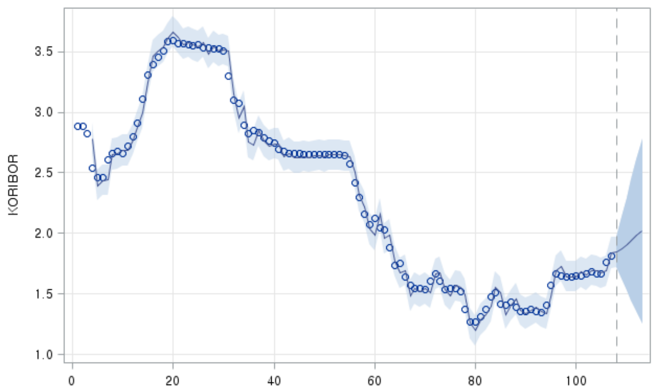

Figure4: Forecasts and Forecast Intervals of KORIBOR Rates

The forecasts from December 2018 to May 2019 and the 95% confidence intervals are shown in (Table 9).

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Table 9: Forecasts for Six Month

Variable	Time	Forecast	95% Confidence Limits	
NWB	DEC 2018	3.28556	3.14485	3.42628
	JAN 2019	3.29516	3.03731	3.55301
	FEB 2019	3.30094	2.94307	3.65882
	MAR 2019	3.30269	2.86465	3.74074
	APR 2019	3.30196	2.80127	3.80266
	MAY 2019	3.30018	2.75040	3.84996
BS	DEC 2018	3.23984	3.20071	3.27897
	JAN 2019	3.24989	3.15677	3.34301
	FEB 2019	3.25883	3.10082	3.41684
	MAR 2019	3.26581	3.03931	3.49231
	APR 2019	3.27071	2.97717	3.56426
	MAY 2019	3.27383	2.91740	3.56426
KORIBOR	DEC 2018	1.83668	1.71194	1.96142
	JAN 2019	1.85138	1.61768	2.08508
	FEB 2019	1.85937	1.52491	2.19384
	MAR 2019	1.86349	1.43885	2.28812
	APR 2019	1.86539	1.36087	3.36990
	MAY 2019	1.86608	1.29066	2.44150

4. CONCLUSION

The sample data used in this paper was monthly data on the new wage base (NWB) and the balance standard (BS) of mortgage rate, and KORIBOR provided by the Bank of Korea's Economic Statistics System and the Korea Federation of Banks from January 2010 to November 2018. As a research model, the vector error correction model was applied. We performed the Granger causality test, cointegration test, and multivariate Portmanteau test to estimate the prediction model and to test the model's suitability. The main results are as follows.

As the result of the Granger causality test, the p-values of the chi-square statistic are all less than the significance level of 0.05, indicating that each time series variable has a bidirectional linear dependency that is affected by the past values of itself and the other two time series variables. .

The order of the vector autoregressive model was determined as VAR(2) by the Schwarz Bayesian Criterion statistic. As the result of cointegration test using trace statistics, interest rate prediction model was finally determined as VECM(2) with constant intercept in error correction term. The significance test of the cross-correlation matrix with respect to the residual vector in the goodness-of-fit test of the prediction model showed that the white noise process was followed up to the time lags 1~12. In addition, the multivariate Portmanteau test showed that the cross-correlation no longer existed because the P-values of the chi-square statistics were all greater than the significance level of 0.05 until the maximum delay of 3 to 12 lags. These results indicate that the prediction model presented in this study is appropriate. It can be used as an important evidence for forecasting interest rate hikes for household debt policy makers and the general public who are the main sources of savings and consumption. It is also expected to provide useful information for real economic forecasting and monetary policy of government and financial institutions.

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