Research Article

Forecasting the Price of Natural Rubber in Thailand Using the ARIMA Model

Sukanya Cherdchoongam* and Vichai Rungreunganun
Department of Industrial Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

* Corresponding author. E-mail: s.cherdchoongam@gmail.com DOI: 10.14416/j.ijast.2016.11.005
Received: 25 April 2016; Accepted: 23 June 2016; Published online: 17 November 2016

Abstract
Objectives of this research are to create the model that can be used to forecast natural rubber price of Thailand with independent variables such as world natural rubber price, synthetic rubber price, Advance market price of Tokyo Commodity Exchange (*TOCOM*), consumption of natural rubber, production of natural rubber with Autoregressive Integrated Moving Average (ARIMA) model. The study is divided as 4 procedures; first is time series analysis for forecasting natural rubber price of Thailand. It was found that the ARIMA(1,0,1) model is most suitable that can be explained for variations of natural rubber price of Thailand for 94.54% with Mean Absolute Percentage Error (MAPE) of 5.923. the second step is ARIMA analysis for forecasting natural rubber price of Thailand together with independent variables, it was found that ARIMAX(0,1,1) was most appropriate with variation explanation of Thailand's natural rubber price of 99.89% and MAPE of 1.11. The third step is model analysis to forecast independent variables and the last step is using values from independent variable forecast in the third procedure to forecast Thailand's natural rubber price.

Keywords: ARIMA model, Price of natural rubber, Forecasting

1 Introduction

Rubber has been one of the most essential economic plants in the world in past 5 years. It is found that the world cultivation area for rubber trees increases every year from 28.92 million acre in 2011 to 30.68 million acre in 2015 [1] especially in China in which the cultivation area is expanded about 102,796 acre per year. World rubber productivity increases from 11.23 million ton in 2011 to 12.00 million tons in 2015 [1] as a result of high rubber price as motivation to expand the cultivation area since 2004. However, the fluctuating weather resulted in the decrease of world rubber productivity in 2014 to 11.7 million tons. Needs of using rubber are likely to increase from 10.98 million tons in 2011 to 12.124 million ton in 2015 especially China that has rapid economic growth resulting in continuous expansion of automobile industry. Speaking of rubber export of Thailand, it increased from 3.06 million ton in 2011 to 3.70 million ton in 2015 as a result of increasing needs in rubbers of China and India.

In past 5 years, the world rubber price has continually decreased especially during 2012–2015. the price of smoked rubber sheet decreased from 123 baht per kilogram (January 2012) to 44.93 baht per kilogram (December 2015) [2], [10] and Thailand's rubber price decreased with many influencing factors including rubber price trend in world market, world synthetic rubber price, world natural rubber productivity, world natural rubber consumption or advance price in Tokyo Commodity Exchange. These changes of such factors substantially affect the rubber price in Thailand.

In the past, there were some researches about

Please cite this article as: S. Cherdchoongam and V. Rungreunganun, "Forecasting the price of natural rubber in Thailand using the ARIMA model," *KMUTNB Int J Appl Sci Technol*, vol. 9, no. 4, pp. 271–277, Oct.–Dec. 2016.

rubber price with various and different statistical instrument and forecast methods for analysis such as Romprasert [3] Forecasting the Price of the Thailand natural rubber Ribbed Smoked Sheet no. 3 (RSS3) using regression analysis, exponential smoothing, Holt's linear exponential, and Box-Jenkins.

Khin [4] forecasting the Price of SMR20 using an Autoregressive Integrated Moving Average (ARIMA) and Multivariate Autoregressive Moving Average (MARMA) models with independent variables of price of RSS1 natural rubber production and consumption.

In [5] forecasting models for futures price of the the natural rubber RSS3. The results from the most efficient model can inform the decision of investors on buying and selling at the proper time. The study employs the least mean squared error as a criterion for the selection of the best prediction model. It includes an analysis of factors affecting the RSS3 futures prices in Thailand's futures market.

Chawananon [6] study was to estimate the econometric model of demand and supply of natural rubber in Thailand and determine if a relationship exists between the supply of rubber and its determinants. The instrumental variables estimation by two-stage least squares was used to solve and analyze the demand and supply of rubber.

Kwadwo [7] study the interdependency of the price of tea, rubber and coconut production in Sri Lanka. The strength of the linear interrelationship between the assets using the lag-l Cross-correlation Matrix (CCM) and also fit a VAR-model using selection criteria based on the AIC, SIC and HQIC. Examined the individual behaviour of the separate prices of each asset and then analyzed the combined effects of the prices. Out of all computing models, observed that tea price was ARIMA (0,1,0), rubber price was ARIMA (3, 1, 1) and coconut price is ARIMA (0, 1, 3).

Although Thailand is leading rubber manufacturer of the world, the rubber price in world market cannot be controlled resulting in the price changes of Thailand's natural rubbers which are dependent on major factors. They include changes of needs and productivity of world natural rubber that affect fluctuation of world natural rubber price as well as movement of advance foreign market price that the entrepreneurs emphasize on and it has the trend as same as natural rubber price in Thailand. With these reasons, the researcher is attentive to study characteristics of Thailand's natural rubber price movement by analyzing and creating mathematical model suitable for Thailand's natural rubber price forecast in the future.

2 Methodology

Box-Jenkins forecasting models are based on statistical concepts and principles and are able to model a wide spectrum of time series behavior. It has a large class of models to choose from and a systematic approach for identifying the correct model form. There are both statistical tests for verifying model validity and statistical measures of forecast uncertainty. In contrast, traditional forecasting models offer a limited number of models relative to the complex behavior of many time series with little in the way of guidelines and statistical tests for verifying the validity of the selected model.

There are many different forecasting approaches that are available to forecast time series data. Here, an approach is the Box-Jenkins ARIMA, Seasonal Autoregressive Integrated Moving Average (SARIMA) and Autoregressive Moving Average with Exogenous variables (ARIMAX).

2.1 *Box-Jenkins ARIMA model*

The ARIMA linear models have dominated in many parts of time series forecasting for more than half a century. ARIMA is usually possible to find a process which provides an adequate description to our data. A nonseasonal time series, ARIMA(p,d,q), can generally be modelled as a combination of past values and past errors. With ARIMA(p,d,q) equation as follows [8]

$$\phi_p(B)(1-B)^d Y_t = \theta_q(B)\varepsilon_t \qquad (1)$$

With

$$\phi_p(B) = 1-\phi_1 B-\phi_2 B^2-\ldots-\phi_p B^p$$

$$\theta_q(B) = 1-\theta_1 B-\theta_2 B^2-\ldots-\theta_q B^q$$

Where Y_t is appropriately transformed in period t. B is the backshift operator has the effect of changing time period t to time period t–1. Thus $BY_t = Y_{t-1}$ and $B^2Y_t = Y_{t-2}$. d is the order of differencing, and ε_t is the purely random process.

2.2 Box-Jenkins SARIMA model

SARIMA models are the application of ARIMA model with time series and seasonal influence involved. Therefore, Box and Jenkins then proposed multiplicative seasonal model for analyzing time series with both positive and multiplicative seasonal models resulting SARIMA (p,d,q)(P,D,Q)$_s$ equation as follows [8]

$$\phi_p(B)\Phi_P(B)(1-B)^d(1-B^s)^D Y_t = \theta_q(B)\Theta_Q(B^s)\varepsilon_t \quad (2)$$

With

$$\phi_p(B) = 1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p$$

$$\Phi_P(B) = 1 - \Phi_1 B^s - \Phi_2 B^{2s} - \ldots - \Phi_P B^{Ps}$$

$$\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q$$

$$\Theta_Q(B) = 1 - \Theta_1 B^s - \Theta_2 B^{2s} - \ldots - \Theta_Q B^{Qs}$$

Where Y_t is appropriately transformed in period t. B is the backshift operator has the effect of changing time period t to time period t–1. Thus $BY_t = Y_{t-1}$ and $B^2Y_t = Y_{t-2}$. d is the order of differencing, D is the order of seasonal differencing, s is the number of seasons per year, and ε_t is the purely random process.

2.3 Box-Jenkins ARIMAX model

ARIMAX model is application of ARIMA model by adding independent variable (x) to forecast initial variable resulting in equation of ARIMAX(p,d,q) model as follows [8]

$$\phi_p(B)(1-B)^d Y_t = \phi_p(B)X_t + \theta_q(B)\varepsilon_t \quad (3)$$

Where Y_t is appropriately transformed in period t. X_t is a vector of exogenous variables. B is the backshift operator has the effect of changing time period t to time period t–1. Thus $BY_t = Y_{t-1}$ and $B^2Y_t = Y_{t-2}$. d is the order of differencing and ε_t is the purely random process.

2.4 Box-Jenkins ARIMA modeling step

The modelling step of Box-Jenkins ARIMA model involves an iterative five stage process as follows [8]:

1. Preparation of data including transformations and differencing,
2. Identification of the potential models by looking at the sample autocorrelations and the partial autocorrelations,
3. Estimation of the unknown parameters,
4. Checking the adequacy of fitted model by performing normal probability plot, and
5. Forecast future outcomes based on the known data.

2.5 Forecasting performance evaluation

Statistics that are used to inspect accuracy include Mean Absolute Percentage Error (MAPE) and good model shall comprise of the lowest MAPE and it can be calculated from following formula

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{Y_t - \widehat{Y}_t}{Y_t}\right| \times 100 \quad (4)$$

Where Y_t is the actual value, $\widehat{Y}_t$ is the predicted value and n is the number of the predicted value

The derived statistical values are used to consider deviation and they shall be low or near to 0 indicating high accuracy of forecasting.

3 Results and Discussion

The observed data in this study are monthly data accumulated from January 2002 to December 2015 including 168 samples. Data of RSS3 F.O.B. Bangkok represented Thailand natural rubber price (*PriceNRT*) and RSS3 price in futures market of Tokyo Commodity Exchange (*TOCOM*) obtained from the Rubber Authority of Thailand [9]. World natural rubber price (*PriceNRW*) and synthetic rubber price (*PriceSRW*) obtained from world trade atlas and Global trade atlas [10]. Data of world consumption and production of natural rubber (*ConsumptionNRW* and *ProductionNRW*) obtained from International Rubber Study Group (IRSG) [11]

Data were analyzed to find the forecasting model with SPSS Software and it is divided as 2 parts including part 1: data from January 2002 to December 2014 for 156 months to find the suitable model for forecasting and part 2: data from January 2015 to December 2015 for 12 months is compared to find the advance forecast value from the forecasting model.

3.1 *Analysis of ARIMA model for forecasting Thailand's natural rubber price*

From considering time series graph of *PriceNRT* (Figure 1) ACF (Auto Correlation Function) Graph and PACF (Partial Auto Correlation Function) of *PriceNRT* (Figure 2), it was found that the time series of *PriceNRT* was quite constant because there was no composition of seasonal tendency and variation in the graph (Figure 1) and when ACF Plot was considered, it was found that it exponentially decreased while PACF Plot was different from zero significantly. In second lag, the time series most suitable for forecasting *PriceNRT* was ARIMA(2,0,0) or ARIMA(1,0,1).

From the analysis of ARIMA(1,0,1) and ARIMA(2,0,0) model for forecasting *PriceNRT* and testing the remainders, it was found that the values varied around zero randomly indicating the deviation with stable variability. However, for the test pertaining to normal distribution of randomized deviation with Kolmogorov-Smirnov statistics, it could be summarized that the randomized deviation had normal distribution with significance level of 0.05. Thus, the result of ARIMA(1,0,1) and ARIMA(2,0,0) model analysis for forecasting *PriceNRT* was presented in Table 1.

Table 1: Model fit statistics of ARIMA(1,0,1) model and ARIMA (2,0,0) model

Model	*Model Fit Statistics*		*Ljung-Box Q(18)*		
	R-squared	*MAPE*	*Statistics*	*DF*	*Sig.*
ARIMA(1,0,1)	0.945456	6.920271	11.581354	16	0.772261
ARIMA(2,0,0)	0.945238	6.985013	11.889947	16	0.751520

Table 1 shown indicating comparative values of the forecasting efficiency of ARIMA(1,0,1) model and ARIMA(2,0,0) model and it was found that Ljung-Box Q was not statistically significant with level of significance at 0.05. Conclusively, random deviation of ARIMA(1,0,1) model and ARIMA(2,0,0) model did not comprise self-correlation in accordance with the preliminary agreement of ARIMA model. When considering MAPE, ARIMA(1,0,1) model was less than ARIMA(2,0,0) model and ARIMA(1,0,1) model was thus selected for forecasting *PriceNRT*. The estimated parameter of ARIMA(1,0,1) model was shown in Table 2.

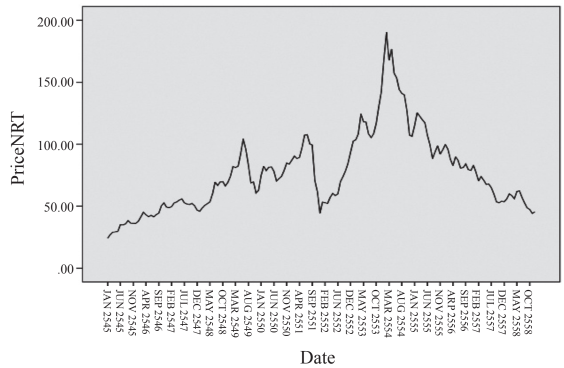

Figure 1: Time series plot from actual natural rubber price of Thailand.

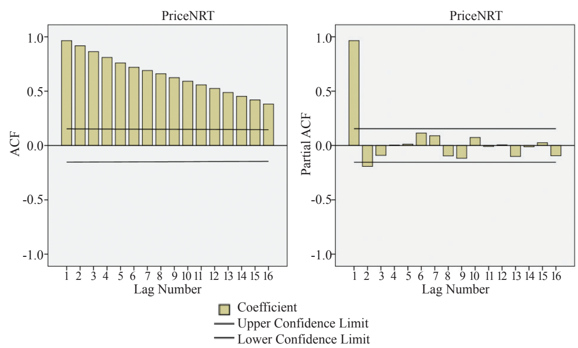

Figure 2: ACF and PACF plots from actual natural rubber price of Thailand.

Table 2: Estimated parameter of ARIMA(1,0,1) model

		Estimate	*SE*	*t*	*Sig.*
PriceNRT No Transformation	Constant	3.978	.351	11.316	.000
	AR Lag 1	.983	.013	76.414	.000
	MA Lag 1	-.226	.080	-2.836	.005

From ARIMA(1,0,1) model and estimated parameter (Table 2), it could be written as the equation according to the theory of Box-Jenkins ARIMA model as follows:

$$PriceNRT_t = 3.978 + 0.983\,PriceNRT_{t-1} + \varepsilon_t + 0.2263\,\varepsilon_{t-1} \quad (5)$$

Equation (5), *PriceNRT* could be forecasted with R-squared value is 0.9454. In other words, this forecast equation could be used to explain data variability of Thailand's natural rubber price up to 94.54% and MAPE, equals to 6.92%.

3.2 *Analysis of ARIMAX model for forecasting Thailand's natural rubber price*

To analyze ARIMAX model for forecasting Thailand's natural rubber price shall be considered if there were independent variables of *PriceNRW*, *PriceSRW*, *ConsumptionNRW*, *ProductionNRW* and *TOCOM* analyzed ARIMA(0,1,0) model for independent variables as presented in Table 3.

Table 3: Model fit statistics of ARIMAX model of *PriceNRT*

Model	*Model Fit Statistics*		*Ljung-Box Q(18)*		
	R-squared	*MAPE*	*Statistics*	*DF*	*Sig.*
ARIMA (1,1,1)	0.998903	1.121163	17.043	16	.376
ARIMA (1,1,0)	0.998565	1.312829	37.781	17	.003
ARIMA (1,0,1)	0.969011	5.573762	8.278	16	.940
ARIMA (0,1,1)	0.998912	1.108574	20.553	17	.247

Table 3 shown indicating comparative values of forecasting efficiency of ARIMA(1,1,1), ARIMA(1,1,0), ARIMA(1,0,1) and ARIMA(0,1,1) models, it was found that ARIMA(0,1,1) model had MAPE less than other models and ARIMA(0,1,1) was hence selected for forecasting *PriceNRT* with estimated parameter of ARIMA(0,1,1) model for independent variables of *PriceNRW*, *PriceSRW*, *ConsumptionNRW*, *ProductionNRW* and *TOCOM* shown in Table 4.

Table 4: Estimated parameter of ARIMA(0,1,1) model for independent variables.

		Estimate	*SE*	*t*	*Sig.*
PriceNRT	Constant	-0.085776	.038	-2.262	.025
	Difference	1			
	MA Lag 1	0.996379	.204	4.890	.000
PriceNRW	Numerator Lag 0	0.872435	.043	20.166	.000
	Difference	1			
PriceSRW	Numerator Lag 0	0.002289	.001	4.019	.000
ProductionNRW	Numerator Lag 0	-0.001064	.000	-2.185	.031
	Difference	1			
ConsumptionNRW	Numerator Lag 0	-0.009657	.002	-5.433	.000
	Difference	1			
TOCOM	Numerator Lag 0	0.112481	.044	2.573	.011
	Difference	1			

From ARIMA(0,1,1) model and Estimated Parameter (Table 4), it could be written as equation according to the theory of Box-Jenkins ARIMAX model as follows:

$$\begin{aligned} PriceNRT_t = & -0.086 + PriceNRT_{t-1} \\ & +0.872\left(PriceNRW_t - PriceNRW_{t-1}\right) \\ & +0.002\left(PriceSRW_t\right) \\ & -0.001\left(ProductionNRW_t - ProductionNRW_{t-1}\right) \\ & -0.010\left(ConsumptionNRW_t - ConsumptionNRW_{t-1}\right) \\ & +0.112\left(TOCOM_t - TOCOM_{t-1}\right) \\ & +\varepsilon_t - 0.996379\varepsilon_{t-1} \end{aligned} \quad (6)$$

Equation (6) could be used to forecast *PriceNRT* for independent variables of *PriceNRW*, *PriceSRW*, *ConsumptionNRW*, *ProductionNRW* and *TOCOM* with R-squared value is 0.9989. In other words, this forecasting equation could explain variability of Thailand's natural rubber price up to 99.89% with MAPE, equals to 1.11%.

3.3 *Analysis of model for forecasting independent variables*

Forecasting *PriceNRT* with the equation (6) needs forecast of *PriceNRW*, *PriceSRW*, *ConsumptionNRW*, *ProductionNRW* and *TOCOM* first. In this case, they will be forecasted in advance for 12 periods from January 2015 to December 2015. From analyzing the model for forecasting *PriceNRW*, *PriceSRW*, *ConsumptionNRW*, *ProductionNRW* and *TOCOM* with Expert Modeler in SPSS software, the suitable models are shown in Table 5

Table 5: Result of model analysis for forecasting 5 independent variables

Model	Model Type	Model Fit Statistics		
		Stationary R-squared	R-squared	MAPE
PriceNRW	Simple Seasonal	.499	.950	6.257
PriceSRW	Simple Seasonal	.706	.600	10.302
ProductionNRW	Simple Seasonal	.355	.721	13.451
ConsumptionNRW	Winters' Additive	.227	.931	4.214
TOCOM	Simple Seasonal	.515	.943	6.825

Exponential Smoothing Model Parameters

			Estimate	SE	t	Sig.
PriceNRW	No Transformation	Alpha (Level)	.999	.082	12.256	.000
		Delta (Season)	.000	28.379	1.240E-5	1.000
PriceSRW	No Transformation	Alpha (Level)	.400	.065	6.135	.000
		Delta (Season)	6.109E-5	.076	.001	.999
ProductionNRW	No Transformation	Alpha (Level)	.800	.079	10.097	.000
		Delta (Season)	4.879E-7	.136	3.593E-6	1.000
ConsumptionNRW	No Transformation	Alpha (Level)	.700	.078	8.941	.000
		Gamma (Trend)	4.656E-6	.020	.000	1.000
		Delta (Season)	3.296E-5	.093	.000	1.000
TOCOM	No Transformation	Alpha (Level)	.999	.082	12.151	.000
		Delta (Season)	.001	37.473	1.395E-5	1.000

From the model for forecasting independent variables in Table 5 used to forecast in advance for 12 periods from January 2015 to December 2015, the result of forecasting was shown in table 6.

Table 6: Values of advance forecast for 12 periods of independent variables

Time	Forecast				
	Price NRW	**Price SRW**	**Production NRW**	**Consumption NRW**	**TOCOM**
Jan-15	56.48	64.12	723.16	1097.15	56.15
Feb-15	59.91	62.55	448.53	1071.64	58.60
Mar-15	57.83	70.97	375.30	1117.60	56.20
Apr-15	60.49	57.11	381.23	1094.11	57.32
May-15	60.34	66.52	405.07	1094.40	57.30
Jun-15	60.40	67.61	394.00	1123.36	58.29
Jul-15	56.82	74.39	451.25	1150.25	56.03
Aug-15	55.24	68.64	582.66	1143.03	55.11
Sep-15	55.30	67.44	666.17	1138.24	54.23
Oct-15	53.72	70.15	742.07	1092.44	52.75
Nov-15	51.48	67.20	777.93	1116.17	52.00
Dec-15	52.76	68.18	730.42	1148.71	51.94

3.4 *Thailand's natural rubber price forecasting*

The result of forecasting the price of Thailand's natural rubber (*PriceNRT*) in advance for 12 periods from January 2015 to December 2015 with equations (5) and (6) was as follows:

Table 7: Actual and forecast *PriceNRT*, in 2015

Time	Actual	ARIMA(1,0,1) Model			ARIMAX(0,1,1)		
		Forecast	**UCL**	**LCL**	**Forecast**	**UCL**	**LCL**
Jan-15	55.76	53.82	67.80	39.84	57.79	60.06	55.52
Feb-15	59.96	54.24	75.89	32.59	62.31	64.63	59.99
Mar-15	58.59	54.65	81.58	27.72	60.41	62.78	58.05
Apr-15	56.05	55.04	86.12	23.97	62.73	65.14	60.32
May-15	61.97	55.43	89.94	20.92	62.28	64.74	59.83
Jun-15	62.38	55.80	93.25	18.35	62.30	64.79	59.80
Jul-15	57.10	56.16	96.17	16.15	58.39	60.93	55.86
Aug-15	52.61	56.51	98.78	14.23	56.03	58.61	53.46
Sep-15	48.70	56.84	101.13	12.56	55.48	58.10	52.86
Oct-15	47.38	57.17	103.27	11.07	53.41	56.07	50.75
Nov-15	44.19	57.48	105.22	9.75	50.97	53.67	48.28
Dec-15	45.49	57.79	107.01	8.57	52.33	55.07	49.60
MAPE		**12.18**			**7.42**		

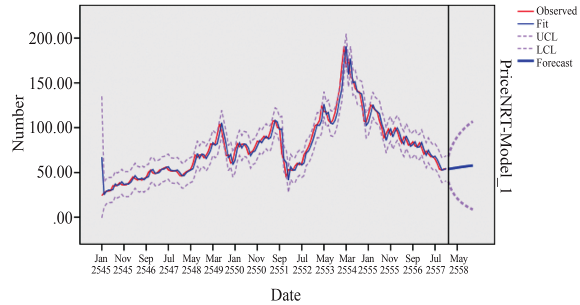

Figure 3: Time series plot of *PriceNRT* Forecast with ARIMA(1,0,1) model.

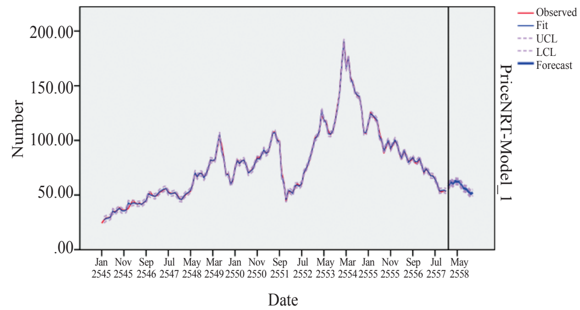

Figure 4: Time series plot of *PriceNRT* forecast with ARIMAX(0,1,1) model for independent variables.

According to Table 7, it showed the comparison between Actual *PriceNRT* and forecasting from ARIMA (1,0,1) model (Figure 3) and ARIMAX(0,1,1) model (Figure 4). After implementing F-Test Two-Sample for Variances of forecast values of ARIMA (1,0,1) model and ARIMAX(0,1,1) model at 0.05 significant level, P-value was 0.0002 indicating that forecast value from ARIMA (1,0,1) model and ARIMAX(0,1,1) model was different. Nevertheless, when F-Test Two-Sample for Variances was conducted between Actual *PriceNRT* and forecast values from ARIMA(1,0,1) at 0.05 significant level, it was found that P-value was 0.0000041 indicating that forecast value from ARIMA(1,0,1) was distinct from Actual *PriceNRT*. However, when F-Test Two-Sample for Variances was conducted between Actual *PriceNRT* and forecast value from ARIMAX(0,1,1) at 0.05 significant level, P-value was equal to 0.09 showing that forecast values from ARIMAX(0,1,1) were not contrasted to Actual *PriceNRT* which enabled ARIMAX(0,1,1) model to be agreeably suitable for natural rubber forecasting in Thailand.

4 Conclusions

From analyzing the time series with Box-Jenkins method, it was found that the suitable model for forecasting Thailand's Natural rubber price was ARIMA(1,0,1) model that could forecast data variability of palm cluster price up to 94.54% and MAPE of 6.92%. When considering ARIMAX model for forecasting Thailand's Natural rubber price together with independent variables of *PriceNRW*, *PriceSRW*, *ConsumptionNRW*, *ProductionNRW* and *TOCOM*, it was found that ARIMAX(0,1,1) model was most fitting that could explain variability of Thailand's natural rubber price up to 99.89% and MAPE of 1.11%. After that, the result of forecasting *PriceNRT* from ARIMA(1,0,1) model and ARIMAX (0,1,1) model was compared by forecasting in advance for 12 periods, it was found that ARIMAX(0,1,1) model had MAPE less than ARIMA(1,0,1) model.

From such result, it indicated that the model with independent variables could give more accurate forecast result than the model without independent variables. Therefore, selecting surrounding factors or independent variables for creating the forecast model was substantially essential and the factors presented in this research were based on only the opinions of the researcher and there may be other factors that are more suitable than ones presented by the author.

References

[1] Office of Agricultural Economics, "The agricultural Situation and Outlook 2016" Ministry of Agriculture and cooperative, Thailand, pp. 82–83, 2016.

[2] Bank of Thailand : Rates of Exchange of Commercial Banks in Bangkok Metropolis. (2002). [Online]. Available: http://www2.bot.or.th/statistics/ReportPage.aspx?reportID=123&language=en

[3] S. Romprasert, "Forecasting model of RSS3 price in futures market," *Kaetsart University Journal of Economics*, vol. 16, no. 1, pp. 54–74, 2009.

[4] A. A. Khin, M. Zainalabidin, M.N. Shamsudin, F.C. Eddie Chiew, and F.M. Arshad, "Estimation methodology of short-term natural rubber price forecasting models," *Journal of Environmental Science and Engineering*, vol. 5, no. 4, pp. 460–474, 2011.

[5] S. In, "Forecasting the price of natural rubber in malaysia," M.S. thesis, Department of Economics, California State University, 2012.

[6] C. Chawananon, "Factors affecting the Thai natural rubber market equilibrium: Demand and supply response analysis using two-stage least squares approach," M.S. thesis, Department of Science in Agribusiness, Faculty of California Polytechnic State University, 2014.

[7] A. N. Kwadwo, B. L. Peiris, and L. H. P. Gunaratne, "Analysis of the interrelationships between the prices of Sri Lankan rubber, tea and coconut production using multivariate time series," *Advances in Economics and Business*, vol. 3, no. 2, pp. 50–56, 2015.

[8] G. E. P. Box, G. M. Jenkins, and G. C. Reinsel, *Time Series Analysis: Forecasting and Control*, 4th edition. New Jersey: John Wiley and sons, 1998.

[9] RAOT : Rubber Authority of Thailand. Rubber price [Online]. Available:http://www.rubberthai.com/price/eng/price_eng.htm

[10] GTIS: World Trade Atlas. U.S. State Export Edition [Online]. Available: http://www.worldtradestatistics.com/state/

[11] IRSG : International Rubber Study Group. (1975–2001). World Rubber Statistics Handbook [Online]. Available: http://www.rubberstudy.com/statistics.aspx