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Forecasting equilibrium quantity and price on the world natural rubber market

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Abstract

Natural rubber on the world market has had small increases in demand and big increases in supply. Therefore, demand and supply are imbalanced and this impacts the natural rubber price of the world market causing a decline. This study aimed: (1) to develop de-mand and supply models to predict the world natural rubber quantity using simultaneous equations; (2) to predict all explanatory variables in the demand and supply models using the simple moving average technique; and (3) to estimate the equilibrium quantity and price for world natural rubber during 2017–2026. First, in the demand model, there was a positive relationship of the explanatory variables of world natural rubber production quantity, synthetic rubber price, percentage year of year (%YOY) of gross domestic product (GDP), and the exchange rate, while the negative relationship variable was natural rubber price. In the supply model, the positive relationship variables were natural rubber price, mature area, rainfall, and crude oil price, while the negative relationship variables were world natural rubber stock and urea price. Second, the predicted variables indicated that production, %YOY of GDP, exchange rate, amount of stock, and the mature area tended to gradually increase, while the synthetic rubber price, urea price, rainfall, and crude oil price tended to slowly decrease from 2017 to 2026. Finally, the equilibrium quantity forecast tended to gradually increase from 953.75 to 957.15 thousand tonnes, and the equilibrium price tended to fluctuate and decrease from 169.78 to 162.05 thousand yen from 2017 to 2026. Consequently, this study may be helpful to the governments of the world's important natural rubber producing countries to plan policies to reduce natural rubber production costs and stabilize the natural rubber price in the future, such as by setting suitable areas of world natural rubber plantation in each country, and defining appropriate and sustainable alternative crop areas in each country.

Introduction

The natural rubber market of the world is primarily concentrated in China, Europe, India, USA, and Japan, respectively, which were the top five countries of natural rubber consumption in 2015 (International Rubber Study

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Group, 2016a). China was the world's largest consumer of natural rubber, consuming 4,820 thousand tonnes in 2015, with a 1.26 percent increase from the previous year, making up 39.03 percent of the world's total consumption, an increase by 33.84 percent from 2011 (International Rubber Study Group, 2016a; Reportlinker, 2015). However, weather conditions were the main factor to impact the output of natural rubber market in China that was rather low, at only 794 thousand tonnes in 2015, or 6.47 percent of the total world market, and the percentage change is decreased by 5.49 percent from the previous year (International Rubber Study Group, 2016a). China had to import a large amount of natural rubber from Thailand, Indonesia, and Malaysia to meet its demand and supply gap, with imports reaching 3,803.2 thousand tonnes in 2015, or 78.9 percent of total consumption that year (International Rubber Study Group, 2016a; Reportlinker, 2015).

The demand increase was from the automotive and tire industries in China, where natural rubber consumption is expected to continue to grow and reach 6,791 thousand tonnes by 2018 (Pitakpaibulkij, Jarurungsipong, & Suntornpagasit, 2015; Reportlinker, 2015). However, the continuous decreasing price of natural rubber over the last three years has convinced producers to reduce production. The stock of natural rubber on the world market decreased to 3.16 million tonnes in 2015 (International Rubber Study Group, 2016a). Although the gap between production and usage reduced, natural rubber stock is still above three million tonnes, which is a high level. The high inventory levels will keep a limit on natural rubber prices (Pitakpaibulkij et al., 2015).

The International Rubber Study Group (IRSG) expected that the oversupply situation would continue for the next few years and then gradually decline because of slow growth in natural rubber production (Pitakpaibulkij et al., 2015). Production growth would slow due to the EI Nino effect and the continuing drop in natural rubber prices, while the automotive sector is forecast to increase the usage of natural rubber (Pitakpaibulkij et al., 2015).

Natural rubber forecasts are necessary to help in decision making and long term investment decisions, for which a simultaneous equation is one of the more efficient measures in terms of statistical criteria for a supply, demand, and price system model (Khin, Zainalabidin, Nasir, Chong, & Mohamed, 2011).

The objectives of the study were: (1) to develop a demand and supply model to predict the amount of world natural rubber production, (2) to predict all the explanatory variables in the demand and supply model, and (3) to estimate the equilibrium quantity and price for world natural rubber. The results of this study will be used to help governments to plan policy for natural rubber plantation in countries that have the natural rubber as an economic crop such as Thailand, Indonesia, Vietnam, and Malaysia, by determining the suitable area of world natural rubber plantation in each country, and defining the appropriate alternative crop area in each country based on topography, weather, and soil, especially sustainable alternative crops in the future.

Methods

Data Collection

This study aimed to estimate the equilibrium quantity and price in the world natural rubber market. The study also considered the demand for and supply of natural rubber on the world market as endogenous variables, which can be viewed as a function of several explanatory variables. The procedure that was used in selecting the variables was based on the theoretical background of demand and supply theories and influential macroeconomic data. The equilibrium quantity and price in the natural rubber of the world market were estimated by using the monthly time series data for the period 2004–2015. There were several explanatory variables in this study: (1) quantity of natural rubber consumption (Q: 000 tonnes) on the world market, (2) quantity of natural rubber production (Qs: 000 tonnes) on the world market, (3) natural rubber price (NRPRICE: 000 yen) in physical market price of RSS3 (cif) on the Tokyo market, (4) synthetic rubber price (SRPRICE: USD per tonne) on the USA market, which represented the world market in this study, (5) %YOY of GDP (YGDP: percentage) of the world, (6) exchange rate from Chinese yuan to Thai baht (CNY: baht) that represented the exchange rate of the world in this study, since China is the number one natural rubber consumer in the world and Thailand is the number one natural rubber producer in the world (International Rubber Study Group, 2016a), (7) amount of natural rubber stock (STOCK: 000 tonnes) on the world market, (8) mature area of natural rubber plantation in Thailand (MAREA_TH: hectares), (9) urea f.o.b. price (UPRICE: USD per metric tonne) in Eastern Europe, (10) rainfall in Thailand (RAINFALL_TH: millimeters), (11) oil palm future price (OPPRICE: USD per metric tonne) on the Malaysian market, and (12) crude oil price of petroleum (CPETRO: USD per barrel), as the simple average of three spot prices—Dated Brent, West Texas Intermediate, and the Dubai Fateh. There were five main sources of the data: (1) International Rubber Study Group (IRSG) that reported Q, Qs, NRPRICE, SRPRICE, STOCK and MAREA_TH (International Rubber Study Group, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015a, 2015b, 2016a, 2016b), (2) IndexMundi website that reported UPRICE, CPETRO and OPPRICE (IndexMundi, 1987–2015), (3) Thomson Reuters (2000–2021) reported YGDP, (4) Bank of Thailand presented CNY (Bank of Thailand, 2004–2015), and (5) Meteorological Department of Thailand reported RAINFALL_TH (Meteorological Department of Thailand, 2004–2015). For YGDP from the Data Stream Database, the data were transformed from quarterly data to monthly data using the moving average technique.

Data Analysis

In the first analysis, the initial equations were developed by using the above variables. There were two equations for estimating the quantity of natural rubber consumption on the world market in the demand model and in the supply model by applying simultaneous equations according to the three-stage least square (3SLS) technique and the monthly data from 2004 to 2015. The equations for the amount of natural rubber consumption on the world market in this study were:

Demand Model

$$Q_t = \alpha_0 + \alpha_1 Q_{st} + \alpha_2 NRPRICE_t + \alpha_3 SRPRICE_t + \alpha_4 YGDP_t + \alpha_5 CNY_t + \varepsilon_{1t} \quad (1)$$

where

Q_t = quantity of natural rubber consumption of the world market (000 tonnes)
Q_{st} = quantity of natural rubber production of the world market (000 tonnes)
$NRPRICE_t$ = natural rubber price (000 yen) on the Tokyo market
$SRPRICE_t$ = synthetic rubber price (USD per tonne) on the USA market
$YGDP_t$ = %YOY of GDP of the world (percentage)
CNY_t = exchange rate from yuan to baht (baht)
ε_{1t} = residual term

Supply Model

$$Q_t = \beta_0 + \beta_1 NRPRICE_t + \beta_2 STOCK_t + \beta_3 MAREA\_TH_t + \beta_4 UPRICE_t + \beta_5 RAINFALL\_TH_t + \beta_6 OPPRICE_t + \beta_7 CPETRO_t + \varepsilon_{2t} \quad (2)$$

where

$NRPRICE_t$ = natural rubber price (000 yen) at Tokyo market
$STOCK_t$ = amount of natural rubber stock on the world market (000 tonnes)
$MAREA\_TH_t$ = mature area of natural rubber plantation in Thailand (hectares)
$UPRICE_t$ = urea f.o.b. price (USD per metric tonne) in Eastern Europe
$RAINFALL\_TH_t$ = rainfall in Thailand (millimeters)
$OPPRICE_t$ = palm oil future price (USD per metric tonne) on the Malaysian market
$CPETRO_t$ = crude oil price of petroleum (USD per barrel)
ε_{2t} = residual term

According to Equation (1) above, the signs of the coefficients of variables were expected to be: $\alpha_1 > 0$, $\alpha_2 < 0$, $\alpha_3 > 0$, $\alpha_4 > 0$, $\alpha_5 > 0$. The coefficients of Qs, SRPRICE, YGDP and CNY were expected to be positive. The coefficient of Qs was expected to be positive because the increase in natural rubber production results in a drop in the natural rubber price, so the natural rubber demand increases. The price of synthetic rubber—the substitute for natural rubber—increases which helps reduce the demand of synthetic rubber, while it increases the demand for nature rubber. Therefore, the coefficient of SRPRICE was expected to be positive. The %YOY of GDP represents the income of people which means that if the %YOY increases, the people increase their demand for natural rubber. A CNY increase means that one yuan can increase its value in baht, which impacts the increase in the natural rubber demand. The coefficient of NRPRICE was expected to be negative because there is an adverse relationship between natural rubber price and demand. If the natural rubber price increases, the demand for natural rubber decreases, due to normal market forces.

The signs of the coefficients of the variables in Equation (2) were expected to be: $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 > 0$, $\beta_4 < 0$, $\beta_5 > 0$, $\beta_6 < 0$, $\beta_7 > 0$. The coefficients of NRPRICE, MAREA_TH, RAINFALL_TH and CPETRO were expected to be positive. A natural rubber price increase affects the motivation natural rubber plantation farmers. The mature area of natural rubber plantation in Thailand, which is the number one of producer of the world (International Rubber Study Group, 2016a), directly impacts the number of natural rubber suppliers on the world market. If the mature area of natural rubber plantation in Thailand increases, the amount of supply increases. If the rainfall increases, which is an important input factor in growing rubber trees and on the amount of natural rubber latex produced, the supply of the natural rubber increases. If the crude oil price of petroleum, which is the main raw material of synthetic rubber, increases, the synthetic rubber price increases. Therefore, demand and supply in natural rubber will be increased by normal market forces. The coefficients of STOCK, UPRICE, OPPRICE and CPETRO were expected to be negative. If the amount of stock increases, the natural rubber price reduces, which makes natural rubber production decrease and the national rubber supply decreases. If the price of urea, which is an important fertilizer of natural rubber, increases, the use of fertilizer reduces and the production of natural rubber decreases. If the price of palm oil, which is an important alternative crop of natural rubber (Office of Agricultural Economics of Thailand, 2012a, 2012b), increases, the area of natural rubber plantation and natural rubber production reduce. If the petroleum crude oil price, which is the main raw material of natural rubber production, increases, the number of natural rubber production producers decreases.

For the second part of the analysis, the initial equations were used to develop the appropriate form of the models for predicting the quantity of natural rubber consumption in demand and supply using simultaneous equations and the three-stage least square (3SLS) approach. All explanatory variables in the demand and supply models were predicted using the simple moving average technique, using the monthly data between 2011 and 2015.

For the last part of the analysis, the estimated variables were used to predict the equilibrium of the quantity and price of natural rubber on the world market from 2017 to 2026. The results can help governments plan their policy for natural rubber plantation in countries where natural rubber export is important.

Results and Discussion

Demand and Supply Development

This study identified two initial equations for developing the demand and supply models that are shown in Equations (1) and (2). All variables were examined in the unit root test with an Augmented Dickey—Fuller (ADF) test. The results of the unit root test indicated that NRPRICE, SRPRICE, CNY, STOCK, MAREA_TH, UPRICE, CPETRO, and OPPRICE were non-stationary at the 5 percent significance level, and that at the first difference of their log-transformation, they were stationary. Then, their variables were set as I(1) or integrated of order 1 for estimating the model. The Qs and RAINFALL_TH were already stationary at the 5 percent significance level, while YGDP was stationary at the 10 percent significance level. Therefore, all variables were tested for developing the demand and supply model. In this study, three-stage least square of simultaneous equation was used to estimate the coefficients, which are reported in Table 1 and the models were estimated as follows:

Demand Model

$$\begin{aligned} ln\ Q_t &= 2.86133 + 0.11114\ lnQ_{st} \\ &\quad - 0.01661\ lnNRPRICE_{t-6} + 0.25652\ lnSRPRICE_t \\ &\quad + 0.04164\ lnYGDP_{t-6} + 0.77049\ lnCNY_t \end{aligned} \tag{3}$$

Supply Model

$$\begin{aligned} lnQ_t &= 1.92106 + 0.04523\ lnNRPRICE_{t-6} \\ &\quad - 0.05435\ lnSTOCK_t + 0.64831\ lnMAREA\_TH_t \\ &\quad - 0.03933\ lnUPRICE_{t-6} + 0.01835\ lnRAINFALL\_TH_t \\ &\quad + 0.04980\ lnCPETRO_t \end{aligned} \tag{4}$$

Based on the coefficients in the demand model, the intercept was estimated as 2.86, which was significant at the 5 percent level. The coefficient of Qs was estimated at 0.11, which was significant at the 5 percent level, which indicated that any one percent increase in Qs will increase Q by 0.11 percent. The coefficient of NRPRICE in the past six months was estimated at −0.02, which was not significant. As the price is an important explanatory variable to predict the demand model, this study still holds the price to be an independent variable for forecasting the demand model. The coefficient of SRPRICE was estimated at 0.26, which was significant at the 5 percent level, which indicated that SRPRICE increased by one percent, while Q increased by 0.26 percent. The coefficient of YGDP in the past six months was estimated at 0.04, which was significant at 5 percent level, which indicated that if YGDP increases by one percent, Q increases by 0.04 percent. The coefficient of CNY was estimated at 0.77, which was significant at the 5 percent level, which indicated that if CNY increases by one percent, Q increases 0.77 percent. The root mean square error, which shows the accuracy of the demand equation, was calculated as 0.09. The R-square value was calculated as 0.54, which showed the goodness of fit of the demand model. This demand model was significant at the 5 percent level.

Table 1
Coefficients of demand and supply by 3SLS

(n=128)

Variable	Coefficient	*p*
Demand equation		
Constant	2.86**	.00
lnQ_{st}	0.11**	.04
$lnNRPRICE_{t-6}$	−0.02	.68
$lnSRPRICE_t$	0.26**	.00
$lnYGDP_{t-6}$	0.04**	.01
$lnCNY_t$	0.77**	.00
Root mean square error = 0.09, R-square = 0.54, *p* = .00		
Supply equation		
Constant	1.92**	.00
$lnNRPRICE_{t-6}$	0.05*	.06
$lnSTOCK_t$	−0.05**	.01
$lnMAREA\_TH_t$	0.65**	.00
$lnUPRICE_{t-6}$	−0.04**	.05
$lnRAINFALL\_TH_t$	0.02**	.00
$lnCPETRO_t$	0.05**	.00
Root mean square error = 0.06, R-square = 0.79, *p* = .00		

Endogenous variables: lnQ_t
Exogenous variables: lnQ_{st}, $lnNRPRICE_{t-6}$, $lnSRPRICE_t$, $lnYGDP_{t-6}$, $lnCNY_t$, $lnSTOCK_t$, $lnMAREA\_TH_t$, $lnUPRICE_{t-6}$, $lnRAINFALL\_TH_t$, $lnCPETRO_t$
*Indicates significant at 10%, **indicates significant at 5%

The explanatory variables in the demand model with a positive relationship were Q_s, SRPRICE, YGDP in the past six months, and CNY, while there was a negative relationship for NRPRICE in the past six months. The coefficient of Q_s was positive because the increase in world natural rubber production in the market results in a drop in the natural rubber price, therefore natural rubber demand increases. Synthetic rubber is a perfect substitute good for natural rubber (Romprasert, 2011); as the synthetic rubber price increases, it helps reduce the demand for synthetic rubber, and affects the increase in the demand of natural rubber. These results were supported by the study of Khin, Chong, Mohamed, and Shamsudin (2008). The GDP shows improvement in the world economy, so an increase in GDP leads to an increase in natural rubber demand. The result was similar to those reported by Romprasert (2011), Khin et al. (2008), and Mani (1984). An increase in the exchange rate from Chinese yuan to Thai baht means that one yuan can increase its value in baht, which impacts the increase in the natural rubber demand. The natural rubber price has an inverse relationship with natural rubber price and demand. If the natural rubber price increases, the demand for natural rubber decreases according to normal market forces.

Based on the coefficients in the supply model, the intercept was estimated at 1.92, which was significant at the 5 percent level. The coefficient of NRPRICE in the past six months was estimated at 0.05, which was significant at the 1 percent level, which indicated that if NRPRICE in the past six months increases by one percent, Q increases 0.05 percent. The coefficient of STOCK was estimated at −0.05, which was significant at the 5 percent level, which indicated that if STOCK increases by one percent, Q decreases 0.05 percent. The coefficient of MAREA_TH was estimated at 0.65, which was significant at the 5 percent level, which indicated that if MAREA_TH increases one percent, Q increases 0.65 percent. The coefficient of UPRICE in the past six months was estimated at −0.04, which was significant at the 5 percent level, which indicated that if UPRICE

Table 2
Predicted data of natural rubber consumption (Q) and residuals from January 2015 to June 2016 using actual data terms and percentage change in independent variables terms

		Consumption	Actual data				Percentage change			
			Demand model		Supply model		Demand model		Supply model	
			Q forecast	Residual	Q forecast	Residual	Q forecast	Residual	Q forecast	Residual
2015	Jan	1,019	963.49	−55.51	945.84	−73.16	999.62	−19.38	995.57	−23.43
	Feb	858	914.98	56.98	942.21	84.21	1,041.65	183.65	1,038.36	180.36
	Mar	1,064	897.81	−166.19	956.87	−107.13	879.51	−184.49	875.72	−188.28
	Apr	1,048	871.71	−176.29	978.71	−69.29	1,088.20	40.20	1,086.29	38.29
	May	1,068	902.28	−165.72	995.46	−72.54	1,077.78	9.78	1,069.18	1.18
	Jun	1,083	917.19	−165.81	1,001.70	−81.30	1,100.59	17.59	1,089.20	6.20
	Jul	1,079	931.79	−147.21	1,003.43	−75.57	1,113.35	34.35	1,103.99	24.99
	Aug	1,072	964.56	−107.44	1,003.44	−68.56	1,114.89	42.89	1,099.55	27.55
	Sep	1,057	982.67	−74.33	1,008.15	−48.85	1,104.64	47.64	1,092.25	35.25
	Oct	1,023	981.96	−41.04	996.60	−26.40	1,087.41	64.41	1,076.39	53.39
	Nov	1,006	962.65	−43.35	983.40	−22.60	1,047.96	41.96	1,041.63	35.63
	Dec	970	952.74	−17.26	955.02	−14.98	1,034.41	64.41	1,024.28	54.28
			Average	−91.93	Average	−48.01	Average	28.58	Average	20.45
2016	Jan	1,016	938.26	−77.74	1,003.30	−12.70	997.07	−18.93	1,004.37	−11.63
	Feb	896	910.39	14.39	977.51	81.51	1,042.59	146.59	1,035.28	139.28
	Mar	1,130	897.24	−232.76	981.84	−148.16	920.25	−209.75	914.58	−215.42
	Apr	1,076	873.05	−202.95	1,011.39	−64.61	1,157.69	81.69	1,153.51	77.51
	May	1,085	884.61	−200.39	1,047.37	−37.63	1,107.54	22.54	1,097.91	12.91
	Jun	1,070	912.55	−157.45	1,065.99	−4.01	1,123.96	53.96	1,106.55	36.55
			Average	−142.82	Average	−30.93	Average	12.68	Average	6.53
Total			Average	−108.89	Average	−42.32	Average	23.28	Average	15.81

increases by one percent, Q decreases 0.04 percent. The coefficient of RAINFALL_TH was estimated at 0.02, which was significant at the 5 percent level, which indicated that if RAINFALL_TH increases by one percent, Q increases 0.02 percent. The coefficient of CPETRO was estimated at 0.05, which was significant at the 5 percent level, which indicated that if CPETRO increases by one percent, Q increases 0.05 percent. The root mean square error was calculated as 0.06, which showed the accuracy of the supply equation. The R-square value was calculated as 0.79, which showed the goodness of fit of supply model. This supply model was significant at the 5 percent level.

The explanatory variables in the supply model with a positive relationship were NRPRICE in the past six months, MAREA_TH, RAINFALL_TH, and CPETRO, while there was a negative relationship for STOCK and UPRICE in the past six months. Maya (2003) reported that price is the major factor which can influence the farming decision regarding the quantity offered for sale in the market. Thus the natural rubber price increase affects the motivation of natural rubber plantation farmers. The mature area of natural rubber plantation in Thailand, which is the number one producer in the world, directly impacts the number of natural rubber suppliers on the world market. Similarly, the study of Maya (2003) found that production of natural rubber was directly related to the growable area and yield per hectare in that year. The rainfall is an important input factor in growing rubber trees and amount of natural rubber latex. When rainfall increases, it increases the natural rubber supply. The crude oil in petroleum is the main raw material of synthetic rubber, so when the crude oil price increases, it increases the synthetic rubber price. Therefore, demand and supply for natural rubber will increase due to the normal market forces. The amount of natural rubber stock directly impacts the natural rubber price which means that if stock increases, price will decrease. Therefore, the natural rubber supply on the world market will reduce due to the normal market forces. Maya (2003) noted that the actual production, which is governed by the application of inputs and biological processes, involved the allocation of other inputs like fertilizers. The main fertilizer for natural rubber trees is urea, so if the urea price increases, farmers will decrease the amount of urea applied on their plantations and natural rubber production decreases.

This study predicted the quantity of natural rubber consumption and residuals in the monthly data from January 2015 to June 2016 using: (1) actual data terms and (2) the percentage change in the independent variable term. The results are shown in Table 2.

From Table 2, the average residuals were separated into three periods: (1) 2015, (2) the first half of 2016, and (3) from January 2015 to June 2016. The residuals in predicted Q with the demand and supply models using actual data terms in the explanatory variables terms both underestimated the trend in a similar manner. In the demand model, the average of residuals were −91.93, −142.82 and −108.89, respectively, while in the supply model, they were −48.01, −30.93 and −42.32, respectively. The percentage change of explanatory variables terms with the demand and supply model both overestimated the trend in a similar manner. In the demand model, the average of the residuals were 28.58, 12.68 and 23.28, respectively, while in the supply model, they were 20.45, 6.53 and 15.81, respectively.

Explanatory Variables Forecast

In the next step, this study determined the values of explanatory variables in monthly data from January 2017 to

Table 3
Average yearly predicted future data of Qs, SRPRICE, YGDP, CNY, STOCK, MAREA_TH, UPRICE, RAINFALL_TH, and CPETRO from 2017 to 2026 using a simple moving average technique

	Qs	SRPRICE	YGDP	CNY	STOCK	MAREA_TH	UPRICE	RAINFALL_TH	CPETRO
2017	998.70	2,795.73	1.45	5.18	2,557.75	2,404.41	328.22	135.09	87.66
2018	1,005.37	2,694.04	1.58	5.24	2,670.26	2,447.26	316.34	134.71	84.22
2019	1,003.60	2,639.75	1.60	5.25	2,663.97	2,469.37	315.09	134.05	79.91
2020	1,007.26	2,681.70	1.56	5.24	2,599.60	2,446.15	318.63	135.94	81.12
2021	1,002.11	2,727.10	1.54	5.21	2,594.97	2,431.98	322.53	135.18	84.12
2022	1,003.99	2,697.21	1.56	5.23	2,626.03	2,443.97	319.06	134.90	82.93
2023	1,004.50	2,685.10	1.57	5.23	2,628.82	2,448.64	318.44	134.86	82.22
2024	1,004.54	2,690.58	1.56	5.23	2,617.63	2,445.77	319.11	135.03	82.19
2025	1,004.28	2,699.69	1.55	5.23	2,613.96	2,442.31	319.81	135.11	82.75
2026	1,004.11	2,696.59	1.56	5.23	2,619.22	2,443.85	319.44	134.98	82.69
Average overall	1,003.85	2,700.75	1.55	5.23	2,619.22	2,442.37	319.67	134.98	82.98

December 2026 using a simple moving average technique for the monthly data for the period 2011 to 2015. Then, the averages of the predicted yearly future data for all explanatory variables between 2017 and 2026 were calculated, and the results are shown in Table 3.

Table 3 shows the average yearly predicted future data for 10 years from 2017 to 2026 of Qs, SRPRICE, YGDP, CNY, STOCK, MAREA_TH, UPRICE, RAINFALL_TH, and CPETRO; the average total predicted data for 10 years was 1,003.85 thousand tonnes, USD 2,700.75 per tonne, 1.55 percent, 5.23 baht, 2,619.22 thousand tonnes, 2,442.37 ha, USD 319.67 per metric tonne, 134.98 mm, and USD 82.98 per barrel, respectively.

For the monthly predicted data, the accuracy of explanatory variables were calculated using the mean absolute division (MAD), mean square error (MSE), root mean square error (RMSE), and mean absolute percent error (MAPE) which are shown in Table 4. This study considered the fitted model using MAPE since most people are comfortable with thinking in percentage terms and it is easy to compare and interpret results. In the demand model, the Qs, SRPRICE, YGDP, and CNY had MAPE equal to 12.67, 23.16, 37.12, and 4.93, respectively. In the supply model, the STOCK, MAREA_TH, UPRICE, RAINFALL_TH, and CPETRO had MAPE equal to 27.01, 12.56, 16.37, 208.72, and 32.63, respectively. The MAPE in YGDP and CPETRO had high errors. The YGDP and CPETRO are difficult to predict, since the growth in the world economy fluctuates greatly and there are several factors that impact on the world GDP and the crude oil price. Moreover, the MAPE of the predicted data for RAINFALL_TH was higher than that of the other variables because rainfall is a natural phenomenon that is hard to control and difficult to exactly predict. Therefore, we may change the techniques for forecasting, and instead use several variables that impact rainfall in Thailand.

The Q from January 2015 to June 2016 were estimated by using the actual predicted and percentage changes in the predicted explanatory variables. The results are shown in Table 5. The average residuals in predicted Q from January 2015 to June 2016 were separated into three periods; (1) 2015, (2) the first half of 2016, and (3) from January 2015 to June 2016. All residuals average values underestimated the trend in a similar manner. The predicted data used actual data terms in the explanatory variables terms. In the demand model, the average residuals were −91.93, −81.71, and −88.52, respectively, while in supply model, they were −48.01, −95.80, and −63.94, respectively. Using the percentage change, the average residuals were −99.04, −89.26, and −95.78, respectively, in demand model and −46.81, −95.40, and −63.01, respectively, in the supply model.

World Natural Rubber Consumption Quantity Prediction

This study used predicted explanatory variables to forecast the Q in monthly data from January 2017 to December 2026 from actual predicted data and the percentage change in explanatory variables. Then, this study calculated the average yearly quantity of natural rubber consumption (Q), and the results are shown in Table 6.

From Table 6, the average predicted natural rubber quantity in the demand model tended to increase from 948.26 thousand tonnes in 2017 to 949.85 thousand tonnes in 2026, and the average over 10 years was 949.67 thousand tonnes. For the supply model, the average predicted natural rubber quantity tended to gradually increase from 968.89 thousand tonnes in 2017 to 977.29 thousand tonnes in 2026, and the average over 10 years was 976.92 thousand tonnes. Looking at the percentage change, the average predicted natural rubber quantity in the demand model tended to increase from 948.33 thousand tonnes in 2017 to

Table 4
Accuracy of Qs, SRPRICE, YGDP, CNY, STOCK, MAREA_TH, UPRICE, RAINFALL_TH, and CPETRO using a simple moving average technique

	Qs	SRPRICE	YGDP	CNY	STOCK	MAREA_TH	UPRICE	RAINFALL_TH	CPETRO
MAD	126.87	670.96	0.58	0.26	656.39	297.46	56.6	80.28	23.35
MSE	20,739.44	593,671.9	0.51	0.1	593,568.2	97,989.46	5,205.08	8,216.93	727
RMSE	144.01	770.5	0.71	0.31	770.43	313.03	72.15	90.65	26.96
MAPE	12.67	23.16	37.12	4.93	27.01	12.56	16.37	208.72	32.63

Table 5
Predicted data of natural rubber consumption (Q) and residuals from January 2015 to June 2016 using predicted independent variables from a simple moving average technique

		Consumption	Actual predicted data				Percentage change			
			Demand model		Supply model		Demand model		Supply model	
			Q forecast	Residual	Q forecast	Residual	Q forecast	Residual	Q forecast	Residual
2015	Jan	1,019	963.49	−55.51	945.84	−73.16	970.23	−48.77	968.41	−50.59
	Feb	858	914.98	56.98	942.21	84.21	953.28	95.28	945.45	87.45
	Mar	1,064	897.81	−166.19	956.87	−107.13	919.62	−144.38	943.76	−120.24
	Apr	1,048	871.71	−176.29	978.71	−69.29	879.74	−168.26	959.15	−88.85
	May	1,068	902.28	−165.72	995.46	−72.54	857.81	−210.19	980.42	−87.58
	Jun	1,083	917.19	−165.81	1,001.70	−81.30	888.16	−194.84	996.09	−86.91
	Jul	1,079	931.79	−147.21	1,003.43	−75.57	903.23	−175.77	1,001.87	−77.13
	Aug	1,072	964.56	−107.44	1,003.44	−68.56	921.19	−150.81	1,003.43	−68.57
	Sep	1,057	982.67	−74.33	1,008.15	−48.85	956.23	−100.77	1,003.91	−53.09
	Oct	1,023	981.96	−41.04	996.60	−26.40	975.57	−47.43	1,007.01	−15.99
	Nov	1,006	962.65	−43.35	983.40	−22.60	976.06	−29.94	995.28	−10.72
	Dec	970	952.74	−17.26	955.02	−14.98	957.35	−12.65	980.51	10.51
			Average	−91.93	Average	−48.01	Average	−99.04	Average	−46.81
2016	Jan	1,016	960.65	−55.35	953.76	−62.24	951.78	−64.22	954.89	−61.11
	Feb	896	962.67	66.67	950.03	54.03	955.40	59.40	953.37	57.37
	Mar	1,130	964.64	−165.36	948.63	−181.37	970.33	−159.67	949.88	−180.12
	Apr	1,076	964.89	−111.11	948.88	−127.12	950.03	−125.97	948.65	−127.35
	May	1,085	966.36	−118.64	944.58	−140.42	954.71	−130.29	948.42	−136.58
	Jun	1,070	963.52	−106.48	952.32	−117.68	955.17	−114.83	945.40	−124.60
			Average	−81.71	Average	−95.80	Average	−89.26	Average	−95.40
Total			Average	−88.52	Average	−63.94	Average	−95.78	Average	−63.01

949.86 thousand tonnes in 2026. For the supply model, the results showed an increase from 968.29 thousand tonnes in 2017 to 977.26 thousand tonnes in 2026, and the average over 10 years was 976.82 thousand tonnes.

The results of the comparison of amount of demand and supply showed that the trend for supply was greater than that of demand in 2017–2026 for both the actual predicted data and the percentage change techniques. With the actual predicted data, the average gap between supply and demand was 27.25 thousand tonnes per year, and the accumulated difference was 272.5 thousand tonnes over the next 10 years. The amount of natural rubber stock continuously increases every year from 2017 to 2026. Similarly with the percentage change, the average gap between the supply and demand quantities was 27.12 thousand tonnes per year, and the accumulated difference was 271.2 thousand tonnes in 2026, showing that natural rubber stock will steadily increase in the next 10 years.

Table 6
Average yearly natural rubber consumption (Q) from 2017 to 2026 using predicted actual data and percentage change in explanatory variables

	Actual predicted data		Percentage change	
	Demand model	Supply model	Demand model	Supply model
2017	948.26	968.89	948.33	968.29
2018	949.50	977.77	949.39	977.06
2019	949.00	981.83	949.06	981.97
2020	950.74	978.04	950.58	978.43
2021	949.91	975.21	950.00	975.09
2022	949.65	977.21	949.63	977.08
2023	949.84	978.21	949.84	978.19
2024	949.94	977.68	949.93	977.74
2025	950.02	977.08	950.03	977.10
2026	949.85	977.29	949.86	977.26
Average overall	949.67	976.92	949.66	976.82

Estimated Equilibrium Quantity and Price on World Natural Rubber Market

Lastly, this study estimated the equilibrium quantity and price on the world natural rubber market between January 2017 and December 2026 for monthly data using the demand and supply model in simultaneous equations and the predicted explanatory variables from a simple moving average technique. Then, this study calculated the average yearly equilibrium for quantity and price on the world natural rubber market from 2017 to 2026; the results are shown in Table 7.

Table 7
Average yearly equilibrium of quantity and price on world natural rubber market from 2017 to 2026

	Equilibrium quantity		Equilibrium price	
	Actual predicted data	Percentage change	Actual predicted data	Percentage change
	(Thousand tonnes)	(Thousand tonnes)	(Thousand yen)	(Thousand yen)
2017	953.75	953.65	169.78	170.49
2018	957.01	956.74	150.13	150.54
2019	957.71	957.79	153.97	153.51
2020	957.99	957.98	170.35	170.19
2021	956.64	956.67	164.52	164.74
2022	956.97	956.93	160.47	160.53
2023	957.38	957.37	160.40	160.34
2024	957.31	957.32	162.85	162.79
2025	957.21	957.23	163.04	163.09
2026	957.15	957.14	162.05	162.08
Average	956.91	956.88	161.76	161.83

The results from the actual predicted explanatory variables showed that the average equilibrium of the amount of natural rubber tended to gradually increase for 10 years from 953.75 thousand tonnes in 2017 to 957.15 thousand tonnes in 2026, and the average over the 10 years was 956.91 thousand tonnes. The percentage change showed that the average equilibrium of the amount of natural rubber tended to increase from 953.65 thousand tonnes in 2017 to 957.14 in 2026, and the average over the 10 was 956.88 thousand tonnes. The gradual increase in the equilibrium of the amount of natural rubber in the next 10 years relates to the world economic slowdown and automotive industry sluggishness. Natural rubber is the main raw material in the automotive business, especially in tires, so automotive business sluggishness results in only a slight increase in natural rubber demand on the world market.

The equilibrium in the world natural rubber price tended to decrease for 10 years from 169.78 thousand yen in 2017 to 162.05 thousand yen in 2026 for the actual predicted data, and to reduce from 170.49 thousand yen in 2017 to 162.08 thousand yen in 2026 for the percentage change. The average over the 10 years was 161.76 thousand yen and 161.83 thousand yen, respectively. The equilibrium reduction in the world natural rubber price relates to the continuous decrease in the crude oil price and thus the synthetic rubber price.

Conclusion

In this study, we developed demand and supply models to forecast equilibrium in amount and price on the world natural rubber market using monthly data from 2004 to 2015 with a three-stage least square technique and simultaneous equations. Two equations were developed to estimate demand and supply, respectively.

The explanatory variables in the demand model with a positive relationship were Qs, SRPRICE, YGDP in the past six months, and CNY, while there was a negative relationship for NRPRICE in the past six months. The explanatory variables in the supply model with a positive relationship were NRPRICE in the past six months, MAREA_TH, RAINFALL_TH, and CPETRO, while there was a negative relationship for STOCK and UPRICE in the past six months.

The explanatory variables, which affect the demand and supply model using the monthly data for the period of 2011–2015, were predicted in 2017–2026 using a simple moving average technique. Using the actual predicted data of explanatory variables, the explanatory variables which tended to increase were Qs, YGDP, CNY, STOCK, and MAREA_TH. All predicted data gradually increased from 2017 to 2026. The predicted data of explanatory variables which tended to decrease were SRPRICE, UPRICE, and CPETRO. All predicted data gradually decreased from 2017 to 2026. The RAINFALL_TH value tended to be stationary as predicted in the data from 2017 to 2026. The accuracy of the explanatory variables was considered in the fitted model using MAPE, since most people are comfortable with thinking in percentage terms and it is easy to compare and interpret. All MAPE values in this forecasting were in the acceptable range, except for YGDP, CPETRO, and RAINFALL_TH, which were higher than the other variables.

The predicted explanatory variables in the demand and supply models were used to estimate the equilibrium quantity and price on the world natural rubber market between 2017 and 2026. The predicted equilibrium amount of world natural rubber tended to very gradually increase and the equilibrium world natural rubber price tended to decrease for the next 10 years.

From the results of this study, the predicted values for Qs, STOCK and MAREA_TH tended to increase in the next 10 years and this directly impacted the increase in the amount of world natural rubber, while the predicted CPETRO and SRPRICE values tended to decrease for the next 10 years and this directly impacted the world natural rubber price decreasing.

Recommendation

The natural rubber stakeholders, especially the governments, in the important natural rubber exporting countries, should co-operate in planning and setting up appropriate natural rubber policies, involving setting a suitable area of natural rubber plantation in each country and defining appropriate alternative crops and their areas in each country. Setting a suitable area of natural rubber plantation in each country would help to balance supply and demand on the world market which would impact natural rubber price stabilization in the future. Defining appropriate alternative crops and their areas in each country would help to increase alternative income for farmers. Appropriate alternative crops should be considered based on the topography, weather and soil in each country, especially with regard to achieving sustainable alternative crops in the future.

Future Study

Further study could develop a suitable model for forecasting the appropriate area of natural rubber plantation in the important natural rubber exporting countries, especially in Southeast Asia, such as in Thailand, Indonesia, Vietnam and Malaysia, for matching with the natural rubber quantity and price on the world market in the future.

Conflict of interest

There is no conflict of interest.

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