THE NATURAL RUBBER PRODUCTION, CONSUMPTION AND PRICE ANALYSIS IN SELECTED ASEAN COUNTRIES AND WORLD MARKET

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ABSTRACT

THE NATURAL RUBBER PRODUCTION, CONSUMPTION AND PRICE ANALYSIS IN SELECTED ASEAN COUNTRIES AND WORLD MARKET

Fong Yi Chiun

Imbalance of the supply-demand in the natural rubber (NR) market has been happening especially during the recent years where the consumption far exceeded production. It is said that NR market can no longer be explained solely by the fundamental factors (supply and demand), which involves others external causes. For example, world crude oil price, synthetic rubber (SR) price and real exchange rate. The emerging China economy has impacted the NR market too. Therefore, Shanghai NR price would act as an important indicator in the NR market. General objective of the study is to develop 3 models namely the NR production, consumption and price in particular ASEAN countries as well as in the world market. Panel data analysis will be employed the NR production model (Thailand, Indonesia, Malaysia, Vietnam, Myanmar) and NR consumption model (China, India, Japan, USA), by using annual data from 2004 to 2017; VECM will be employed for NR price model, with the estimation period from January 2008 to December 2017. Results indicated (1) in the production model, NR price and total planted area of NR are both having positive relationships with NR production; (2) in the NR consumption model, NR price and NR stock are both having negative relationships with NR consumption; (3) in the NR SMR20 price model, NR world production, Shanghai NR price and SR price are positively related to NR SMR20 price, while NR world consumption is negatively related with NR SMR20 price. Besides, sustainability of NR industry has always been a policy issue especially in producing countries. Government should implement policy to enable the stable and sustainable growth of NR in the countries. Future studies could analyze other emerging NR markets or countries by extending the sampling period as well as adding more relevant variables prior to data availability.

Keywords: Production, Consumption, Price, Panel Data, VECM

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APPROVAL SHEET

This dissertation entitled "THE NATURAL RUBBER PRODUCTION, CONSUMPTION, AND PRICE MODELS IN SELECTED ASEAN COUNTRIES AND WORLD MARKET" was prepared by FONG YI CHIUN and submitted as partial fulfilment of the requirements for the degree of Master of Philosophy in Faculty of Accountancy and Management at Universiti Tunku Abdul Rahman.

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SUBMISSION OF DISSERTATION

It is hereby certified that **FONG YI CHIUN** (ID No: **1705668**) has completed this dissertation entitled "THE NATURAL RUBBER PRODUCTION, CONSUMPTION, AND PRICE MODELS IN SELECTED ASEAN COUNTRIES AND WORLD MARKET" under the supervision of **DR. AYE AYE KHIN** from the Department of Economics, Faculty of Accountancy and Management, and **DR. LIM CHEE SEONG** from the Department of Economics, Faculty of Accountancy and Management.

I understand that the University will upload softcopy of my dissertation in pdf format into UTAR Institutional Repository, which may be made accessible to UTAR community and public.

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(**FONG YI CHIUN)**

DECLARATION

I **FONG YI CHIUN** hereby declare that the dissertation is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

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LIST OF ABBREVIATIONS

2SLS	**Two Stage Least Square**
3SLS	Three Stage Least Square
ADF	Augmented Dickey Fuller
ANN	Artificial Neural Network
ANRPC	Association of Natural Rubber Producing Countries
ARIMA	Autoregressive Integrated Moving Average
ASEAN	Association of Southeast Asian Nations
BNM	Bank Negara Malaysia
BPLM	Breusch-Pagan Lagrange Multiplier
CLRM	Classical Linear Regression Model
CPETRO	Crude Oil Price
DF	Dickey-Fuller
ECM	Cointegration Equation
FEM	Fixed Effect Model
GDP	Gross Domestic Product
GRM	Global Rubber Market
IMF	International Monetary Fund
IPIW	World Industrial Production Index
IRSG	International Rubber Study Group
JB	Jarque-Bera
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
MAREA_TH	Natural Rubber Plantation

MARMA	Multivariate Autoregressive Moving Average
NR	Natural Rubber
NRPRICE	Natural Rubber Price
OECD	Organization for Economic Co-Operation and Development
OLS	Ordinary Least Square
OPPRICE	Palm Oil Price
PMG	Pool Mean Group
POLS	Pooled Ordinary Least Sqaure
PP	Phillip-Perron
PRW	Natural Rubber World Price
PSR	Synthetic Rubber World Price
RAINFALL_TH	Rainfall
REM	Random Effect Model
RMSE	Root Mean Square Error
RSRW	Natural Rubber Stock Ratio
SARIMA	Seasonal ARIMA
SICOM	Singapore Commodity Exchange
SMR20	Standard Malaysian Rubber Price
SRPRICE	Synthetic Rubber Price
SR	Synthetic Rubber
STOCK	Natural Rubber Stock
SVM	Support Vector Machine
TOCOM	Tokyo Commodity Exchange
USA	United States of America
USD	US Dollar

VAR	Vector Autoregressive
VECM	Vector Error Correction Method
VIF	Variance Inflation Factor
DW	Durbin-Watson
RMSE	Root Mean Square Error
MAPD	Mean Absolute Percentage Deviation

CHAPTER I

INTRODUCTION

1.0 Introduction

I discusses the background of the study and the current situation of natural rubber (NR) in ASEAN and the world market. Then, it is followed by the problem statement, research objectives and research questions of the study. Besides, the significance of the study will be described and the organization of the study is the end of this chapter.

1.1 Background of the NR Market

Fundamentally, NR is made from latex that is obtained or tapped from a certain species of plant (Sundaram, 2010). That particular species of plant is known as *Hevea Brasiliensis,* where almost 99 per cent of the production of NR use latex that is obtained from *Hevea* trees (Woodford, 2017). Latex is obtained through a method called "tapping" on the *Hevea* tree by making a long cut (Chanchaichujit & Saavedra-Rosas, 2018). Moreover, *Hevea* trees consist of an economic life span of approximately 32 years of plantations. Throughout the period, it requires well-drained and well-weathered soils and it takes around six years from initial planting to first commercial production.

Hevea were originally found in Brazil and its seeds were familiarized and circulated to Southeast Asia Countries during late 19th century especially in Thailand, Malaysia and Indonesia (Priyadarshan & Clement-demange, 2004; Khin & Thambiah, 2014). In Southeast Asia countries, there was no specific tapping season as compared to other four-season countries which will ultimately affect the production of NR. Thus, due to the optimal conditions for *Hevea* trees, there were large scale plantations in many parts of mainland Southeast Asia countries. They were also expanding rapidly and cultivated widely after the introduction of *Hevea* trees. Production of NR in Southeast Asia had increased by almost 1500% from just around 300,000 tonnes in 1961 to over five million tonnes in 2011.

In the rubber industry, overall, two kinds of rubbers are being utilized. There are NR and synthetic rubber (SR). NR, as mentioned, it is derived naturally from latex obtained from *Hevea* trees. It is being utilized diversely in numerous industries due to both of its advantageous physical and chemical characteristics (Herath, Samita & Wijesuriya, 2012). Such useful features include heat resistance, flexibility as well as the elasticity which make NR become one of the most significant agricultural commodities. Thus, it is also playing a vital role to contribute to the economic development especially in NR producing countries.

On the other hand, SR is recognized as the substitute product of NR which would influence the NR market (Soontaranurak & Dawson, 2015). Rubber in its native form could be said as useless unless certain chemicals are

added to produce wide-range rubber products. SR is substituted for NR in many events. SR can be as hard as a bowling ball or as resilient as a rubber band or as soft as a sponge, depending on the chemicals added and the properties associated with it. Nowadays, there is approximately 70% of all rubber used are one from many SR varieties. However, alternatives to NR are still limited as SR produced from petroleum refining does not match its resilience, elasticity, and abrasion resistance (Mooibroek & Cornish, 2000).

1.2 Current Situation of the ASEAN and World Natural Rubber Market

1.2.1 Natural Rubber Production

Table 1.1 NR Production ('000 tonnes)

Year	*Thailand*	*Indonesia*	*Malaysia*	*Vietnam*	*Myanmar*
2013	4170.00	3237.00	826.50	949.10	176.90
2014	4324.00	3153.20	668.10	953.70	198.00
2015	4473.25	3145.40	721.55	1012.70	212.10
2016	4469.00	3208.10	673.55	1032.10	229.90
2017	4755.00	3409.00	738.80	1086.00	249.10
% of World Total NR Production (2017)	***36%***	***25%***	***6%***	***8%***	***2%***

Source: IRSG (2017)

The production and consumption of NR have been increasing gradually with slight fluctuation. NR production and consumption have been already

growing gradually since the 1990s. It is because of the upturn in the innovation and world technology during that period especially for the manufacturing of vehicles that require tonnes of NR for the production of car, truck and aircraft tires (Umar, Giroh, Agbonkpolor & Mesike, 2011).

Table 1.1 reveals the NR production in selected ASEAN countries from the year 2013 to 2017. Statistics by International Rubber Study Group (IRSG) showed that among the NR producers, the top five NR producing countries are known as Thailand, Indonesia, Malaysia, Vietnam and Myanmar. Percentage of the world total NR production is computed as of 2017. It shows that Thailand produced almost 36% of the world NR which is the world top NR producer. All the top five producing countries together contributed 77% of the world total production of NR; while the remaining 23% of the production was produced by other producing countries. It includes Cambodia, Philippines, Sri Lanka and many other European countries that only produced a little amount of production as compared to the top five producers, therefore, they are not included in the reporting table.

Overall, we can see that the productions of NR were increasing steadily over the years, where Thailand and Indonesia continued to hold the top position as NR producer in the market. Except for Malaysia where its production started to drop from the year 2011 onwards even until now. According to Naidu (2016), it could be due to several factors such as overstock, oil price issue, economics situations in both rubber consuming and producing countries in the world, which all led to the decrease in the production of NR in Malaysia. Besides, Malaysia

was among the countries which cut down production and at the same time increased its consumption. And, from the table, we can see that even Vietnam had already surpassed the production of Malaysia. This issue will become one of the research problems that will be discussed later.

Moreover, NR market in Malaysia is anticipated to have higher demand and trade in early 2018 mainly because of the better weather conditions especially in major NR producing countries as well as the upsurge in the global oil price (GRM, 2018). Furthermore, it was also revealed that the NR world production has increased by 0.85 million tonnes in 1-year time, from 2016 to 2017 (ANRPC, 2018). Approximately 90% of the world supply of NR originated from the member countries of ANRPC. Also, it is anticipated that the global NR supply will reach 13.8 million tonnes in 2018. The slow production growth in 2018 might be mainly due to the lower production growth in Thailand, which is at 4.375 million tonnes that have been decreased by 1.2% on a year to year basis. However, the NR market in Vietnam is now growing steadily when its export capacity increased significantly especially in 2017. It even hit a new peak of the historical statistics in the same year, in August 2017 (GRM, 2018).

1.2.2 Natural Rubber Total Planted Area

Table 1.2 Total Planted Area of NR ('000 hectares)

Year	*Thailand*	*Indonesia*	*Malaysia*	*Vietnam*	*Myanmar*
2013	2708.30	3492.00	1057.50	920.10	567.90
2014	2816.60	3606.00	1071.10	977.70	603.30
2015	3769.70	3621.00	1078.60	981.70	650.80
2016	3734.40	3639.00	1072.90	976.10	680.00
2017	3730.00	3659.00	1077.80	971.00	655.50

Source: IRSG (2017)

Table 1.2 presents the total planted area of NR in selected ASEAN countries which are also the major NR producing countries from the year 2013 to 2017. Over the years, the total planted area of NR in these five countries increases. This could be due to the favorable planting conditions especially in South East Asia countries as mentioned in the previous part. Thailand, Indonesia and Malaysia have been the top position in the world NR market and therefore, there are more hectares of plantation area as compared to Vietnam and Myanmar.

After lagging behind the world's primary NR producers for years, Vietnam's and Myanmar's NR markets are now developing faster than ever mainly due to the tremendous growth of global consumption and demand. In fact, over the last several decades, there is even more than one million hectares of land have been transformed to *Hevea* plantations in the areas of China, Laos, Thailand, Vietnam, Cambodia and Myanmar, where the *Hevea* trees were not habitually grown. Besides, there are also many entrepreneurs from China,

Vietnam, Malaysia, and Thailand starts to invest heavily in rubber plantations in non-traditional rubber tree planting areas such as Cambodia, Vietnam and Myanmar. They also start to discover and invest in some areas in their own countries like northeast Thailand and northwest Vietnam (Li & Fox, 2012). Plantation area is also expected to grow especially in Vietnam and Myanmar.

1.2.3 Natural Rubber Consumption

Table 1. 3 NR Consumption ('000 tonnes)

Year	*China*	*India*	*USA*	*Japan*
2013	9591.60	1433.10	2611.20	1667.60
2014	9031.20	1538.30	2787.20	1660.00
2015	8805.20	1533.60	2905.20	1587.40
2016	9250.90	1622.00	2843.80	1543.40
2017	9432.30	1678.60	2843.40	1555.50
% of World Total NR Consumption (2017)	***33%***	***6%***	***10%***	***6%***

Source: IRSG (2017)

Table 1.3 reveals the NR consumption in major consuming countries from the year 2013 to 2017. According to IRSG, the top four NR consuming countries in the world are China, India, USA and Japan. Percentage of the world total NR consumption is computed as of 2017. China consumes almost 33% of the total consumption of NR which indicates that China is the world top NR consumer. Other than the top four consuming countries, there is a total remaining of 45% of NR consumption, undoubtedly including the producing countries, European countries

and countries in Asia-Pacific. According to Li & Fox (2012), since 1900, the worldwide consumption of NR is already increasing at an average rate of 5.8% per year as it is a crucial commodity because the aircraft tires and truck tires are all made almost entirely of NR. However, the global consumption of NR is also expected to continue to grow, and rising prices in the immediate future are likely (Prachaya, 2015).

China, driven by the continuous development and enlargement of the automobile industry, absolutely holds the position as the biggest NR consuming country in the world. Besides, according to Global Rubber Market (GRM, 2018), China consumes 90% of NR in the manufacturing of radial tires and it is predicted that China would consume up to 5.8 million tonnes of NR by 2021. On top of that, Myanmar and Vietnam export 80% and 50% of the NR respectively to China for their continuous rising of demand, and the quantity is expected to be even higher in the near future as its demand is still increasing.

China, India and the USA were having an increasing consumption from the year 2010, with slight fluctuation indeed, most probably due to normal market forces and fundamental factors. However, Japan's consumption had been decreasing over time since 2010. According to Jacob (2017), this could be due to the currencies depreciation in Japanese Yen. The last quarter of 2016, Japan suffered a 13.5% depreciation against USD, which they need to spend more Japanese Yen to consume NR as compared to before. Therefore, this could be one of the reasons that Japan's consumption decreased overtime. According to ANRPC, NR world consumption in 2017 accounted for a total of 12.9 million tonnes. In the

following year, the global demand for NR is anticipated to have a 2.8% growth and it is expected to reach 13.33 million tonnes of consumption.

1.2.4 NR SMR20 Price, Shanghai NR Price and the SR Price

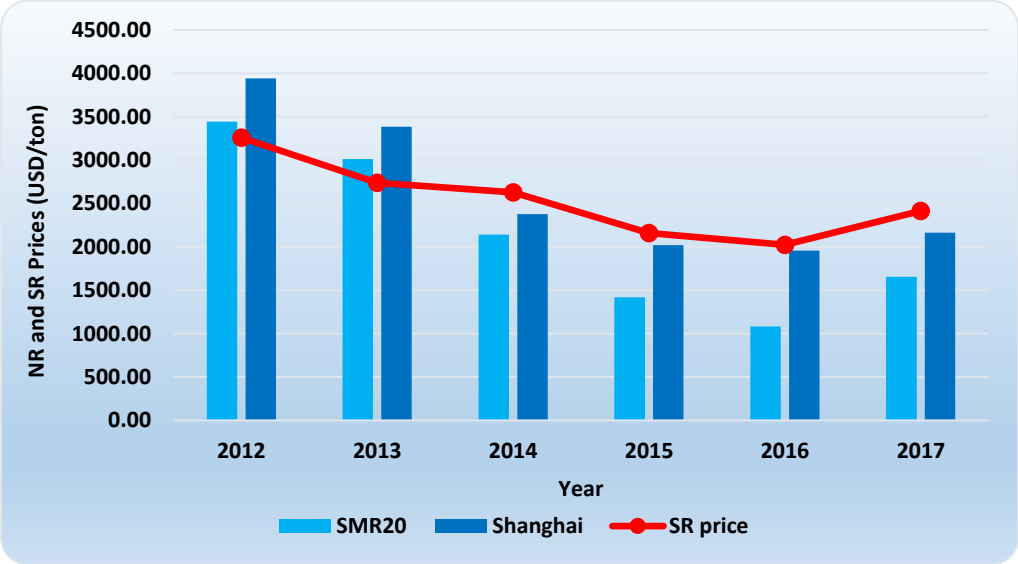


Figure 1.1 NR SMR20 Price, Shanghai NR Price and SR Price

Source: IRSG (2017)

Figure 1.1 illustrates the trends of two NR prices, namely the Standard Malaysia Rubber price (SMR20) and the Shanghai NR price, as well as the world SR price from the year 2012 to 2017. From the graph, we can see that there are decreasing trends of all the rubber prices in recent years. However, it is believed that the factors behind the current low price of NR are not only the economic fundamentals (supply-demand) anymore. Normal supply-demand market forces can no longer explain the NR price in the world market. It is indeed affected by many external factors. For instance, the reduction in production in Thailand, Malaysia and Indonesia are anticipated due to low NR

prices, climate change problem compounded by unusually heavy rains in northern Thailand (Mahpar, 2017).

Moreover, due to the falling of global crude oil price, NR is facing severe competition from the SR which is a petroleum-derived product. Thus, the declining price of crude oil boosted SR production, and it also becomes cheaper which leads to an increase in the usage of SR substantially (Joseph, 2015). So, even if there was also a decreasing trend of SR price, but the NR prices show a steeper trend than SR price, which means that NR prices decrease more than SR price. Besides, the economic slowdown in both developed and developing countries also contributed to the price instability of NR ever since the global financial crisis in the year 2008. The decline in NR price, due to many factors, have made the NR sector less profitable especially for smallholders. Smallholders started to switch to other commodities which are more profitable such as palm oil. Linking up all those factors together, it explains why there is a decreasing trend in the NR prices.

1.2.5 NR Price and Real Exchange Rate

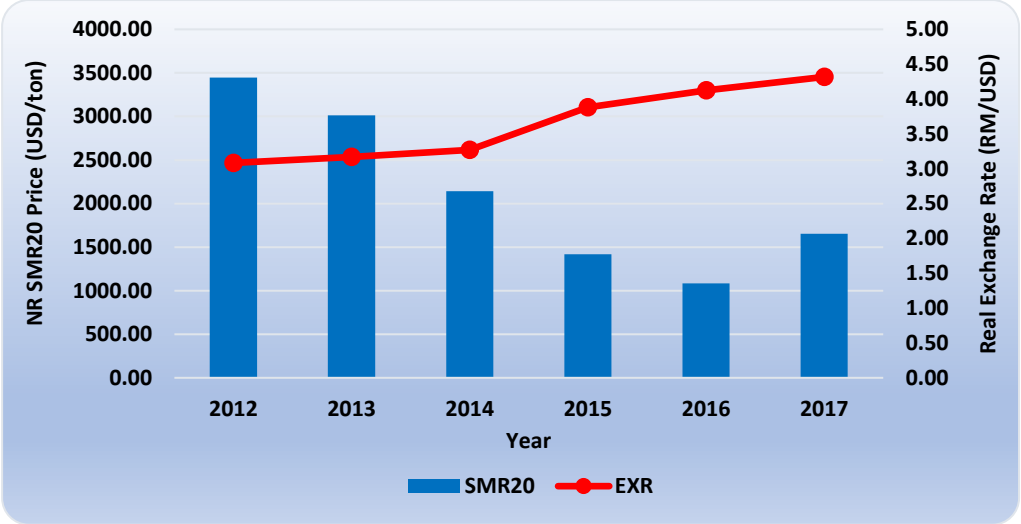


Figure 1.2: NR SMR20 Price and Real Exchange Rate

Source: IRSG (2017)

Figure 1.2 illustrates the trend of NR SMR20 price and the exchange rate (USD/RM) from the year 2012 to 2017. It shows that the NR price and exchange rate move in the opposite direction, which means that both of the variables are negatively related (Mdludin, Applanaidu & Abdullah, 2016). The exchange rate variability due to the crisis also causes fluctuation in the NR price, making it more volatile than ever before (Raju, 2016). The upward sloping curve of exchange rate indicates that the Malaysian Ringgit (RM) depreciates against US Dollar (USD), which means that we need to pay more amount of RM for 1 USD, thus the NR price would be decreased (Khin, Zainalabidin & Nasir, 2011).

Since the commodities including NR is being traded-in USD in the world market, any fluctuation in the exchange rate will have an impact to the rubber-producing and exporting countries such as Malaysia, either directly or indirectly

(Burger, Smit & Vogelvang, 2002). The changes in exchange rate impact on the export price in the rubber exporting countries directly; while the indirect impact came from provisional demand, which could be either commodity tentative or foreign exchange tentative. Moreover, in the short term, the movements of the exchange rate could cause the NR price to fluctuate. However, this type of impact on price will not have an immediate effect on the supply and demand for NR. On the other hand, in the long term, the volatility of the exchange rate will affect the supply and demand side of the NR market.

1.2.6 NR Price and Crude Oil Price

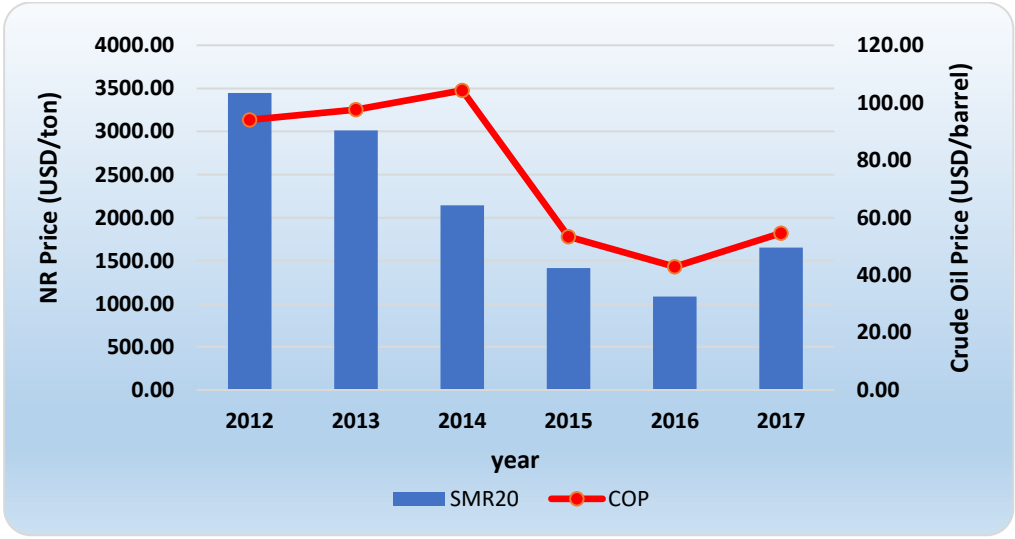


Figure 1.3: NR SMR20 Price and Crude Oil Price

Source: IRSG (2017)

Figure 1.3 demonstrates the movement of NR SMR20 price and crude oil price from the year 2012 to 2017. Crude oil is one of the most important commodities in the world. It is having an impact on most of the other commodities market too, including food and agricultural commodities such as

NR market. Zhang & Qu (2015) investigated the effect of oil price shocks on different agricultural commodities in China. It is proved that among other agricultural commodities, NR is more sensitive to the rise in crude oil price. According to theory, crude oil price and NR price are moving together in the same direction, which means that they are positively related. Romprasert (2011) and Khin *et al.* (2011) both found out that world crude oil price is the primary indicator of the price trend of NR.

Crude oil is the key raw material in SR's production. It means that any fluctuation in the crude oil price will impact the SR price directly. For instance, when the crude oil price rises, the production cost of SR increases which will drive up SR price. As NR is the substitute product of SR, when SR price rises, consumers tend to switch their preferences to NR instead of SR. Therefore, over time, the NR price will increase. However, referring to figure 1.3, data from 2012 to 2014 do not show a positive connection between both of them, which could be due to the oil price shock happened from 2008. The crude oil price had been unstable and highly volatile during that period and had affected the NR market severely. Rise of the crude oil price from 2016 onwards positively affected the NR price to increase back.

1.3 Problem Statements

NR industry has been a substantial industry, particularly in the producing nations. NR is also a crucial agricultural commodity which is utilized in the manufacturing of a wide range of goods and products that are useful for our daily

lives such as tires, gloves, catheters, footwear and so on. Besides, according to Industrial Rubber Goods (2017), NR is acting as a vital role for most of the NR producers as one of the contributions to economic growth. NR industry has an impact on socioeconomics aspect especially in the NR producing countries who at the same time are considered as developing countries too.

For the production side, there is almost more than 20 million families are reliant on the NR market for their foundations for living. For instance, according to Sharib & Halog (2017), approximately 92% of the rubber plantation is managed by smallholders in Malaysia. It also indicates that NR industries are not only contributing to the nations' economic growth and development but also contributes to the primary earning for the smallholders of NR. However, production of NR has been severely affected by the unfavorable weather condition in recent years. For example, unseasonal downpours that ended up with flood which hindered the latex collection and eventually, reduced in production. When the NR market started to underperform, farmers and smallholders tend to switch to another crop such as palm oil which might have a better market as compared to NR. This has further hurt the NR market, especially on the production side.

For the consumption side, the major problem is the overconsumption of NR in the world market. According to the latest statistic from ANRPC, during the first four months of 2019, global production of NR has fallen 5% compared to previous years about 3.9 million tonnes of total volume decreased. While for consumption, it rises 1% compared to previous years and it is recorded at 4.591 million tonnes. It shows that there are around 0.5 million tonnes of consumer surplus in 2019. It is

mainly due to the booming automobile industry especially in China and India who are among the biggest consumers of NR in the world. Both of the countries consume almost 40% of the total NR consumption (refer back to table 1.3). Moreover, another reason for the upsurge of NR consumption is that the increase of world crude oil price. When oil price rises, it means that SR price will rise too, as the main input cost has risen. It indirectly reduces the competitiveness of SR as compare to NR which makes NR even more favorable to consumers. Eventually, problems arise from both producing and consuming sides have caused the imbalance of production and consumption in the NR market.

On the other hand, the volatility of NR price had caused the imbalance of the world NR production and consumption. Decreasing of NR price discouraged farmers to continue tapping of latex, while on the other side, the low price becomes favorable for consumption. For the NR consuming countries (refer to table 1.3), we can see that all the top four rubber consumers increase their rubber consumption over years until 2017 except for Japan which decreases its consumption due to factor such as currency problem. The rising consumption has already exceeded the supply of NR causing the imbalance in the market. For instance, in India, according to ANRPC (2017), the consumption and import of NR reach a new peak in the provisional data for 2017-18. Besides, the Rubber Board of India also revealed that the NR production rise by 0.4% while at the same time the consumption increased by 6.4%. It could be due to the favorably NR price that drives up the consumption instead of production.

Besides, the volatility of NR price had been affecting the NR market itself as well as farmers and smallholders whose income is narrowing down (Ahrends, Hollingsworth, Ziegler, Fox, Chen, Su & Xu, 2015). Recently, the NR price and production have fallen and also was the lowest as compared to five years ago. It caused the farmers to even stop tapping due to low income, and directly slowing down the growth and productivity in the industry. For instance, Malaysia was hit by the decline of nearly 70% of the NR price (Naidu, 2016) which is falling too much and too low for rubber tappers to continue tapping for living. According to Raju (2016), NR price volatility has an impact on their income level in the long run and it will influence the plantation and production to be even more difficult for them to continue.

Moreover, there has been a severe competition between NR with its substitute product which is SR. Crude oil is important in the production of SR, and therefore NR price moves when crude oil price fluctuates (Varma, 2018). When crude oil price rises, it means that the SR price will rise too, and NR will become cheaper than SR and more favorable for consumers. Although SR is said to be the close substitute of NR, however, in real life or practically, it is not. It is because there are still some differences in the characteristics of both types of rubber such as the resilient of heat, the flexibility and other factors. For instance, tire production especially aircraft tires and truck tires are almost entirely made from NR. This shows that not every rubber-made product can switch its input from NR and SR easily. As such, fluctuation of crude oil has made the NR price volatile.

Apart from that, to obtain findings and insights in the NR markets in both producing and consuming countries as well as in the world market, different research methodology will be performed in this study. Panel data models are conducted for NR production model and NR consumption model. The former includes the five primary NR producers while the latter includes the four major NR consumers. Panel data analysis would be a suitable methodology because this it combines cross-sectional and time-series data for investigation, which is the research interest in this study. This study aims to find out the variables that affect NR production and consumption in different countries over time. Therefore, panel data analysis is selected. The other method that will be performed is VECM that use only time series data for analysis. This would be suitable to study the NR price model as a whole, in the world market. By using monthly data, long-run and short-run relationships would be determined among variables by using this method.

In short, NR economy is very important for NR producing and consuming countries of the ASEAN and world market. It was strongly influenced by external factors such as the global economic slowdown and many other rubber-related factors. It includes crude petroleum oil price fluctuation, exchange rate volatility, time-lag, NR stock, NR production and consumption situation, NR price decreasing in a couple of years, slowing growth in agricultural productivity, as well as government policies in the different countries. NR economy needs a balance of both supply and demand sides for the stability of the NR market and development of NR price in the world market.

1.4 Objective of the Study

The general objective is to investigate the factors affecting the NR production, consumption and price models in selected ASEAN countries and world market.

The specific objectives are as follows:

1. To analyze the relationship between NR price and total planted area of NR with NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.
2. To examine the relationship between NR price and NR stock with NR consumption in China, India, Japan and the USA.
3. To explore the relationship between NR world production, world consumption, Shanghai NR price, real exchange rate, crude oil price and world SR price with NR SMR20 price.
4. To find out the directional causal relationships (unidirectional or bi-directional) between variables in each NR model.

1.5 Research Questions

1. Are total planted area of NR and NR price having an effect on NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar?

2. What are the relationship between NR price and NR stock with NR consumption in China, India, Japan and the USA?
3. Are there any relationship between NR world production, world consumption, Shanghai NR price, real exchange rate, crude oil price and world SR price with NR SMR20 price?
4. Are there any directional causal relationship running between variables in each NR model?

1.6 Significance of the Study

For NR production, the outcome of the study will contribute to the policymakers and government policy implication on NR industry, especially in NR producing countries which the industry is one of the main contributions to its countries economic development. It is important to ensure the production stability of NR in producing countries by balancing both supply and demand side to enhance the rubber economy. Furthermore, the effectiveness and sustainability of the rubber economy will be ultimately benefiting farmers' and smallholders' livelihood in rural areas. Therefore, sustainable production of NR is a significant aspect not only to the country's economic position but also to the standard of living of the smallholders (In, 2012; & Karunakaran, 2017).

For consumption, the results of the study will be the interest of businesses or organizations in manufacturing industries such as tires, gloves and other products that require rubber as raw material. It contributes to the business decision-making process when they are now having more new

information about the NR trends and prices in the recent years. This information is crucial for those industries such as the automobile industry to implement business strategies to best fit their company situation. Majority of the NR consumption is in the production of car tires. Industries like automobile concern about the price of NR as it may affect the production cost and pull up the price of the finished product (Sudiyana, 2015).

Moreover, consuming countries should be aware of the issue of overconsumption of NR in the market. By over consuming NR, it has further enlarged the gap between the falling production and rising consumption. The outcome of the study would act as a warning or reminder to the government policy implementation in consuming countries to look into this serious issue. Consuming countries could invest in the new plantation area and replantation area in home countries. Also, continuous of research and development in the plantation and cultivation of *Hevea* trees can be done to discover the best or alternative way to cultivate NR plantation even if it might be four-season countries where tapping of latex will be only limited to a certain season. Hence, the government of consuming countries should take action on the issue based on the outcome of the study.

Besides, it is important to know that the relationship between NR and SR prices, especially for those businesses that can switch their input material between these two types of rubber. For instance, NR accounts for approximately 50% in the production of tire manufacturers. It is crucial that when the NR price is instable, which will reduce the profit margin of the

manufacturers. As such, they can change their input material by shifting to SR as alternative raw material to secure their profit earning (Chawla & Jha, 2009). Moreover, in recent years, the relationship between NR and SR seems to be varying compare to the historical and theoretical relationship which could be due to other external factors. As such, they would need the information to adjust their production by using NR or SR. The movement of rubber prices will ultimately affect their input costs and the selling price, which will then trigger their revenue and profit (Petchseechoung, 2016).

On the other hand, there are several study gaps in this research. Firstly, it will be the research methodology of the study. It is found that there are fewer researchers using panel data analysis to study the NR market in different countries. Majority of the literature focuses only on forecasting, cointegration and other tests to find out the relationship between the studied factors in the NR market; but very fewer works of literature are found to employ panel data analysis in this field. By extension, the researchers that study the NR market tend to focus only in one country, for instance, they investigate the NR market in Thailand, Malaysia, or as a whole, in the world market.

Some examples of study such as the study by Arunwarakorn, Suthiwartnarueput & Pornchaiwiseskul (2017), Khin & Thambiah (2014), Kannan (2013), which all of these studies only focus on one country. However, in this study, the NR market in different countries will be studied rather than only one country. For example, NR producers such as Thailand, Indonesia, Malaysia, Vietnam and Myanmar will be studied using panel data analysis; for NR

consumption, top 4 consuming countries namely China, India, USA and Japan will be studied using panel data analysis too. Clearly, it shows the gap of study which the countries chose to be studied and the research methods are different.

Moreover, there are many pieces of research in the same field studied the association between crude oil and NR price because NR price always follows the trend of crude oil. However, since crude oil is the major ingredient of the production of SR, it might be better to study the relationship between NR price and SR price. Therefore, in this research, SR price will be set as one of the independent variables in the NR world price model. There are a few works of literature that try to analyze the relationship between NR and SR price.

Furthermore, another new variable added in this research is the Shanghai NR price. According to Jacob (2017), there are several major future exchanges in the NR market which include Bangkok, Singapore, Tokyo and also Shanghai future exchange. Crude oil prices influence the decision of speculative investors in the futures market of NR that identify SR as the substitute of NR. Therefore, when crude oil prices change, they would monitor the oil trend and invest in either NR or SR based on possible substitution. Since China is the biggest consumer of NR in the world, therefore, Shanghai NR price could be one of the important factors influencing the world price too and worth investigating. There is very limited literature that investigates such relationship between Shanghai NR price and the NR world price.

1.7 Organization of the Study

Chapter I have clarified the NR market background and current situation of the world NR market. It also explained the problem statements, general and specific objectives, research questions, significance of the study and ended with the layout of the study.

Chapter II will be delivering the theoretical reviews on the price theory and the theory behind the NR market supply and demand, followed by the empirical reviews of the previous studies on the production, consumption and price of NR, as well as the empirical reviews of the research methods of the study.

Chapter III reveals the research methodology which first explaining the variables and equations of the major models, followed by the conceptual framework, research hypotheses, research procedure and data collection. Lastly, all the research methodologies will be discussed.

Chapter IV reveals the empirical findings from various research methods, including equations, interpretation, explanation as well as the tables or summary of the results and some graphical illustrations.

Last but not least, Chapter V concludes the study with a summary of research findings, discusses the limitation of the study and recommendations for the future research to further improve on the research on NR market.

CHAPTER II

LITERATURE REVIEW

2.0 Introduction

Chapter II reveals the theoretical reviews of the world NR production, consumption and price theories, and analyses the empirical reviews based on the previous studies which are related to NR production, consumption, and price, followed by a brief conclusion of this chapter.

2.1 Conceptual Reviews

2.1.1 Conceptual Framework for NR Production Model

Figure 2.1 reveals the factors for the world NR production. NR price (NRPRICE) is estimated to positively influence the NR production. It is because when NRPRICE increases, it will motivate the farmers to produce more to increase their income. NR stock (STOCK) is negatively related to NR production which can be explained as when stock increases; the price of NR will fall, which will then decrease the production as well. Besides, NR plantation (MAREA_TH) and the rainfall (RAINFALL_TH) both influence the NR production positively. When there is a more mature area that is suitable for rubber plantation, it directly affects the production and supply positively, and also increase the rubber supplier in the world market; rainfall is one of the crucial elements that affect the growth of rubber trees, thus when rainfall increase, rubber supply will rise as well. Urea is used as

fertilizer to help ingrowths of the rubber tree. When urea price increases, the input cost will rise and farmers will then reduce the usage of fertilizer, which will then affect the supply and production of rubber negatively (Arunwarakorn *et al.*, 2017).

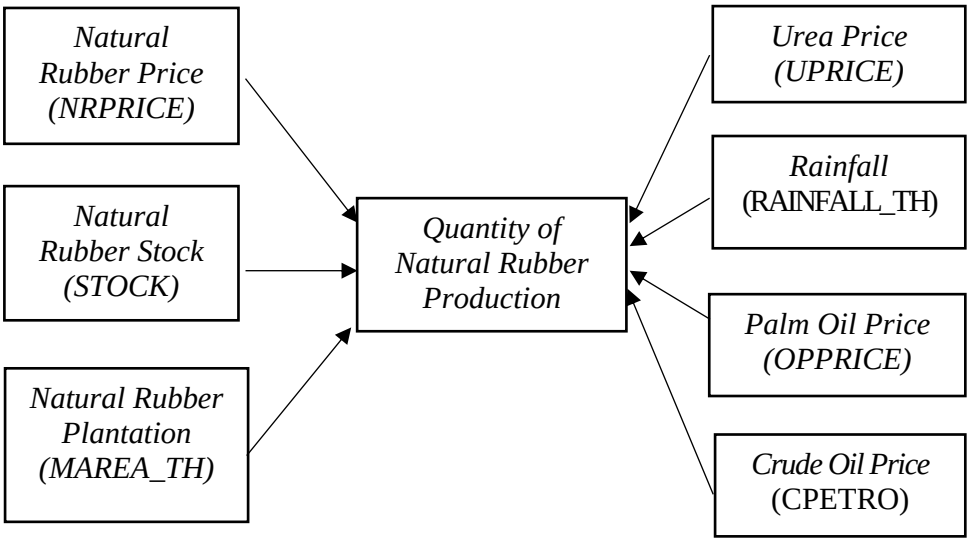


Figure 2.1 Conceptual Framework for NR Production Model

Source: (Arunwarakorn *et al.*, 2017)

Lastly, palm oil price (OPPRICE) and crude oil price (CPETRO) are predicted to negatively influence the production of NR. Palm oil is known as a substitute crop of rubber. When the price of palm oil increase, farmers will now switch to the plantation of palm oil instead of NR, thus rubber supply and production reduce. Crude oil is one of the key ingredients to produce SR. Therefore, when crude oil price increases, the cost to produce SR rises too, and it will then become more expensive, thus consumers will demand more NR. When rubber demand increase, the price will increase, therefore supply and production of rubber will rise as well due to the market forces (Arunwarakorn *et al.*, 2017).

2.1.2 Conceptual Framework for NR Consumption Model

Figure 2.2 shows the factors of the world NR consumption. NR production is said to be positively related to its consumption because when production increases, NR price will decrease which will trigger the demand and rise up the consumption. For SR, since it is the substitute product of NR, increase in SR price (SRPRICE) will have a positive impact on the NR consumption. It is because when SR price increases, consumer or manufacturer will switch to its alternative, which is NR where its price is now lower than SR. Hence, they will consume more NR to stabilize their cost and thus drive up the NR consumption (Arunwarakorn et al., 2017).

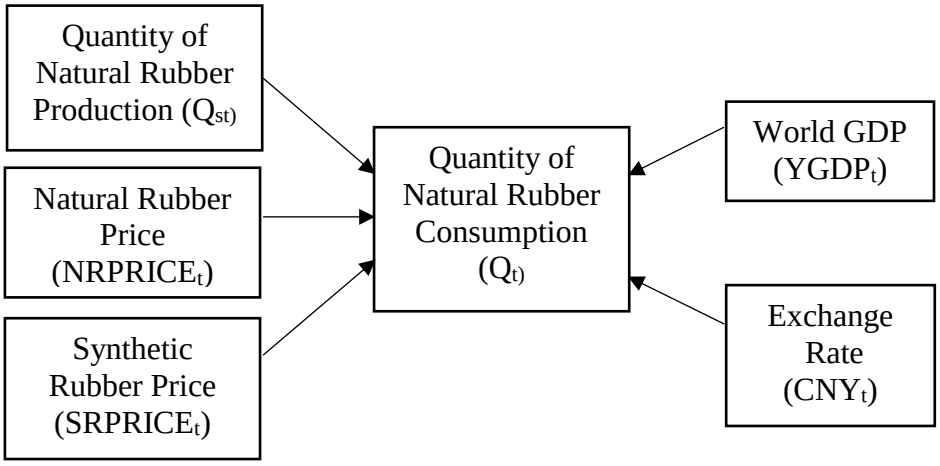


Figure 2.2 Conceptual Framework for NR Consumption Model

Source: (Arunwarakorn *et al.*, 2017)

Besides, exchange rate and Gross Domestic Product (GDP) are positively related with NR consumption. As consumers' income increase, they will consume more due to the increase in spending power; as exchange rate appreciates, the

product will now become cheaper than before, thus demand will increase as well. Because of the typical market force, when the price rises, demand will drop. Thus, NRPRICE is negatively related to NR consumption (Arunwarakorn *et al.,* 2017).

2.1.3 Conceptual Framework for NR Price Model

As shown in Figure 2.3 below, there are several elements that impact the NR world price (PRW), namely the SR world price (PSR), world industrial production index (IPIW), and also NR stock ratio (RSRW). It is known that SR and NR have been the substitute products for each other, thus PRW and PSR will be positively related, that is, when one of the product price rises, consumer can always choose another product with a lower price as a substitute, but when the product's demand increases, its price will also increase eventually. Industrial production index is an economic indicator which measures the output quantity from a particular industry. When IPIW rises, it will increase demand among consumers, thus the price will rise as well (Yusof, 1988).

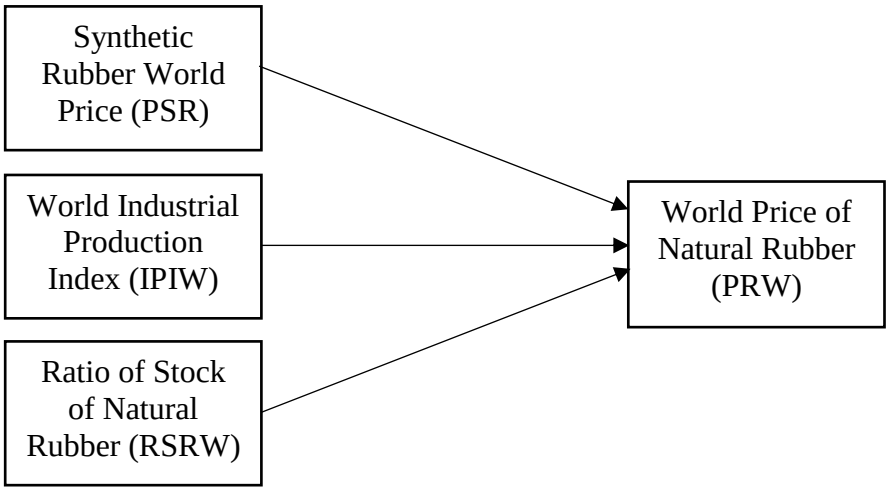


Figure 2.3: Conceptual Framework for NR Price Model

Source: (Yusof, 1988)

Therefore, PSR and IPIW are having a positive relationship as well. RSRW indicates the stock ratio of NR both in producing and consuming countries. It implies that when the stock in producing countries is more than the stock in consuming countries, rubber price will fall as the producing countries will lower their price in order to clear the stocks.

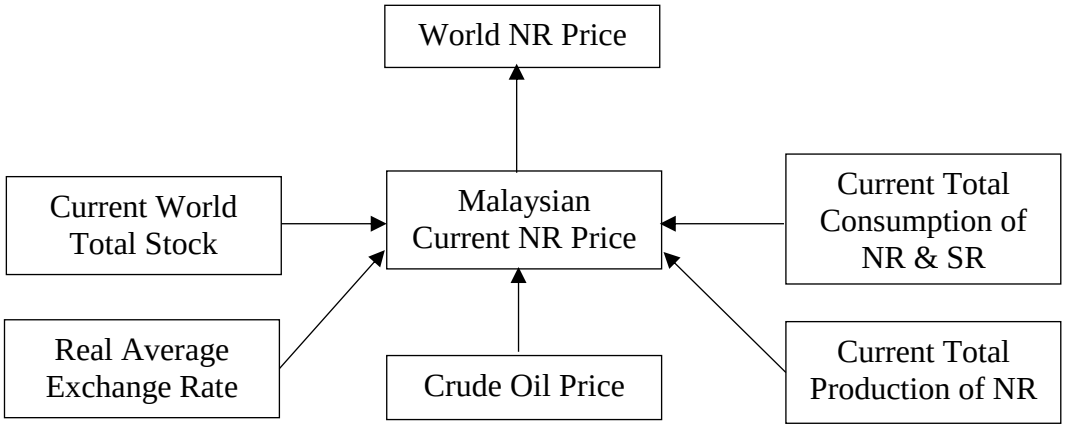


Figure 2.4: Conceptual Framework of Malaysia's NR Industry

Source: (Khin & Thambiah, 2015)

Figure 2.4 illustrates another NR price model developed by Khin & Thambiah (2015). In the study, authors aimed to provide a conceptual framework of VECM model of the supply, demand and price forecasting which can define particularly for the Malaysia's NR industry, as shown in the figure above. In the model, Malaysia NR price was the function of total production of NR, total consumption of NR and SR, NR world stock, real exchange rate as well as crude oil price. Eventually, it would represent the NR world price. This conceptual framework provides an initial idea for future researchers to have a perspective of the NR economy development, in general.

2.2 Empirical Reviews

2.2.1 Natural Rubber Production

Undeniably, NR industry acts as one of the economic growth indicator and plays an important role especially in producing countries. By using annual data from 1980 to 2012, Mdludin *et al.* (2016) conducted an econometric investigation of the Malaysia NR market to explore the factors behind the NR industries. Results indicated that government expenditure, time trend, hectare NR as well as price of palm oil affected NR production in the Malaysia market. NR production would decrease as palm oil price rise and government expenditure would be an incentive for the smallholder to increase NR production. Moreover, it is also found out that the domestic NR price was influenced by the world NR price and the domestic inventory. Besides, the lagged world NR price and the world price of crude oil were the significant causes of the world NR price.

Chawananon (2014) studied the dynamics of supply-demand of rubber and analyzed the factors affecting the rubber market in Thailand context. Estimation period of the study was yearly data from 1977 to 2012. Study found out that rainfall and expected price of rubber had the impact to the production of rubber in Thailand's market and it could be supported by Mesike & Esekhade (2014) and Arunwarakorn *et al.* (2017). Besides, it was also proved that expected rubber price and the production were related which could be supported by Mesike, Okoh & Inoni (2010). This could be clarified as when the price increased, smallholders and planters were to be stimulated to stay in the rubber market, instead of hoping to another agricultural crop. They would eventually produce and supply more rubber and to the market to satisfy the demand, and so, the rubber production escalates.

Another study done by Khin & Thambiah (2014) investigated the price behaviour of NR market in Malaysia. It aimed to choose the best and most accurate forecasting model by employing the simultaneous equations of supply-demand as well as a univariate model of ARIMA for the Malaysia NR price (SMR20). Quarterly data (Q1 1993 - Q4 2013) were employed for both models for analysis.

NR supply model showed that lag total rubber production and consumption were the important variables which accounted for 85% of the variation in the model. NR demand model showed that lag total rubber consumption and the rubber production were the significant aspects influencing NR consumption. It is also statistical significance at $\alpha = 0.01$ level. On the other hand, in the SMR20 price model, the lag SMR20 and the RSS1 price influenced the SMR20 price, explaining 93% of the model's variation; and for the RSS1

price model, the lag RSS1 and the SMR20 price affected the RSS1 price, accounted for 94% model's variation.

Kannan (2013) had studied the NR market in India to find out the various factors affecting the rubber production and export. Two models were developed which were production model and export model. Secondary data from 1991-92 to 2010-11 were collected and a simple Ordinary Least Square (OLS) was used to find out the connection between variables. It was found that, in the production model, the price had a direct impact on the production of NR, and results also proved that domestic price and the production of NR were positively related and was statistical significance at $\alpha = 0.05$ level. This was also supported by a recent study by Karunakaran (2017) and Khin, Lim, Kho, Wong, Lau & Goh (2020) who revealed that declined in NR production could be due to the volatility of NR price, which also had an impact on farmers' livelihood. Other factors that were influencing the rubber production were the export and stock of NR, which both of these variables were also having a positive relationship with rubber production. While for the export model, domestic price and stock negatively affected the rubber export, and world price and world population positively influenced rubber export.

Moreover, Khin *et al.* (2011) conducted a research to forecast the NR price in the Malaysia market and then compared the forecasting models according to their estimation accuracy. Estimation period from January 1990 to December 2008 were used, and the research methods used were Vector Error Correction Method (VECM), Multivariate Autoregressive Moving Average (MARMA), and

Autoregressive Integrated Moving Average (ARIMA). From the VECM model, results indicated that the NR price had a positive impact on NR production when there was an increase of 1% in NR price, it will lead to an increase in NR production by 0.16% with statistical significance at $\alpha = 0.01$ level. It was also supported by the recent research of Arunwarakorn *et al.* (2017) and Asselt, Htoo & Dorosh(2017). Besides, a recent study by Su, Liu, Tao & Lobont (2019) has also indicated that the NR production is affected by its price. It indicated the existence of a long-term positive relationship between production and price of NR. For MARMA model, when there was a 1% rise in NR price, it will escalate the NR production by 0.49% with statistical significance at $\alpha = 0.01$ level.

2.2.2 Natural Rubber Consumption

Fluctuations and variation of the NR price had been the crucial factor that hurt the NR market. Therefore, it was important to discover the reasons of the volatility of NR price. Therefore, Khin & Thambiah (2015) studied and forecasted the NR price by using simultaneous equation of supply-demand as well as the VECM model. Estimation period from Q1 1990 to Q4 2013 proved that NR production, consumption and the NR RSS1 price were the most important factors in the models. It was also found out that these variables were having association with the NR price.

Besides, it also proved that NR consumption was negative related with NR price at $\alpha = 0.05$ level. On top of that, cointegration equation showed that NR price and NR consumption were having a long run cointegrated relationship.

In short term, VECM equation suggested the existence of short term dynamics between NR price with its fundamentals (production and consumption), exchange rate as well as NR inventory.

Another study was done by Amoro & Shen (2012) also investigated the factors affecting the export of agricultural products specifically rubber and cocoa in Cote d'Ivoire. This study could support the finding by Abolagba, Onyekwere, Agbonkpolor & Umar (2010). The same methodology OLS and data period were used for this analysis. It was found out that the domestic consumption of NR negatively influenced the rubber export and it was statistical significance at $\alpha = 0.01$ level.

A previous research done by Khin *et al.* (2011) was aimed to compare the forecasting models of the short-term price of NR. Cointegration equation of VECM showed that the total NR production and consumption were the most significant variables in NR price model, which mean that long-term associations existed among these factors. Besides, the NR price had a negative relationship with total consumption of NR. When the NR SMR20 price increased by 1%, it led to a decrease of 0.71% in the total consumption of NR and SR. Results from MARMA model indicated that there was also an adverse effect on the total world stock of NR and the price. 1% increase in the price of NR SMR20 will decrease the total world stock by 0.45% and was significant at $\alpha = 0.01$ level.

Abolagba *et al.* (2010) explored the elements of exports of agricultural in Nigeria, specifically cocoa and rubber for this study. Annual data from the year

1970 to 2005 were collected and a simple OLS was employed. The factors investigated in this study included NR output or supply, producer price and the world price of NR, exchange rate, interest rate, rainfall, as well as domestic consumption of NR. Results from the OLS indicated that production and price of rubber as well as the interest rate were positively related with rubber export; while exchange rate and domestic rubber consumption were negatively associated with rubber export. All variables except world price of rubber were the significant factors in the model studied and were the major determinants of export of NR.

In short, after studying the above literature in the production and consumption models, the methodologies used in the previous researches include simultaneous equation of supply-demand, simple OLS as well as VECM model. Most of the tests were aimed to find out the relationships between variables in the NR production models. A simple OLS only provides a simple regression and relationships between variables with basic interpretations. Simultaneous equation can find out the relationships between two equations namely the supply and demand equations of NR while VECM model estimated the short-run and long-run relationship between variables in the models. As mentioned in previous chapter under significance of study, there is very little literature that employed panel data analysis to study NR models. Panel data model can study the variable in different entities (countries) in different time frame. After studying and reviewing the previous literature, it is found out that panel data model could be an appropriate model to adhere to the research objectives and research problems of this study.

2.2.3 Natural Rubber Price

Other than fundamental factors (production and consumption), there are many external factors that actually influence the NR price directly or indirectly. For instance, volatility and fluctuation of the exchange rate could affect the NR price because almost every agricultural commodity including NR are traded in US dollar (Khin, Wong & Ung, 2016). Khin *et al.* (2016) conducted the study by employing monthly data from January 1990 to December 2015 and proved that real exchange rate impacted NR prices (RSS4 and SMR20).

Moreover, statistical results also proved that NR SMR20 price and exchange rate were long run cointegrated, which could be supported by the studies of Vijayakumar (2019) who also proposed that the exchange rate could explain NR price. Besides, NR RSS4 price was also found to Granger cause NR SMR20 price in one direction. On top of that, an increasing trend of NR price was forecasted using ex-ante method during the period from January to June 2016, which might be explained by the changing behaviors in government and traders which they increased the consumptions of NR for the stabilization of the demand and supply balance of the NR. Vijayakumar (2019) also indicated that the NR price is not only influenced by exchange rate, but also influenced by crude oil price.

Another research conducted by In (2012) to study on the relationship of price volatility of NR with consumers and producers as well as others that involved in the NR production. VECM, Vector Autoregressive (VAR) and

ARIMA model were employed, using monthly data from January 2000 to September 2011 for the analysis. Outcomes of the study revealed that NR price and exchange rate were negatively related. It was supported by Khin *et al.* (2016) as well as a recent study by Purnomo (2017).

SR undeniably is the substitute product of NR. Thus, they are actually highly dependent on each other (Romprasert, 2011). SR production and consumption have been increasing overtime due to the increasing technology advancement especially in automotive industry for the production of vehicle tires (Sudiyana, 2015). However, there are still some differences in NR and SR in its component, and thus NR is still playing a vital role in tire consumption due to its superior tear strength and high resistance of heat (Hayashi, 2009; Ahrends *et al.*, 2015). Sudiyana (2015) also mentioned that SR still cannot entirely replace and surpass NR which has made tire industry are having high dependency on NR.

Therefore, there were researches that studied the association between the SR price and NR price as well as with other variables such as NR production, consumption and even other macroeconomics variables. Khin, Mohamed & Hameed (2012) conducted a research to study the world crude oil price's impact on the supply-demand of NR as well as the SR price. Results showed that, in the short-term model of the SMR20 price, among all the explanatory variables SR price was one of the most crucial variables with statistically significance at $\alpha = 0.05$ level. Yusof (1988) also proved that NR price could be explained by the SR price, and they were having positive relationship and correlation. 10% increases in SR price will cause an increase of

8% in NR price. This is because when SR price increased, consumer would switch to NR and thereby driving the price up.

2.3 Conclusion

Chapter II had clarified theoretical framework of NR production, consumption and price models. It is then followed by the empirical reviews on the NR production, consumption and price models as well as empirical reviews on the research methods. Previous researches tend to focus in only one country when studying the NR market, either in production, consumption or price context. For example, they investigated the NR market in Thailand, Malaysia or India. Besides, they tend to employ a long sampling period from at least 10 to 40 years data (either annual or monthly data).

For production and consumption model, previous studies indicated that NR price is an important variable that almost every previous research had included price in both of the model. Theoretically, production is affected by many factors such as price, consumption, plantation area (Mdludin *et al.*, 2016), fertilizer price (Arunwarakorn *et al.*, 2017), rainfall (Mesike *et al.*, 2010) and others; while consumption is also affected by price, production and stock. However, due to data availability, not every research could collect data for different countries which it would become the limitation of study. For example, it would be difficult to obtain data such as rainfall of a country, which will be even harder to obtain data for several countries at the same time (in the case of this study).

In views of research methods, previous researches mostly employ time series econometrics such as OLS, simultaneous equation, VECM, forecasting. There was very limited literature that actually used panel data analysis to study NR market perhaps due to the difficulty of collection of data in several countries at a specific time frame. For production model, Kannan (2013) employed a simple OLS to study the NR market in India. OLS can product efficient and consistent results when the error terms are not having heteroskedasticity and autocorrelation issues. However, in this study, it is aimed to study more than that. Therefore, a simple OLS might not be considered. Besides, simultaneous equation also been used by previous researches. It may be suitable to be employed when studying production and consumption together in one entity or country. However, in this study, there are more than one country to be studied in both producing and consuming countries. Therefore, after reviewing the previous research, panel data might be the suitable method to study the NR production and consumption model in the study where combination of cross-sectional and time series data is allowed, instead of just study the time series data.

On top of that, for NR price model, VECM might be an appropriate method to study the NR world price model since the model will be studied using time series data instead of panel data. After studying the producing and consuming countries on their own, one more model that can represent as a whole, or in the world market could be added. VECM would be suitable for this study as it can provide the both long and short-term relationship between variables and to fulfill specific objectives.

CHAPTER III

RESEARCH METHODOLOGY

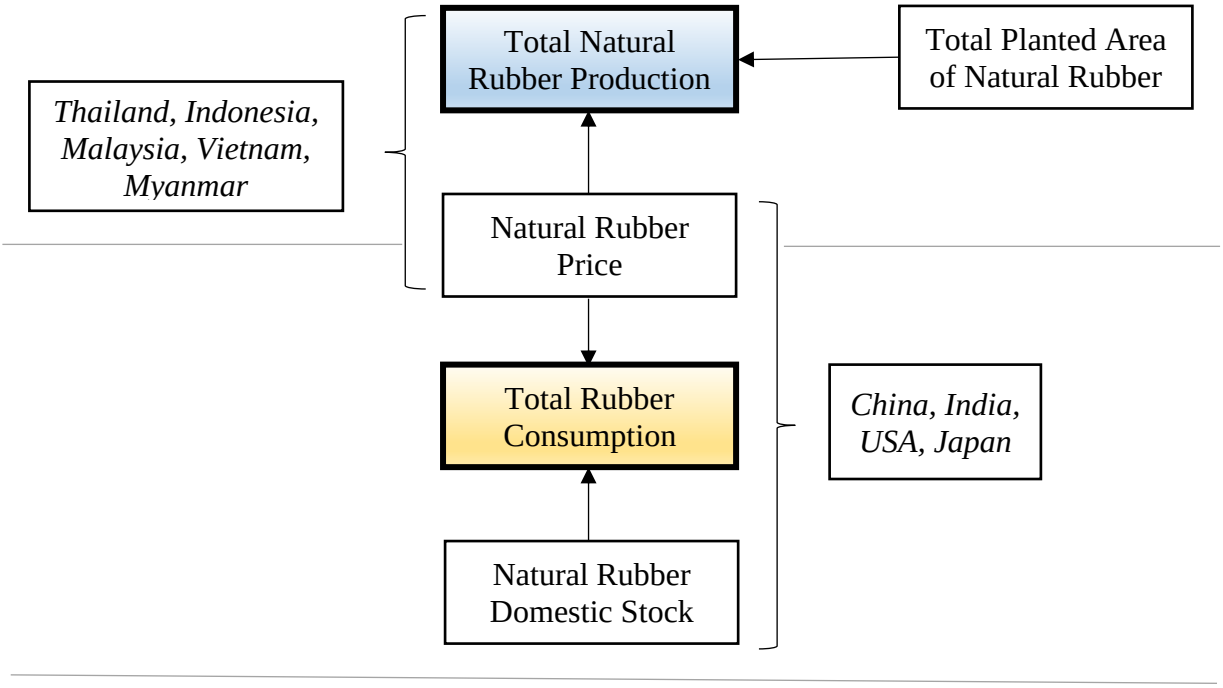
3.0 Introduction

Chapter III presents the research methodology of the study. Firstly, it describes the variables, illustrates the research conceptual framework and model specification. Then, data collection and research procedure will be discussed, followed by the research hypotheses, research methods and the residual diagnostics. Lastly, it defines the model evaluation and ends with the conclusion of this chapter.

3.1 Conceptual Framework

Figure 3.1 illustrates the conceptual framework. Generally, it can be separated into two major parts: Panel data analysis and VECM analysis. For the upper part (panel data analysis), it can be further separated into two models namely the NR production model and NR consumption model. Total NR production is the function of NR price and total planted area of NR in five major producing countries; Total NR consumption is the function of NR price and NR stock in four major consuming countries. While the bottom part shows that NR SMR20 price is the function of NR world production, NR world consumption, Shanghai NR price, real exchange rate, crude oil price and SR price.

Panel Data Analysis:



VECM Analysis:

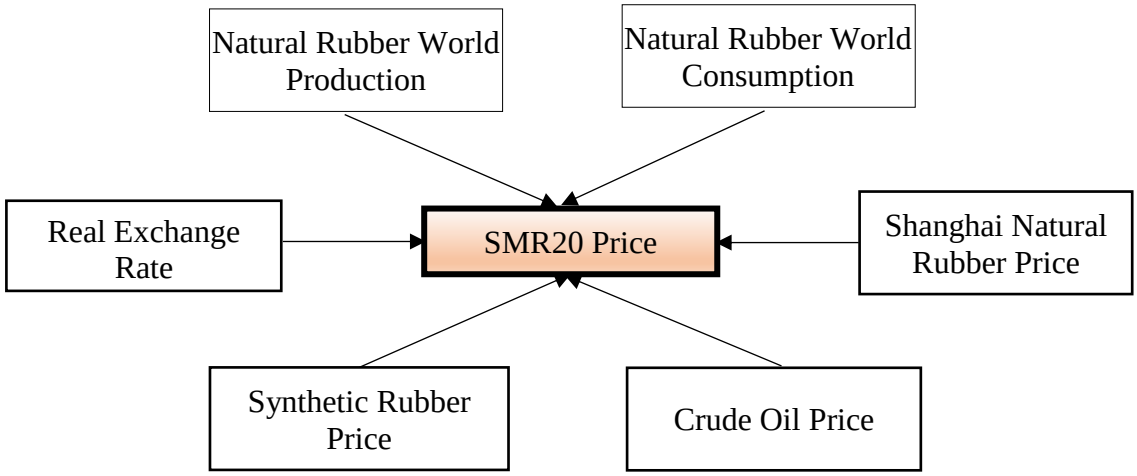


Figure 3.1: Conceptual Framework of the NR Production, Consumption, and Price Models

Panel data analysis is selected for the NR production and consumption models. According to most of the previous studies, researchers tend to adopt only time series analysis on the same field to find out the relationships between

variables in a particular country, or the world market. It is one of the motivations to adopt panel data analysis in this study. Besides, by adopting panel data analysis, it can provide more informative data and results (more elaboration on the methodology will be discussed later). For this study, cross-sectional and time-series data are available and collected for NR producing and consuming countries. Thus, panel data analysis can be performed.

On the other hand, VECM analysis is used to study the NR market as a whole, or in the world market. VECM is chosen because it can provide both long run and the short-run relationship between variables in a model. By having a panel data analysis to study both the producing and consuming countries, it would be good to add another methodology to study the world market as what the previous studies would have done. Besides, the sampling period is different from previous studies. Therefore, results might be different from the previous outcomes although the same variables are included.

3.2 Empirical Model Specification

In this part, the selection of variables and factors will be discussed and justified, according to the models (NR production, consumption and price models). Besides, it also shows how the specific objectives of the study are examined and achieved through the discussion below with the illustration of equations of all the models in this study.

3.2.1 NR Production Model

For NR production model, panel data analysis will be employed for analysis which involves five major NR producers in the world namely Thailand, Indonesia, Malaysia, Vietnam and Myanmar (refer to equation 3.1). The dependent variable is the NR production and independent variable are the NR price and total planted area of NR in the 5 major NR producing countries. According to the NR supply theory, there are supposed to have several factors of NR production that could be involved in the model for analysis such as the rainfall and fertiliser price (Arunwarakorn *et al.*, 2017).

However, due to the availability of data, it is unable to collect such data for the analysis. For instance, although it might be possible to obtain the data of rainfall in our own country (Malaysia), it is difficult to obtain data in other countries which might be costly to purchase from their government. Eventually, the NR price and its total planted area are set as the independent variables in the model. The sampling period is from the year 2004 to 2017 (annual data). Therefore, the NR world production model for panel data analysis is as below:

$$\boldsymbol{NRP_{it} = \beta_0 + \beta_1\, NRPPrices_{it} + \beta_2\, TPA_{it} + e_{it1}} \qquad (3.1)$$

Where,

NRP_{it} = NR production (‘000 tonnes) in Thailand, Indonesia, Malaysia, Vietnam and Myanmar

$NRPPrices_{it}$ = NR price (USD/ton) in Thailand, Indonesia, Malaysia, Vietnam and Myanmar

TPA_{it} = Total planted area of NR ('000 hectares)

β_0 = Intercept

β_1 & β_2 = Regression coefficient/slope

e_{it1} = Error term

it = Panel data from 2004 to 2017 yearly of Thailand, Indonesia, Malaysia, Vietnam and Myanmar

3.2.2 NR Consumption Model

Similar to the NR production model, NR consumption model will also be analysed by using panel data analysis, which involves the top four major consuming countries namely China, India, USA and Japan (refer to equation 3.2). In the consumption model, NR consumption is the dependent variable while the independent variables are NR prices and NR domestic stock in the 4 countries. As mentioned, due to the availability of the data, it is difficult and costly to obtain other data of the variables according to the theoretical framework.

Thus, NR price is set as one of the independent variables, and another independent variable is the domestic stock of NR in the countries. Many researchers studied the relationship between NR stock and price (Khin & Thambiah, 2015; Arunwarakorn *et al.*, 2017), but there is very limited literature that reveals the relationship between NR consumption and its stock or inventory. Thus, it might be a good variable worth studying. Therefore, NR consumption model for panel data analysis is as below:

$$NRC_{it} = \beta_3 + \beta_4 NRCPrices_{it} + \beta_5 Stock_{it} + e_{it2} \quad (3.2)$$

where,

NRC_{it} = NR consumption ('000 tonnes) in China, India, USA and Japan

$NRCPrices_{it}$ = NR price (USD/ton) in China, India, USA and Japan

$Stock_{it}$ = NR domestic stock ('000 tonnes) in China, India, USA and Japan

β_3 = Intercept

β_4 and β_5 = Regression coefficient/slope

e_{it2} = Error term

it = Panel data from 2004 to 2017 yearly of China, India, USA and Japan

3.2.3 NR Price Model

In the NR price model, SMR20 price is set as the dependent variable and the independent variables are Shanghai NR price, NR production, NR consumption, exchange rate as well as SR price (refer to equation 3.3). SMR20 price is the Standard Malaysia Rubber price grade 20. It is selected to be the dependent variable because Malaysia is one of the largest NR producers and exporters in the world ever since the 1990s. (Khin *et al.*, 2011; Khin & Thambiah, 2014). It would be able to represent the NR market as one of the market influencing prices. Although Malaysia's NR production is surpassed by Vietnam during recent years (refer back to table 1.1), but SMR20 price is still a

very influential variable in the rubber economy, since Malaysia had been the third producer in the world for so many years. Besides, the selection of SMR20 price not only can represent the world price, but it can also better represent the Malaysia context and to help in the contribution of further action for Malaysia government in the rubber economy.

Production and consumption of NR are the fundamental factors of its price, thus, the NR production and consumption are considered in the model as the independent variables (Chawananon, 2014; Khin & Thambiah, 2014; Khin & Thambiah, 2015). Next, Shanghai NR price is set as one of the independent variables too. China is the second-largest economy in the world, any changes or fluctuation in almost everything will indirectly have an impact to the rest of the world, including the commodity market and more specifically, in the NR market. As mentioned in Chapter I, Shanghai Future Exchanges is one of the major future exchanges in NR world market (Jacob, 2017). Besides, according to Mathews (2017), the behavior of future markets especially Shanghai future market needs to be studied to understand the impact of non-fundamentals in NR market. It is a very new variable in the NR research field, and it also influences the NR future and spot markets in the world. Thus, Shanghai NR price is considered in the model for study.

Moreover, since NR is traded among the world by USD, therefore, the exchange rate will be an important factor that affects the NR price in the world market (Raju, 2016). Besides, several pieces of research also proved that exchange rate is a crucial factor that causes the volatility of NR price and

negatively impact the price (Khin *et al.*, 2016; Purnomo, 2017). In this study, the unit of the exchange rate is RM/USD since the NR price in the model is set as the Malaysia SMR20 price.

On the other hand, crude oil is known as the main raw material in the production of SR, which is identified as the substitute product of NR. In fact, there are many pieces of research in the literature that study the association NR price and between crude oil price such as the studies by Khin *et al.* (2012), Zhang & Qu (2015), Khin *et al.* (2017) and others. The result showed that crude oil price and NR price are having a positive relationship. Since crude oil is used to produce SR, SR price is considered to add to the NR price model to be studied too. Also, there are only a few previous researches done to reveal such relationships such as the studies by Yusof (1988) and Khin *et al.* (2012). Therefore, it becomes one of the motivation to study the variables of SR and NR price to further confirm the relationship. Therefore, the world NR price model for VECM analysis is below:

$$nrsmr20_t = \beta_6 + \beta_7\, nrshg_{t-1} + \beta_8\, nrwp_{t-1} + \beta_9\, nrwc_{t-1} + \beta_{10}\, exr_{t-1} + \beta_{11}\, srp_{t-1} + \beta_{12}\, cop_{t-1} + e_{t3} \quad (3.3)$$

Where,

$nrsmr20_t$ = NR SMR20 price (USD/ton) deflated by the CPI

$nrshg_{t-1}$ = Shanghai NR price (USD/ton) deflated by the CPI

$nrwp_{t-1}$ = NR world production (‘000 tonnes)

$nrwc_{t-1}$ = NR world consumption (‘000 tonnes)

exr_{t-1} = Real exchange rate (RM/USD)

srp_{t-1} = SR price (USD/ton) deflated by the CPI

cop_{t-1} = Crude oil price (USD/barrel)

β_6 = Intercept

$\beta_7 \ldots \beta_{12}$ = Regression coefficient/ Intercepts

e_{t3} = Error terms

t = Time series data from 2008 to 2017 monthly

3.3 Research Hypotheses

3.3.1 NR Production Model

H_{01}: There is no significant relationship between NR prices and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.

H_{A1}: There is a significant relationship between NR prices and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.

H_{02}: There is no significant relationship between total planted area of NR and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.

H_{A2}: There is a significant relationship between total planted area of NR and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.

3.3.2 NR Consumption Model

H_{03}: There is no significant relationship between NR prices and NR consumption in China, India, Japan and USA.

H_{A3}: There is a significant relationship between NR prices and NR consumption in China, India, Japan and USA.

H_{04}: There is no significant relationship between NR stock and NR consumption in China, India, Japan and USA.

H_{A4}: There is a significant relationship between NR stock and NR consumption in China, India, Japan and USA

3.3.3 NR Price Model

H_{05}: There is no significant relationship between NR world production and NR SMR20 price.

H_{A5}: There is a significant relationship between NR world production and NR SMR20 price.

H_{06}: There is no significant relationship between NR world consumption and NR SMR20 price.

H_{A6}: There is a significant relationship between NR world consumption and NR SMR20 price.

H_{07}: There is no significant relationship between Shanghai NR price and NR SMR20 price.

H_{A7}: There is a significant relationship between Shanghai NR price and NR SMR20 price.

H_{08}: There is no significant relationship between real exchange rate and NR SMR20 price.

H_{A8}: There is a significant relationship between real exchange rate and NR SMR20 price.

H_{09}: There is no significant relationship between crude oil price and NR SMR20 price.

H_{A9}: There is a significant relationship between crude oil price and NR SMR20 price.

H_{010}: There is no significant relationship between SR price and NR SMR20 price.

H_{A10}: There is a significant relationship between SR price and NR SMR20 price.

3.4 Research Procedure

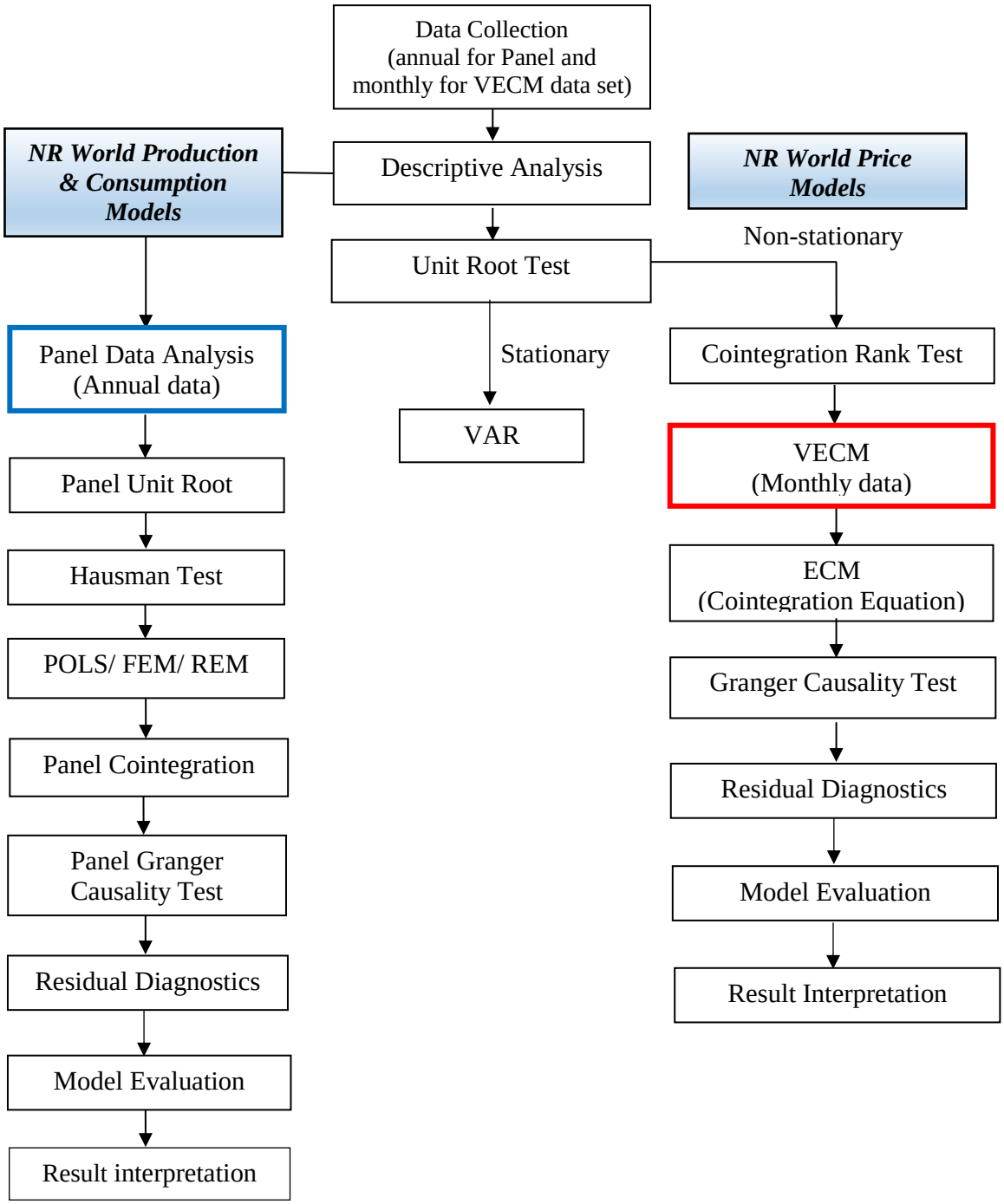


Figure 3.2: Research Procedure

As shown in Figure 3.2 above, after data collection, the first step will be to carry out the descriptive analysis which presents the quantitative description

of the data, followed by the unit root test. Firstly, on the left-hand side in the figure, it shows that panel data analysis is carried out after the descriptive analysis, for the panel model of NR world production and consumption. Panel unit root test will be performed to investigate the stationary of the data, and it is followed by Hausman test to select the appropriate model for regression analysis, either a Fixed Effect Model (FEM) or Random Effect Model (REM), followed by the panel cointegration test. It is used to achieve specific objective 1 and 2.

On the other hand, on the right-hand side in the figure, after checking the stationarity of variables by using unit root test, cointegration rank test will be carried out to test the existence of cointegration in the model. If the series is stationary at level data, a VAR model will be suitable and sufficient for the analysis. However, if the series is not stationary at level data and found to be cointegrated, VECM will then be performed. A VECM model contains a cointegration equation to explain the long-run cointegrated relationship between variables as well as a VECM equation to explain the short-run dynamics between among variables. it is used to achieve specific objective three.

Then, all the three models will be studied using Granger Causality test to find out the causal relationships among variables in different models. It can fulfil the specific objective four. Residual diagnostic tests such as normality, autocorrelation, heteroskedasticity and multicollinearity tests will also be tested for the three models. Lastly, the model evaluation will be employed to find out the best and valid model in terms of forecasting performance.

3.5 Data Collection

Secondary data were collected to conduct econometric analyses. Data for NR prices (including all the countries' prices), SR price, NR stock, production and consumption of NR, crude oil price were obtained from sources such as International Rubber Study Group (IRSG) and Association of Natural Rubber Producing Countries (ANRPC). Another variable such as the real exchange rate was collected from Bank Negara Malaysia (BNM), World Bank and International Monetary Fund (IMF).

For panel data analysis, there are two models which are the NR world production model and world consumption model. For the NR world production model, five major producing countries were involved which were Thailand, Indonesia, Malaysia, Vietnam and Myanmar; while for the NR world consumption model; there were four major consuming countries involved, which were China, India, Japan and USA. Annual data was collected from the year 2004 to 2017 for both models for panel data analysis. On the other hand, NR world price model is going to be studied by using VECM analysis (time series data). Monthly data were collected from January 2008 to December 2017 for data analysis.

3.6 Panel Data Model

Panel data combines cross-sectional data and time series data which is also known as longitudinal data. Its observations involve the cross-section dimension (indicated by subscript *i*) and time series dimension (indicated by subscript *t*). A panel is said to be a balanced panel when each subject has the same number of observation and conversely, it is an unbalanced panel when there is different number of observation of each entity. When the number of cross-sectional subjects *N* is greater that the time periods *T*, it is knowns as a short panel; when *T* is greater than *N*, then it is a long panel. There are few advantages of using panel data analysis. Panel data normally provide more informative data, more efficiency and more variability by combining both cross-sectional and time series data. Besides, panel data includes the information on both the intertemporal dynamics and the individuality to the entities may allow one to control the effects of missing or omitted variables (Hsiao, 2007; Gujarati & Porter, 2009). This method can achieve the specific objective one and two of the study (for NR world production and consumption models).

3.6.1 Fixed Effect Model (FEM)

Fixed effect model (FEM) is a statistical model that in that particular model, the parameters are fixed (non-random) quantities. FEM is used normally when we want to analyze the impact of variables that vary over time, and it also explore relationship between predictor and outcome variables within an entity (country, company, person, etc.). In a FEM, the unobserved variables are

tolerable to have any associations whatsoever with the observed variables. FEM also control for, or partial out, the effects of time-invariant variables with time-invariant effects (Wooldridge, 2001; Verbeek, 2008). The equation for the FEM is as shown below:

$$Y_{it} = \beta_1 X_{it} + \alpha_i + u_{it} \quad (3.6)$$

Where α_i is the unknown intercept for each entity (n entity-specific intercepts); Y_{it} is the dependent variable where *i* = entity and *t* = time; X_{it} represents one independent variable; β_1 is the coefficient of independent variable; and u_{it} is the error term.

3.6.2 Random Effect Model (REM)

Unlike FEM, in random effect model (REM), the variation across entities is assumed to be random and uncorrelated with the predictor or explanatory variables in the model (allows individual effect). REM could be used when it is believed that differences across entities have some influence on the dependent variable. The crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not (Wooldridge, 2001; Verbeek, 2008). An advantage of random effects is that you can include time invariant variables such as gender; in the FEM, these variables are absorbed by the intercept. The equation for the REM is as shown below:

$$Y_{it} = \beta X_{it} + \alpha_i + u_{it} + \varepsilon_{it} \quad (3.7)$$

Where the u_{it} is between-entity error while ε_{it} is within-entity error.

3.6.3 Hausman Test

Hausman (1978) has suggested a test to examine whether FEM or REM is preferred for the panel data analysis. Hausman Test is sometimes described as a test for model misspecification. It is usually applied by researchers to test for FEM and REM and compare directly the random effects estimators $\widehat{\beta}_{RE}$ to the fixed effects estimators $\widehat{\beta}_{FE}$. The null hypothesis is that the preferred model is a REM and the alternative is that the FEM is preferred. Test hypotheses are as follows:

H_0: REM is preferred

H_A: FEM is preferred

It basically tests whether the unique errors μ_i are correlated with the regressors, the null hypothesis is that they are not, while the alternative is that they are correlated. In the presence of a correlation between the individual effects and the regressors, the GLS estimates are inconsistent, while the OLS fixed effects results are consistent. If there is no correlation between the fixed effects and the regressors, both estimators are consistent, but the OLS fixed effects estimator is inefficient (Wooldridge, 2001; Verbeek, 2008; Gujarati & Porter, 2009). In this study, before moving to data analysis part, data has been used to test run the models. Results from Hausman test showed that FEM will be preferred in this study.

3.6.4 Panel Cointegration Test

Like the panel unit root tests, panel cointegration testes can be motivated by the search for more powerful tests than those obtained by applying individual time series cointegration tests (Verbeek, 2008). There are several cointegration tests developed in panel data such as the Kao (1999) test, Pedroni (1999, 2004) test.

Kao (1999) and Pedroni (1999, 2004) extend the Engle-Granger framework to test involving panel data. The basic ideas of Engle Granger are to examine two I(1) series and to see if the residuals of the spurious regression involving these I(1) series are I(0). If this is so, then the series are said to be cointegrated; but If the series are I(1) then the variables are not cointegrated. A test for the null hypothesis of no cointegration can be based on an ADF type unit root test based on residuals.

Firstly, the Kao (1999) test is developed to test the cointegration in homogeneous panels. The Kao test statistics are calculated by pooling all the residuals of all cross-sections in the panel, and it is assumed that in Kao's test that all the cointegrating vectors in every cross-section are identical. The regression equation is as below:

$$y_{it} = \alpha_i + x_{it}\beta + u_{it} \tag{3.8}$$

Where α_i individual constant is term and β is the slope parameter. On the other hand, Pedroni (1999, 2004) suggested several panel cointegration tests

tolerate heterogeneity. The benefits of Pedroni's tests are: it allows multiple regressors, for the cointegration vector to vary across different sections of the panel, and also for heterogeneity in the errors across cross-sectional units. The panel regression model that Pedroni proposes is as below:

$$Y_{it} = \alpha_i + \delta_t + \sum_{m=1}^{M} \beta_{mi} X_{mi,t} + u_{it} \quad (3.9)$$

Where t=1,2,...,T and n=1,2,…,N and m=1,2,…,M. Y and X's are assumed to be integrated of order one I(1). The individual α_i and trend effect δ_t may be set zero if desired.

3.7 Vector Error Correction Model (VECM)

3.7.1 VECM Equation

VECM is the restricted version of VAR model that is suitable for non-stationary and cointegrated time series. In a VECM model, there are cointegration equation and VECM equation. Cointegration equation determines the long-run association between variables while VECM equation would reveal the short-run dynamics between factors. Besides, Granger causality will be employed to separate clearly the relationship and direction of causality, since VECM will not reveal such directions between the variables (Gujarati & Porter, 2009). VECM equation of NR price model is as below:

$$\Delta nrsmr20_t = \beta_{13} + \beta_{14} \Delta nrshg_{t-1} + \beta_{15} \Delta nrwp_{t-1} + \beta_{16} \Delta nrwc_{t-1} + \beta_{17} \Delta exr_{t-1} + \beta_{18} \Delta srp_{t-1} + \beta_{19} \Delta cop_{t-1} + e_{t4} \quad (3.10)$$

Where,

$nrsmr20_t$ = NR SMR20 price (USD/ton) deflated by the CPI

$nrshg_{t-1}$ = Shanghai NR price (USD/ton) deflated by the CPI

$nrwp_{t-1}$ = NR world production ('000 tonnes)

$nrwc_{t-1}$ = NR world consumption ('000 tonnes)

exr_{t-1} = Real exchange rate (RM/USD)

srp_{t-1} = SR price (USD/ton) deflated by the CPI

cop_{t-1} = Crude oil price (USD/barrel)

β_{13} = Intercept

$\beta_{14}…\beta_{19}$ = Regression coefficient/ Intercepts

e_{t4} = Error terms

t = Time series data from 2008 to 2017 monthly

3.7.2 Cointegration Equation

Cointegration is known as the long-run equilibrium in economic theories. If two variables are said to be cointegrated, that is there is a long-term equilibrium relationship between them. Granger Representative Theorem (Granger, 1983; Engle and Granger, 1987) is an important theorem which states that if two variables are cointegrated, it can be said that there is a valid error correction representation of the data (Verbeek, 2008; Gujarati & Porter, 2009). In the short run, there might be some disequilibrium and therefore, error term can be treated as the equilibrium error. ECM is also being popularized by Engle and Granger to correct for disequilibrium. ECM also describes how the two variables perform in the short-run consistent with

a long-run cointegrating relationship. This method can achieve the specific objective 4 of the study. The cointegration equation for NR world price is below:

$$\beta_{20} \Delta nrsmr20_{t-1} + \beta_{21} \Delta nrshg_{t-1} + \beta_{22} \Delta nrwp_{t-1} + \beta_{23} \Delta nrwc_{t-1} + \beta_{24} \Delta exr_{t-1} + \beta_{25} \Delta srp_{t-1} + \beta_{26} \Delta cop_{t-1} = 0 \quad (3.11)$$

where,

$nrsmr20_t$ = NR world price SMR20 (USD/ton) deflated by the CPI

$nrshg_t$ = Shanghai NR price (USD/ton) deflated by the CPI

$nrwp_t$ = NR world production ('000 tonnes)

$nrwc_t$ = NR world consumption ('000 tonnes)

exr_t = Real exchange rate (RM/USD)

srp_t = SR price (USD/ton) deflated by the CPI

cop_t = Crude oil price (USD/barrel)

$\beta_{20} \ldots \beta_{26}$ = Regression coefficient/ Intercepts

3.7.3 Cointegration Rank Test

Cointegration test is to check the long-term cointegrated relationship between two particular variables. Trace test and maximal eigenvalue test are the most commonly used cointegration tests. Maximum eigenvalue statistics examine the null hypothesis that there are *r* co-integrating vectors against the alternative hypothesis of *r+1* co-integrating vectors. Trace statistics, on the other hand, test the null hypothesis of no cointegrating vector against the alternative hypothesis of at least one co-integrating vector (Pindyck & Rubinfeld, 1998; Studenmund, 2014).

3.8 Granger Causality Test

Causality is one of the common concerns in most of the statistical analyses. Researchers would expect that if there are two variables that are cointegrated, it means that there should be some causality relationship running between the variables in at least a single direction. To detect causality relationship, Granger Causality test which is proposed by Granger (1969) will be employed to investigate the causal relationships between variables. Causality is somehow closely related to cause and effect relationship but it is not exactly the same. Variable *X* is said to causal to variable *Y* if *X* is the cause of *Y* or *Y* is the cause of *X*. However, with Granger Causality test, it is to examine if a variable comes before another in a series instead of the cause and effect relationship between them (Gujarati & Porter, 2009; Studenmund, 2014). Hypotheses of the Ganger Causality test are as shown below:

H_0: X does not Granger Cause Y

H_A: X Granger Causes Y

3.9 Conclusion

Chapter III clarified the variables, conceptual framework and model specification of the study. Research hypotheses were then discussed followed by the research procedure and the data collection. After that, the research methods that are going to be employed for data analysis are revealed, especially the major research methods which are the panel data analysis and VECM analysis. Chapter IV will then clarify the data analysis.

CHAPTER IV

DATA ANALYSIS AND RESULTS

4.0 Introduction

This chapter will discuss the data analysis and result interpretation. It will be separated into three parts: the first and second parts are the panel data models (cross-sectional data) of NR world production (Thailand, Indonesia, Malaysia, Vietnam and Myanmar) and NR world consumption (China, India, Japan and USA) respectively. The third part is the Vector Error Correction Method (VECM) models (time series data) of NR world price (NR SMR20 price). Firstly, the preliminary analysis will be conducted such as descriptive analysis, correlation test and unit root tests.

NR world production model includes the variables of production, price and the total planted area of NR in Thailand, Indonesia, Malaysia, Vietnam and Myanmar. NR world consumption model includes the variables of NR consumption, NR price and NR stock in China, India, Japan and the USA. For both the panel data models, firstly, Redundant Fixed Effect Test, Breusch-Pagan Lagrange Multiplier (BPLM) test and Hausman Test are performed to select an appropriate model for the analysis, either fixed or random-effect model. Then, panel regression analysis is carried out and followed by the checking of robustness (adjustment of the standard error to remedy heteroskedasticity and autocorrelation problem in the panel models). Besides, panel cointegration tests

will be performed to find out the long-run cointegrated relationship between variables in the models. After that, it is followed by the Granger causality test to find out the directional causal relationship among variables in each model.

On the other hand, the NR world price model is analyzed with time-series data analysis. After checking the stationary of the data by the unit-root test as well as the cointegration rank test to check the existence of cointegrated relationships among variables, VECM analysis is conducted to find out the short-term dynamic in the world price model. Granger causality test will be performed to determine whether there is a directional causal relationship in the model.

Besides, four residual diagnostic tests will be performed which are the normality, heteroskedasticity, autocorrelation and multicollinearity test. Furthermore, both the panel data models (NR world production and consumption models) and time-series data model of NR world price will be tested for the model evaluation test with graph illustration which reveals the value of RMSE, MAE, MAPE and U-Theil test of the particular model. Lastly, hypotheses testing of world production, world consumption and world price model will be the last part of this chapter.

4.1 Descriptive Analysis

Table 4.1: Descriptive Analysis of NR Production and Consumption Models

	nrp	***nrpprice***	***tpa***	***nrc***	***nrcprice***	***stock***
Mean	1672.858	2246.809	1721.313	3381.620	2185.555	110.842
Median	1022.400	1840.026	1075.400	2092.550	1930.365	55.6100
Maximum	4755.000	5332.000	3769.700	9591.600	5332.000	368.750
Minimum	52.30000	1084.232	234.0000	968.0000	865.4509	16.0000
Std. Dev.	1397.191	1144.268	1231.772	2679.445	1039.130	98.4220
Obs	70	70	70	56	56	56

Table 4.1 shows the descriptive analysis of the production and consumption models of NR. For NR production model, it includes three variables which are the NR production (*nrp*), NR price (*nrpprice*) and total planted area of NR (*tpa*). Annual data from the year 2004 to 2017 for five producing countries (Thailand, Indonesia, Malaysia, Vietnam, Myanmar) is collected, and all are 70 observations. In the five producing countries, the maximum production of NR accounted for 4755 thousand tonnes and the minimum production accounted for only 52.3 thousand tonnes.

For the consumption model, it includes three variables which are the NR consumption (*nrc*), NR price (*nrcprice*) and NR stock (*stock*). Annual data from the year 2004 to 2017 for four consuming countries (China, India, Japan, USA) is collected, and all are 56 observations. In the four consuming countries, maximum consumption accounted for 9591.6 thousand tonnes while the minimum consumption accounted for only 968 thousand tonnes.

Table 4.2: Descriptive Analysis of NR Price Model

	nrsmr20	*nrwp*	*nrwc*	*nrshg*	*exr*	*srp*	*cop*
Mean	2423.329	941.3511	2155.392	3022.989	3.484561	2557.408	78.490
Median	2262.960	960.5000	2195.000	2921.301	3.278750	2509.500	80.700
Maximum	5560.800	1255.000	2603.000	5986.698	4.490000	3933.000	134.522
Minimum	1090.500	617.0599	1418.000	1430.857	2.960000	1559.000	32.450
Std. Dev.	1056.966	159.8987	220.8594	1059.058	0.454540	520.0231	24.712
Obs	120	120	120	120	120	120	120

Table 4.2 reveals the descriptive analysis of NR price models, including seven variables namely the NR SMR20 price, Shanghai NR price, NR world production and consumption, real exchange rate, SR price and crude oil price (*nrsmr20, nrshg, nrwp, nrwc, exr, srp, cop*), respectively. Monthly data from January 2008 to December 2017 is collected, and all are 120 observations for all variables. In this recent 10 years, the maximum world price of NR accounted for about 5560.8 USD/ton and the minimum price accounted for only 1090.5 USD/ton.

4.2 Correlation Test

Table 4.3: Correlation Test of NR Production Model

Variables	*nrp*	*nrpprice*	*tpa*
nrp	1		
nrpprice	0.7602	1	
tpa	0.9441	0.8062	1

Table 4.3 reveals the correlation test results for the NR production model. The value of 0.7602 indicates that there is a strong positive correlation between NR price and NR production; 0.9441 indicates that there is a strong positive

correlation between the total planted area of NR and NR production; and 0.8062 indicates that there is a strong positive correlation between the total planted area of NR and NR price in the 5 major producing countries (Thailand, Indonesia, Malaysia, Vietnam, Myanmar).

Table 4.4: Correlation Test of NR Consumption Model

Variables	*nrc*	*nrcprice*	*stock*
nrc	1		
nrcprice	-0.1793	1	
stock	-0.2434	-0.1655	1

Table 4.4 shows the correlation test results for the NR consumption model. The value of -0.1793 indicates that there is a weak negative correlation between NR price and NR consumption; where -0.2434 indicates that there is a weak negative correlation between NR stock and NR consumption; and -0.1655 indicates that there is a weak negative correlation between the NR stock and NR price in the 4 major consuming countries (China, India, Japan, USA).

Table 4.5: Correlation Test of NR Price Model

variables	*smr20*	*nrwp*	*nrwc*	*nrshg*	*exr*	*srp*	*cop*
nrsmr20	1						
nrwp	0.3086	1					
nrwc	-0.1733	0.5461	1				
nrshg	0.9785	0.2514	-0.1327	1			
exr	-0.6709	-0.4505	-0.2663	-0.7090	1		
srp	-0.6437	0.0334	-0.1188	-0.6470	-0.5531	1	
cop	0.6162	-0.2486	0.0444	0.6318	-0.7824	0.5529	1

Table 4.5 demonstrates the correlation test results for the NR price model. The value of 0.3086 indicates a moderate positive correlation between NR production and NR SMR20 price; -0.1733 indicates a weak negative correlation between NR consumption and NR SMR20 price; 0.9785 indicates a strong positive correlation between the Shanghai NR price and NR SMR20 price; -0.6709 indicates a moderate negative correlation between the real exchange rate and NR SMR20 price; -0.6437 indicates a moderate negative correlation between the SR price and NR SMR20 price; and lastly, 0.6162 indicates a moderate positive correlation between crude oil price and NR SMR20 price.

4.3 Unit Root Tests

Table 4.6: Panel Unit Root Tests of NR Production Model

Variables	*Levin, Lin and Chu*			*Fisher-PP*		
	Level	*Ln*	*1st diff*	*Level*	*Ln*	*1st diff*
nrp	0.0575	-5.1376***	-5.5981***	11.3600	37.1303***	39.2848***
nrpprices	-1.3373	-5.4307***	-6.5899***	11.1810	33.3516***	34.2015***
tpa	-1.5388*	-3.2331***	-4.7875***	4.0379	8.2735	29.1648***

Note: ***statistically significant at 0.01 level
*statistically significant at 0.10 level

Table 4.7: Panel Unit Root Tests of NR Consumption Model

Variables	*Levin, Lin and Chu*			*Fisher-PP*		
	Level	*Ln*	*1st diff*	*Level*	*Ln*	*1st diff*
nrc	-1.5627*	-2.8831***	-7.7392***	13.3129	22.4016***	65.7227***
nrcprices	-0.7359	-0.9009	-5.1668***	7.6878	7.5502	21.7756***
stock	0.0468	-1.6715**	-6.5153 ***	8.7027	7.8159***	30.0666***

Note: ***statistically significant at 0.01 level
*statistically significant at 0.10 level

Table 4.6 and 4.7 present the results of panel unit root tests for NR production and consumption models respectively. Two unit root tests are employed namely the Levin *et al.* (2002) test and Maddala & Wu (1999) test (Fisher-PP).

Test results of Levin *et al.* (2002) test show that in the NR production model, among three variables, there is only one variable namely the total planted area of NR is stationary at level data at 0.10 level. All three variables are then stationary at ln and first difference level and it is statistically significant at α = 0.01 level. Fisher-PP test results indicate that only NR production and price are stationary at ln data at 0.01 level, but all three variables are stationary at first difference level and statistically significant at α = 0.01 level.

Test results of Levin *et al.* (2002) test show that in the NR consumption model, only NR consumption is stationary at both level and ln data at 0.10 and 0.01 level respectively while NR stock is stationary at ln level at 0.05 level. After first differencing, all the variables are stationary and statistically significant at α = 0.01 level. Fisher-PP test results reveal that only two variables namely the NR consumption and NR stock are stationary both at ln data at 0.01 level. However, all the variables are only stationary after first differencing and statistically significant at α = 0.01 level.

Table 4.8: Unit Root Tests of NR Price Model

Variables	*Augmented Dickey Fuller (ADF)*			*Phillips Perron (PP)*		
	Level	***Ln***	***1st diff***	***Level***	***Ln***	***1st diff***
nrsmr20	-1.6332	-1.6658	-7.6801***	-1.4155	-1.4059	-7.7373***
nrwp	-1.0219	-1.4483	-9.7166***	-2.1234	-2.1063	-11.6524***
nrwc	-2.7359*	-3.1371**	-4.4253***	-3.6192***	-3.4689**	-26.2765***
nrshg	-1.7326	-1.6881	-8.1849***	-1.4227	-1.5744	-8.0372***
exr	-0.5977	-0.5555	-9.0955***	-0.6999	-0.5555	-9.0987***
srp	-2.3225	-2.3709	-8.9784***	-2.2853	-2.4314	-9.1074***
cop	-1.7846	-1.7666	-8.4863***	-2.1418	-2.0208	-8.4840***

Note: ***statistically significant at 0.01 level
**statistically significant at 0.05 level
*statistically significant at 0.10 level

Table 4.8 presents the unit root tests results of the time series data model of NR SMR20 price. Two unit root tests are performed which are the ADF and PP unit root tests.

Results suggest that only NR consumption is stationary at both level and ln data at $\alpha = 0.10$, 0.05 and 0.01 level respectively, while all other variables are not. However, all the variables become stationary after first differencing. The null hypothesis can be rejected at $\alpha = 0.01$ level which means that the data now contains no unit root. Conclusively, the first different model will be employed for regression analysis for NR world price model since all the variables are stationary only at first different level I(1).

4.4 Panel Data Model Selection

Table 4.9: Models Selection for NR Production Model

Tests	*Hypothesis*	*P-value*	*Conclusion*
Redundant Fixed Effect Test	H_0= POLS is preferred H_A= FEM is preferred	**0.0000** < α = 0.05	Reject H_0, FEM is preferred.
Breusch-Pagan LM Test	H_0= POLS is preferred H_A= REM is preferred	**0.0000** < α = 0.05	Reject H_0, REM is preferred.
Hausman Test	H_0= REM is preferred H_A= FEM is preferred	**0.8511** > α = 0.05	**Do not reject H_0, REM is preferred.**

Table 4.10: Models Selection for NR Consumption Model

Tests	*Hypothesis*	*P-value*	*Conclusion*
Redundant Fixed Effect Test	H_0= POLS is preferred H_A= FEM is preferred	**0.0060** < α = 0.05	Reject H_0, FEM is preferred.
Breusch-Pagan LM Test	H_0= POLS is preferred H_A= REM is preferred	**0.0008** < α = 0.05	Reject H_0, REM is preferred.
Hausman Test	H_0= REM is preferred H_A= FEM is preferred	**0.9261** > α = 0.05	**Do not reject H_0, REM is preferred.**

Table 4.9 and 4.10 demonstrate the summary of test results of panel data model selection for the NR world production and consumption model respectively. Three tests are employed namely the F-test, Breusch-Pagan LM (BPLM) test and the Hausman test. Test results from F-test for both models indicate that p-value equal to 0.0000 which is smaller than α = 0.05. Therefore, H_0 is rejected, FEM is preferred in this case. Test results from the BPLM test for both models also indicate that p-value equal to 0.0000 which is smaller than α = 0.05. Therefore, H_0 is rejected, REM is preferred in this case. Lastly, the

Hausman test will confirm the selection of FEM or REM model for regression. For the NR world production model, test result from the Hausman test indicates that p-value equal to 0.8511 which is greater than $\alpha = 0.05$. Therefore, do not reject H_0, REM is preferred for the NR world production model. Similarly, for the NR world consumption model, test result from the Hausman test indicates that p-value equal to 0.9261 which is smaller than $\alpha = 0.05$. Therefore, do not reject H_0, REM is preferred for NR world consumption model.

4.5 Panel Data Models of NR Production and Consumption

4.5.1 REM of Panel NR Production Model

$$\boldsymbol{Ln\ nrp_{it} = -1.5793 + 0.0483\ Ln\ nrpprices_{it} + 1.1478\ Ln\ tpa_{it} + 0.4895\ e_{it}} \quad (4.1)$$

t-stat: [2.8000***] [19.4628***]

$R^2 = 0.8711$ Adj $R^2 = 0.8673$

Note: ***statistically significant at 0.01 level

Equation 4.1 shows the Random Effect Model (REM) for the panel NR production model. In the NR production equation, R^2 equals to 0.8711, which means that almost 87.11 percent of the variation in the model is well explained by the explanatory variables, namely the NR price and the total planted area of NR.

Therefore, every one unit (USD/ton) increase in NR price, on average, it will have a positive impact on increasing NR production by 0.0483 unit (‘000 tonnes), holding other variable constant; every 1 unit (‘000 hectares) increase in

the total planted area of NR, on average, it will have a positive impact on increasing NR production by 1.1478 unit ('000 tonnes), holding other variable constant. Therefore, in the five NR producing countries, namely Thailand, Indonesia, Malaysia, Vietnam and Myanmar, NR price and total planted area of NR are having a positive relationship with NR production, which are statistically significant at $\alpha = 0.01$ level respectively.

The increase of NR prices would encourage farmers and smallholders in producing countries to continue to grow and cultivate NR in view of the growing profit in the future. Instead of switching to other more profitable crops, they would choose to stay in the NR industry and thus, increase the planted areas as well. Other than new plantation areas, farmers and smallholders would also continue the plantation in the existing planted area for continuous growth. Therefore, both of the variables are having positive relationships with NR production. The higher coefficient value of the total planted area variable in the model indicates that this variable is more important than NR price in terms of affecting NR production.

4.5.2 REM of Panel NR Consumption Model

$$\boldsymbol{Ln\ nrc_{it} = 7.4554 - 0.0771\ Ln\ nrcprices_{it} - 0.0392\ Ln\ stock_{it} + 0.2421\ e_{it}} \quad (4.2)$$

t-stat: [-3.0347**] [-1.7760*]

$R^2 = 0.2157$ Adj $R^2 = 0.1861$

Note: **statistically significant at 0.05 level
*statistically significant at 0.10 level

Equation 4.2 shows the REM for the panel NR consumption model. NR consumption equation shows that R^2 equals to 0.2157, which indicates that almost 21.57 percent of the variation in the model is well described by the independent variables, namely the NR price and NR stock. NR price is an important variable in the model. Every one unit (USD/ton) increase in NR price, on average, it will have a negative impact on decreasing NR consumption by 0.0771 unit ('000 tonnes), holding other variable constant, and it is statistically significant at α = 0.05 level. Besides, every one unit increase in NR stock ('000 tonnes), on average, it will have a negative impact on decreasing NR consumption by 0.0392 unit ('000 tonnes), holding other variable constant, and it is statistically significant at α = 0.10 level. In short, in the four NR consuming countries, namely China, India, Japan and USA, NR price and stock are having a negative significant relationship with NR consumption.

A decrease in NR price will discourage plantation. However, it favors consumers due to the lower price compared with before. Consumption will increase when NR price decrease. It may benefit the consumers for the short term, but it will indeed harm the NR industry severely in the long run. The continuous low price of NR will definitely lead to the imbalance of production and consumption of NR in the market, which is happening right now in the world market. It makes NR less profitable to farmers and smallholders and discourages the plantation of NR, which further hurts the NR industry.

4.6 Panel Cointegration Test

Table 4.11: Panel Cointegration Tests of NR Production Model

Pedroni Test		***Kao Test***	
Panel v-Statistic	0.0071	***ADF***	**-3.0568*** **
Panel rho-Statistic	0.3432		
Panel PP-Statistic	-0.1937		
Panel ADF-Statistic	-1.0603		
Group rho-Statistic	0.6161		
Group PP-Statistic	-0.5531		
Group ADF-Statistic	**-1.5536***		

Johansen Fisher Panel Cointegration test		
Hypothesized no. of CE(s)	***Trace***	***Max-Eigen***
None	72.64***	71.97***
At most 1	14.55	11.31
At most 2	18.80**	18.80**

Note: ***statistically significant at 0.01 level
**statistically significant at 0.05 level
*statistically significant at 0.10 level

Table 4.12: Panel Cointegration Tests of NR Consumption Model

Pedroni Test		***Kao Test***	
Panel v-Statistic	-0.0046	***ADF***	**-1.5642** **
Panel rho-Statistic	-0.1412		
Panel PP-Statistic	**-2.5270*** **		
Panel ADF-Statistic	**-2.3744*** **		
Group rho-Statistic	1.7714		
Group PP-Statistic	0.9484		
Group ADF-Statistic	1.0165		

Johansen Fisher Panel Cointegration test		
Hypothesized no. of CE(s)	***Trace***	***Max-Eigen***
None	20.01***	11.74**
At most 1	13.22**	8.669
At most 2	13.24**	13.24**

Note: ***statistically significant at 0.01 level
**statistically significant at 0.05 level

Table 4.11 and 4.12 demonstrate the panel cointegration tests for NR production and consumption models respectively. Three tests are performed, namely the Pedroni (2004), Kao (1999) as well as the Johansen's cointegration trace and maximum eigenvalue test which reports the values based on Mackinnon-Haug-Michelis (1999) p-values.

In table 4.11, test results from Pedroni (2004) indicate that only group ADF-statistic is statistically significance at $\alpha = 0.10$ level to reject the null hypothesis; Kao (1999) test result suggests that the null hypothesis can be rejected at $\alpha = 0.01$ level where there is the presence of cointegration relationship among variables. Besides, results of Trace and Max-Eigen values of Johansen's cointegration test indicate that there are more than two cointegrating equations, where the null hypothesis is rejected at $\alpha = 0.05$ level. Conclusively, there is the presence of cointegration among variables in the production model.

On the other hand, in table 4.12, Pedroni (2004) test results reveal that panel PP-statistic and panel ADF-statistic are statistically significance at $\alpha = 0.01$ level; Kao (1999) test also suggests that the null hypothesis can be rejected

at $\alpha = 0.05$ level where there is the presence of cointegration relationship among variables. Moreover, Trace and Max-Eigen values of Johansen's cointegration test show that there are more than two cointegrating equations, where the null hypothesis is rejected at $\alpha = 0.05$ level. Conclusively, there is the presence of cointegration among variables in the consumption model.

4.7 VECM of NR Price Model

4.7.1 Cointegration Equation

$$\textbf{-0.0134}\ \Delta\ nrsmr20_{t-1} + \textbf{0.0043}\ \Delta\ nrwp_{t-1} - \textbf{0.0022}\ \Delta\ nrwc_{t-1} + \textbf{0.0231}\ \Delta\ nrshg_{t-1}$$

t-stat: [-0.9026] [0.7807] [-0.2756] [1.3682*]

$$\textbf{- 0.0055}\ \Delta\ exr_{t-1} + \textbf{0.0602}\ \Delta\ srp_{t-1} + \textbf{0.0488}\ \Delta\ cop_{t-1} = \textbf{0} \qquad (4.3)$$

[-0.9973] [7.0132***] [0.0907]

Note: ***statistically significant at 0.01 level
*statistically significant at 0.10 level

Equation 4.3 shows the cointegration equation of the NR price model. The equation indicates that Shanghai NR price and SR price are the most important variables in the model. Test results reveal that there is a positive long-run cointegrated relationship between Shanghai NR price with the NR SMR20 price, statistically significant at $\alpha = 0.10$ level. While SR price is also having a positive long-run cointegrated relationship with the NR SMR20 price at $\alpha = 0.01$ level. SR price is the most important variable in the cointegration model due to the highest coefficient value and t-statistic. However, there is no long-run

cointegrated relationship between world NR production, world NR consumption, crude oil price and real exchange rate with the NR SMR20 price.

4.7.2 VECM Equation

$$\Delta nrsmr20_t = -0.0092 + 0.3334\,\Delta nrwp_{t-1} - 0.2467\,\Delta nrwc_{t-1}$$

t-stat: [1.3679*] [-1.6409*]

$$+ 0.4121\,\Delta nrshg_{t-1} - 0.1429\,\Delta exr_{t-1} + 0.1779\,\Delta srp_{t-1}$$

[2.8475***] [-0.5637] [1.3267*]

$$+ 0.0019\,\Delta cop_{t-1} + 0.1225\,\Delta nrsmr20_{t-1} + 0.0724\,e_{it} \qquad (4.4)$$

[0.6637] [0.722]

$R^2 = 0.2277$ Adj $R^2 = 0.1709$ d = 2.2079

Note: ***statistically significant at 0.01 level
*statistically significant at 0.10 level

Equation 4.4 derives the VECM equation of the NR world price model. According to the equation, R^2 is equal to 0.2277 which means that only 22.77 percent of the variation in the model is well explained by the explanatory variables. Test statistics show that NR world production, NR world consumption, Shanghai NR price and SR price are the important variables in the model and it is statistically significant at $\alpha = 0.10$ and 0.01 level respectively.

Therefore, every one unit (‘000 tonnes) increase in the NR world production, on average, will have a positive effect on increasing the NR world price by 0.3334 unit (USD/ton), holding other variables constant; every one unit (‘000 tonnes) increase in the NR world consumption, on average, will have a

negative effect on decreasing the NR world price by 0.2467 unit (USD/ton), holding other variables constant; every one unit (USD/ton) increase in the Shanghai NR price (USD/ton), on average, will have a positive effect on increasing the NR world price by 0.4121 unit (USD/ton), holding other variables constant; every one unit (‘000 tonnes) increase in the SR price, on average, will have a positive effect on increasing the NR world price by 0.1779 unit (USD/ton), holding other variables constant.

Among the four significant variables, Shanghai NR price is the most important variable because of the highest coefficient value. It could be due to the rising of China’s economics which is having a substantial effect on the world economy including the agricultural sector. As China is being the main consumer of NR in the world, high consumption and import of NR from all over the world are required for their manufacturing sectors which are related to the NR industry. The other three significant variables namely NR production, consumption and SR price could be considered as equally important as the coefficient values are more or less the same.

NR production and consumption are known as the fundamental factors of NR price, thus, it will and it should be significant and to comply with the theory. As SR price is the substitute product of NR, both of the variables are negatively related. When the SR price decreases, it becomes cheaper than NR, thus, consumer who can switch their product input from NR to SR will definitely do so to maximize profit earning. Besides, results show that there is no short-run relationship between real exchange rate and crude oil price with the NR world

price. The insignificant of these two variables could be mainly due to the sampling period. Further elaboration will be discussed in the hypothesis testing section.

4.8 Cointegration Rank Test of NR Price Model

Table 4.13: Cointegration Rank Tests of NR Price Model

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.4339	178.180	125.615	0.0000
At most 1 *	0.3645	111.033	95.7536	0.0029
At most 2 *	0.1828	57.5204	69.8188	0.3193
At most 3	0.1646	33.6966	47.8561	0.5185
At most 4	0.0509	12.4707	29.7970	0.9143
At most 5	0.0469	6.30471	15.4947	0.6595
At most 6	0.0053	0.63415	3.84146	0.4258

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.4339	67.1471	46.2314	0.0001
At most 1 *	0.3645	53.5126	40.0775	0.0009
At most 2 *	0.1828	23.8237	33.8768	0.4685
At most 3	0.1646	21.2259	27.5843	0.2628
At most 4	0.0509	6.16602	21.1316	0.9794
At most 5	0.0469	5.67056	14.2646	0.6558
At most 6	0.0053	0.63415	3.84146	0.4258

Note: Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 4.13 presents the results of cointegration rank tests for the NR price model. Two cointegration tests are performed namely the Trace test and Maximum Eigenvalue test.

Results from both tests suggest the same decision. P-values of 0.0029 and 0.0009 can reject the null hypothesis of $r \leq 1$ at $\alpha = 0.01$ level. Trace test and Maximum Eigenvalue test results indicate that there are two cointegrating relationships in the NR price model. In short, it is suggested that there is the existence of cointegration relationships in the NR price model. Since the models are only stationary at first difference I(1) and cointegrated, therefore, VECM is suitable for the data analysis.

4.9 Granger Causality Test

4.9.1 NR Production Model

Table 4.14: Granger Causality Test of NR Production Model

Hypothesis (H_A)	***Obs***	***F-Statistic***	***Prob.***	***Conclusion***
nrsmr20 Granger Cause *nrwp*	60	3.4122	**0.0401**	**Supported**
nrwp Granger Cause *nrsmr20*		0.1105	0.8955	Not Supported
tpa Granger Cause *nrwp*	60	0.4008	0.6717	Not Supported
nrwp Granger Cause *tpa*		3.8343	**0.0276**	**Supported**
tpa Granger Cause *nrsmr20*	60	0.9273	0.4017	Not Supported
nrsmr20 Granger Cause *tpa*		0.7767	0.4649	Not Supported

Table 4.14 reveals the summary of panel Granger Causality test results and figure 4.1 illustrates the directions of the causal relationships among variables in the NR production model.

Results indicate that there are two unidirectional causal relationships in the model running from (1) SMR20 price to the NR production at $\alpha = 0.05$ level and (2) NR production to the total planted area of NR $\alpha = 0.05$ level as well. Thus, the alternative hypothesis is supported, SMR20 price Granger causes NR production and NR production Granger causes the total planted area of NR in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.

4.9.2 NR Consumption Model

Table 4.15: Granger Causality Test of NR Consumption Model

Hypothesis (H_A)	***Obs***	***F-Statistic***	***Prob.***	***Conclusion***
nrsmr20 Granger Cause *nrwc*	48	0.2905	0.7493	Not Supported
nrwc Granger Cause *nrsmr20*		1.0559	0.3567	Not Supported
stock Granger Cause *nrwc*	48	0.9329	0.4012	Not Supported
nrwc Granger Cause *stock*		5.4410	**0.0078**	**Supported**
stock Granger Cause *nrsmr20*	48	0.3198	0.7279	Not Supported
nrsmr20 Granger Cause *stock*		0.2700	0.7647	Not Supported

Table 4.15 shows the summary of panel Granger Causality test results and figure 4.2 demonstrates the directions of the causal relationships among variables in the NR consumption model. Statistical results suggest that in the model, there is only one unidirectional causal relationship running from NR consumption to

NR stock. Therefore, alternative hypothesis is supported, NR consumption Granger causes NR stock in China, India, Japan and the USA.

4.9.3 NR Price Model

Table 4.16: Granger Causality Test of NR Price Model

Hypothesis (H_A)	***Obs***	***F-Statistic***	***Prob.***	***Conclusion***
nrshg Granger Cause *nrsmr20*	118	4.1212	**0.0187**	**Supported**
nrsmr20 Granger Cause *nrshg*		0.1307	0.8776	Not Supported
srp Granger Cause *nrsmr20*	118	2.5875	**0.0797**	**Supported**
nrsmr20 Granger Cause *srp*		17.802	**2.E-07**	**Supported**
nrwc Granger Cause *nrwp*	118	12.979	**8.E-06**	**Supported**
nrwp Granger Cause *nrwc*		4.6375	**0.0116**	**Supported**
nrshg Granger Cause *nrwp*	118	1.0931	0.3387	Not Supported
nrwp Granger Cause *nrshg*		2.8680	**0.0610**	**Supported**
cop Granger Cause *nrwp*	118	3.6435	**0.0293**	**Supported**
nrwp Granger Cause *cop*		0.2574	0.7735	Not Supported
exr Granger Cause *nrwc*	118	1.6408	0.1984	Not Supported
nrwc Granger Cause *exr*		3.9061	**0.0229**	**Supported**
cop Granger Cause *nrwc*	118	6.1623	**0.0029**	**Supported**
nrwc Granger Cause *cop*		0.6362	0.5312	Not Supported
srp Granger Cause *nrshg*	118	1.1538	0.3191	Not Supported
nrshg Granger Cause *srp*		20.248	**3.E-08**	**Supported**
cop Granger Cause *exr*	118	0.4123	0.6631	Not Supported
exr Granger Cause *cop*		3.4699	**0.0345**	**Supported**
cop Granger Cause *srp*	118	7.9971	**0.0006**	**Supported**
srp Granger Cause *cop*		0.1432	0.8667	Not Supported

Table 4.16 shows the summary of Granger Causality test results and figure 4.3 illustrates the directions of causality relationships among variables in the NR SMR20 price model. Test results show that there are unidirectional causality

relationships running from (1) Shanghai NR price to NR SMR20 price at $\alpha = 0.05$ level; (2) NR production to Shanghai NR price at $\alpha = 0.10$ level; (3) crude oil price to NR production at $\alpha = 0.05$ level; (4) NR consumption to the real exchange rate at $\alpha = 0.05$ level; (5) crude oil price to NR consumption at $\alpha = 0.01$ level; (6) Shanghai NR price to SR price at $\alpha = 0.01$ level; (7) real exchange rate to crude oil price at $\alpha = 0.05$ level; (8) crude oil price to SR price at $\alpha = 0.01$ level.

On the other hand, there are two bi-directional causality relationships between (1) SR price and NR SMR20 price $\alpha = 0.05$ level where the former Granger causes the latter at $\alpha = 0.10$ level while the latter Granger causes the former at $\alpha = 0.01$ level; and (2) NR consumption and NR production where the former Granger causes the latter at $\alpha = 0.01$ level while the latter Granger causes the former at $\alpha = 0.05$ level. Conclusively, there are eight unidirectional and two bi-directional causal relationships in the NR SMR20 price model.

4.10 Residual Diagnostics

Table 4.17: Residual Diagnostics of NR Production and Consumption Models

NR production model		
Normality	**0.1154** > $\alpha = 0.05$	Do not reject H_0, residuals are normally distributed.
Multicollinearity	VIF = $1 / 1 - R^2$ = $1 / 1 - 0.8711$ = **7.7579 < 10**	Since VIF < 10, therefore do not reject H_0, there is no multicollinearity.
NR consumption model		
Normality	**0.1681** > $\alpha = 0.05$	Do not reject H_0, residuals are normally distributed.

Multicollinearity	VIF = $1 / 1 - R^2$ $= 1 / 1 - 0.2157$ $=$ **$1.2750 < 10$**	Since VIF < 10, therefore do not reject H_0, there is no multicollinearity.

Table 4.17 reveals the test results of the normality test and multicollinearity test of the NR world production and consumption models respectively. The reason of running only two residual tests (instead of four) for both the panel models is because there is no heteroskedasticity test for a REM in EViews 9; and serial correlation test is only applicable for a panel Generalized Moment Method (GMM) instead of a static FEM or REM. On top of that, the REM equations for the NR production and NR consumption have already been tested with robustness check, where it already remedies the heteroskedasticity and autocorrelation problems by adjusting the standard error in the equations. Therefore, in this section, only normality and multicollinearity tests will be discussed. Results in table 4.17 show that, for normality test, p-values in both models are greater than 0.05, therefore, we do not reject H_0, residuals are normally distributed. For the multicollinearity test, the calculated VIF for both models are smaller than 10. Thus, we do not reject H_0, there is no evidence of multicollinearity in the models.

Table 4.18: Residual Diagnostics of NR Price Model

Tests	***P-value***	***Conclusion***
Normality	**0.8569** > α = 0.05	Do not reject H_0, residuals are normally distributed.
Heteroskedasticity	**0.2709** > α = 0.05	Do not reject H_0, there is no heteroskedasticity.
Serial Correlation	**0.3789** > α = 0.05	Do not reject H_0, there is no serial correlation.

Multicollinearity	VIF = $1 / 1 - R^2$ = $1 / 1 - 0.2277$ = **$1.2948 < 10$**	Since VIF < 10, therefore do not reject H_0, there is no multicollinearity.

Table 4.18 summarizes the test results of residual diagnostics tests for the NR world price model. Test statistics show that, under the normality, heteroskedasticity as well as serial correlation tests, p-values are all greater than $\alpha = 0.05$, all the H_0 are fail to be rejected. Therefore, residuals are normally distributed, and there are no evidences of heteroskedasticity and serial correlation problems in the model. Lastly, for multicollinearity test, the result shows that the calculated VIF is equal to 1.2948, which is lesser than 10. Therefore, H_0 is failed to be rejected, multicollinearity does not exist.

4.11 Model Evaluation

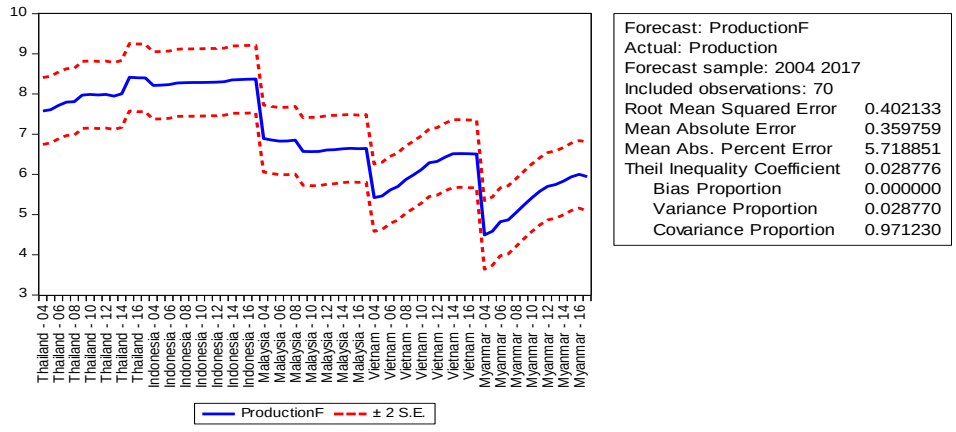


Figure 4.1: Model Evaluation of NR Production Model

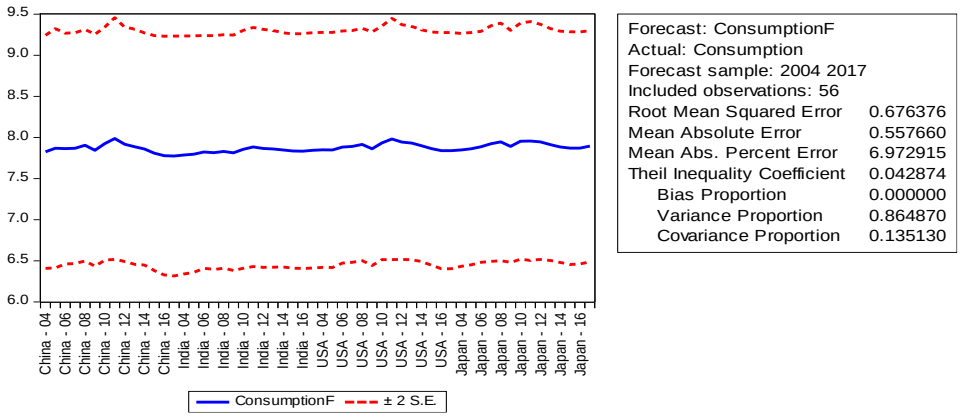


Figure 4.2: Model Evaluation of NR Consumption Model

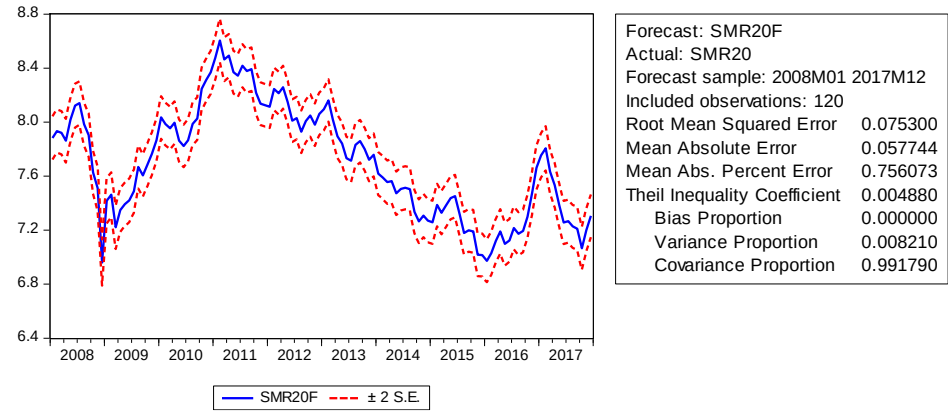


Figure 4.3: Model Evaluation of NR Price Model

Figures 4.1, 4.2 and 4.3 illustrate the model evaluation graphs for the NR world production, world consumption and world price models respectively. The text boxes on the right side of the graphs reveal the values of RMSE, MAE, MAPE and U-Theil of each model. Figures show that all three models contain a low value of RMSE, MAE, MAPE and the Theil's U statistic are less than 1 and close to 0. Lower values of these four statistics indicate that the models are better fit and accurate, and it can be concluded that all three models are having a satisfactory and valid forecasting performance.

4.12 Hypothesis Testing

4.12.1 NR Production Model

Statistical results showed that there is a positive relationship between NR prices and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar. This finding is similar to the theoretical framework in chapter 2.1.1 by Arunwarakorn *et al.* (2017). Besides, it could also be supported by several previous studies in the same field by Khin, Chong, Shamsudin & Mohamed (2008), Kannan (2013) and Karunakaran (2017). Therefore, H_{A1} is supported.

H_{A1}: There is a positive relationship between NR prices and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.

Moreover, it was proved that the total planted area of NR is having a positive relationship with its production. This could be supported by Hameed, Applanaidu & Arshad (2013) who suggested that the planted area is one of the important factors of the production of cocoa in Malaysia which they were having a positive relationship with each other. They mentioned that smallholders of the cocoa plantation depended on the planted area as well as the yield in the equivalent sectors. Although the studies by Hameed were about the cocoa market, this finding could apply in the NR market for these two products are both agricultural crops and they were bound to have some similarities in this study. Thus, this could support the finding of this study where the NR production and the total planted area of NR are positively related. Therefore, H_{A2} is supported.

H_{A2}: There is a positive relationship between total planted area of NR and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.

In short, in the NR production model, both NR prices and total planted area of NR are both having positive relationships with NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar. NR Production is one of the fundamental factors of its price. According to theory, production is positively related to price and therefore, the finding in this model complies with the theory.

As such, based on the results, the government could encourage the plantation and cultivation of *Hevea* trees by providing grants or funds to smallholders to attract them to continue making efforts in the field. Continuous of research and development is definitely needed in both NR producing and consuming countries so that government could discover the new planted area and expand existing plantation area, replantation area, and other offers that favor the production as well as the sustainability of NR. By providing incentives to the producers and cultivators, it would motivate them and drive up the NR production. Driving up production will then trigger the NR price to rise which would ultimately benefit smallholders as well as the country's economic development. Eventually, it would also decrease the deficit gap of the NR supply-demand and further increase the stability of both sides in the NR market.

4.12.2 NR Consumption Model

Results indicated that in the NR consumption model, NR price and NR consumption are negatively related. This finding is similar to the theoretical framework by Arunwarakorn *et al.* (2017) who suggested that NR price and NR consumption were having a negative relationship. When a product's price decrease, it would become cheaper and the consumer will consume more. Besides, this finding could also be supported by previous studies in this field by Khin *et al.* (2011) and Khin & Thambiah (2015). Therefore, H_{A3} is supported.

H_{A3}: There is a negative relationship between NR prices and NR consumption in China, India, Japan and USA.

Moreover, studies found out that NR stock and NR consumption are having a negative relationship too. This finding could be supported by previous studies in this field by Lekshmi, Mohanakumar & George (1996), Ahrends *et al.* (2015) and Khin & Thambiah (2015). The findings of these two hypotheses could contribute to government policy implication, especially for NR consuming countries. When the NR price starts to decrease, they could decide on the amount of purchasing of NR and the inventory of NR. Therefore, H_{A4} is supported.

H_{A4}: There is a negative relationship between NR stock and NR consumption in China, India, Japan and USA

4.12.3 NR Price Model

Supply and demand are the fundamental factors of its price. According to the price theory of NR, production is having a positive relationship with NR price and consumption is having a negative relationship with NR price (Arunwarakorn *et al.*, 2017). Its explanation would be similar to the above hypothesis testing in NR production and consumption model (H_{A1} and H_{A3}). It also complies with the theory as stated in the theoretical framework. Therefore, H_{A5} and H_{A6} are supported.

H_{A5}: There is a positive relationship between NR world production and NR SMR20 price.

H_{A6}: There is a negative relationship between NR world consumption and NR SMR20 price.

Furthermore, one of the major findings or variables in this study is that the Shanghai NR price is positively related to NR SMR20 price. China has been a strong economy that causes a lot of impact on the world, with the Belt and Road Initiatives (BRI), including the commodity market. According to Global Rubber Market (GRM, 2018), even though it is difficult to predict where the rubber economy is heading, but it will definitely be influenced by other factors including China's economic indicators as well as its stock prices. Other than the Singapore Commodity Exchange (SICOM) and Tokyo Commodity Exchange (TOCOM), Shanghai Future Exchange (SHFE) is also an important future exchange in the NR market. SHFE was established in 1999 and is currently the

world's largest NR importer as well as the most heavily traded NR future. Therefore, Shanghai NR price would be a crucial factor in the NR world market.

This result could contribute to the speculative investors in the commodity market. In the rubber future market, speculative investors would consider SR as a substitute for NR. SR's production cost and price are based on the crude oil price since it is petroleum-derived. Therefore, speculative investors will bet on possible substitution between NR and SR by monitoring the crude oil trends. When the crude oil price rises, they tend to invest in NR; when the crude oil price drops, they tend to switch over from NR futures. As such, Shanghai NR price and world NR price are actually moving together in the same direction (Jacob, 2017). On top of that, there was very little literature that studied Shanghai NR price in the NR market, thus this finding could contribute to the literature on this variable. Therefore, H_{A7} is supported.

H_{A7}: There is a positive relationship between Shanghai NR price and NR SMR20 price.

The insignificance of the real exchange rate could be explained by the sampling period as well as its volatility, especially in recent years. The fluctuation of the exchange rate since the subprime crisis during 2008 had affected the commodity market severely because most of the commodities were traded in USD. NR prices became vulnerable to rates of local currencies against USD. Therefore, the insignificance of the real exchange rate in this study could be due to the sampling period as well (from January 2008 onwards). Previous research done by

Khin *et al.* (2011) proved that the exchange rate and SMR20 price were negatively related and it was statistically significant. However, the sampling period used by the study was monthly data from 1990 to 2008, which is a totally different time frame with this study (monthly data from 2008 to 2017). Therefore, this could be the reason for the insignificance of the exchange rate variable in the NR price model in this study. Thus, alternative hypothesis H_{A8} is not supported.

H_{A8}: There is a negative relationship between real exchange rate and NR SMR20 price.

A similar situation with the variable of the real exchange rate and crude oil price is insignificant in the model could be due to the sampling period problem too. For instance, even though Khin *et al.* (2017) proved the crude oil price and NR SMR20 price are positively related, but the sampling period of the study was monthly data from 2000 to 2016. They captured a longer estimation period for almost 17 years of data. However, in recent years, the unstable and fluctuation of the world crude oil price have changed the situation. On top of that, the sampling period of this study is captured from January 2008, which is the year where oil price shocks happened.

From 2004 to 2008, crude oil price had been rising due to the surging demand and low supply (Smith, 2009). The price reached its peak of the historical record at 145 USD/barrel in July 2008 and in the same year, the price decreased sharply to 32 USD/barrel in December 2008, in just five months. Crude oil price continued to rise for the following years and fell again in between 2014-16. Refer

back to graph 1.4, before the year 2014, the movement of crude oil price and NR price were actually in opposite direction, which did not comply with the theory which suggested that NR price moves together with the crude oil price. As such, oil price shocks would be the reason behind the insignificance of the variable of crude oil price in this study. Thus, alternative hypothesis H_{A9} is not supported.

H_{A9}: There is a positive relationship between crude oil price and NR SMR20 price.

Moreover, SR price was found to be positively related to NR price in the NR world price model. It could be supported by the previous study by Yusof (1998) and Khin *et al.* (2012) who suggested that SR and NR were positively related too. Besides, SR is considered as the substitute product of NR. According to theory, the price of substitute goods is positively related (Pindyck & Rubinfeld, 1998). When one of the prices increases, the consumer would switch to another product that is cheaper. For instance, when crude oil price increase, it will ultimately affect the production cost of SR. In this case, SR becomes more expensive than NR. Rubber industries will change their input to NR. Therefore, H_{A10} is supported.

H_{A10}: There is a positive relationship between SR price and NR SMR20 price.

Conclusively, this study could provide an understanding and insights of the NR market not only in the producing countries and consuming countries, but in the world market too. In the NR producing countries, the government could

urge the farmers and smallholders on expanding the plantation area of NR to increase the production of NR in the future. By increasing the production of NR, it could at least remedy the imbalance of the supply-demand situation in the world market. On top of that, in NR consuming countries, the government could implement policy on controlling the NR consumption in a particular country to prevent over-consuming. Despite the seasonality problem in most of the consuming countries, the government could also encourage and increase the plantation area of NR in their country to further stabilize the supply-demand. Ultimately, having a balanced and stable NR market would benefit the farmers and smallholders' livelihood in the rural area. By having incentives and commission, they would remain in the industry instead of switching to other crops and it would continue to enhance the NR economy.

On the other hand, statistical results could also contribute to business and organization, as well as speculative fund investors in the NR future market. New findings in the study such as the relationship between Shanghai NR price and NR world price as well as between SR price and NR world price would be a new understanding in NR market in the recent years. By having new information, they could revise their business strategy or investment decision to achieve the best outcome that is advantageous to the organization.

Table 4.19: Hypothesis Testing of NR Production, Consumption and Price Model

NR Production Model	
H_{A1}: There is a positive relationship between NR prices and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.	(2.8000***) **Supported**
H_{A2}: There is a positive relationship between total planted area of NR and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.	(19.4628***) **Supported**
NR Consumption Model	
H_{A3}: There is a negative relationship between NR prices and NR consumption in China, India, Japan and USA.	(-3.0347**) **Supported**
H_{A4}: There is a negative relationship between NR stock and NR consumption in China, India, Japan and USA.	(-1.776*) **Supported**
NR Price Model	
H_{A5}: There is a positive relationship between NR world production and NR SMR20 price.	(1.3679*) **Supported**
H_{A6}: There is a negative relationship between NR world consumption and NR SMR20 price.	(-1.6409*) **Supported**
H_{A7}: There is a positive relationship between Shanghai NR price and NR SMR20 price.	(2.8475***) **Supported**
H_{A8}: There is a negative relationship between real exchange rate and NR SMR20 price.	(-0.5637) **Not Supported**
H_{A9}: There is a positive relationship between crude oil price and NR SMR20 price.	(0.6637) **Not Supported**
H_{A10}: There is a positive relationship between SR price and NR SMR20 price.	(1.3267*) **Supported**

4.13 Conclusion

Chapter IV discussed the data analysis and results interpretation. Firstly, a preliminary analysis was carried out, including descriptive analysis, correlation test and unit root tests for all the models, namely the NR production model (such as Thailand, Indonesia, Malaysia, Vietnam and Myanmar) and consumption model (such as China, India, Japan and USA) (panel data analysis) and NR SMR20 price model (time series data analysis). After that, the data analysis part was demonstrated accordingly.

For panel data analysis, the first part was to select an appropriate model for the analysis. Three tests were conducted for panel model selection, which are the Redundant Fixed Effect Test, BPLM test and the Hausman test. Results suggested that REM regression was appropriate for both the NR world production and consumption model. Regression analysis for REM was then carried out. The REM equations shown in the previous section (equation 4.1 and 4.2) were the final equations after robustness checking, which it had taken into account of heteroskedasticity and serial correlation problem. The standard error in the equations had been adjusted to remedy the problems, thus, only the final equations were shown to prevent confusion of readers. Besides, panel cointegration tests were carried out and the test statistics suggested that long-run cointegrated relationships existed among variables in both NR world production and consumption models.

Apart from that, time-series data analysis of NR SMR20 price was conducted. Results of unit root tests indicated that all the variables in the model were stationary only at first difference level. Cointegration test was then performed to check the existence of cointegrated relationships among variables in the models. Results showed that there was existence of cointegration in the model. Since the series was I(1) and cointegrated, therefore VECM analysis would be appropriate for the models. Cointegration equations and VECM equations were derived and interpreted.

Furthermore, Granger Causality test (time series data analysis) were demonstrated to check the directional causal relationship among variables in the models. Then, four residual diagnostic tests such as normality, heteroskedasticity, autocorrelation and multicollinearity tests were also conducted for the NR world price model only. For both of the panel data models, a robustness check was already conducted to remedy the heteroskedasticity and serial correlation problem. Lastly, the model evaluation was also tested for world production, consumption and price models which showed the value of RMSE, MAE, MAPE and Theil's U statistic.

CHAPTER V

DISCUSSION, CONCLUSION AND IMPLICATIONS

5.0 Introduction

Chapter V represents the last chapter of this thesis. Firstly, a summary of the study will be discussed, followed by the summary and discussion of the statistical results. Highlights on the major findings of the panel data models of NR production (such as Thailand, Indonesia, Malaysia, Vietnam, Myanmar) and NR consumption (such as China, India, Japan, USA) as well as time-series data models of VECM of NR SMR20 price will be discussed. Besides, the implication of the study will be provided to explain the contributions of the study. Limitations of the study will also be reviewed and recommendations for future study will be suggested. A brief conclusion will be the last part of this chapter.

5.1 Summary of the Study

This study investigated the NR market by focusing the NR top five producing countries of the selected ASEAN countries (such as Thailand, Indonesia, Malaysia, Vietnam, Myanmar) and the NR top four consumption countries (such as China, India, Japan, USA) as well as in the world market, as a whole. This section summarizes the previous chapters about the introduction, literature review, research methodologies and results interpretation of this study.

NR is a vital agricultural commodity in the world that was being used in many sectors and industries. Besides, it even acted as one of the major contributions to a particular country's economic growth and development, especially in Southeast Asia countries where most of the major NR producers located at. According to IRSG, data showed that the five major producers of NR in the world are Thailand, Indonesia, Malaysia, Vietnam and Myanmar; while the four major consumers are China, India, Japan and USA.

In NR producing countries, the majority of the rubber plantation was managed by smallholders who indicated that the market condition determined the smallholders and farmers' living standards. In recent years, there was an imbalance of the supply-demand in the NR market where the consumption far exceeded its production. This could be due to the instability of NR price in the market as well as the impact of exchange rate volatility. Moreover, the NR market had also been facing severe competition from its substitute product; SR. Falling of the crude oil price had made the SR price cheaper. The manufacturers in the industry could switch their raw material to SR, which further hit the NR market. Furthermore, the rising of China's economy also had an impact on the commodity market. The Shanghai NR price (China price) therefore would be a new variable to study in this field as there was a very limited study in the literature that explored it.

With the general objective to develop the NR production, consumption and price models in selected ASEAN countries and world market, panel data analysis and VECM analysis would be performed to accomplish both general and specific

objectives. Theoretical and literature reviews were discussed in Chapter II. The NR world supply, world demand and world price theory were demonstrated; while the literature review on NR production, consumption and price models were stated. Besides, literature on the major research methods that were used in this study (panel data and VECM) was also discussed.

There was a total of three models in this study: two panel data models and one VECM model. The two panel data models were NR production and consumption models. NR production was the function of the NR price and total planted area of NR in Thailand, Indonesia, Malaysia, Vietnam and Myanmar; while NR consumption was the function of NR price and NR stock in China, India, Japan and USA. The VECM model was the NR SMR20 price model which was the function of the NR world production, NR world consumption, Shanghai NR price, real exchange rate, SR price and crude oil price. Secondary data was collected from the International Rubber Study Group (IRSG), Association of Natural Rubber Producing Countries (ANRPC), Malaysia Rubber Board (MRB) and World Bank for data analysis.

Results indicated that in the NR production model, the maximum production in the five major producing countries was 4755 thousand tonnes and the minimum production was 52.3 thousand tonnes. It is found that both the variables namely the NR price and the total planted area of NR were both having a strong positive correlation with NR production. Besides, unit root tests results indicated that variables were stationary at Ln and first difference level. Test results

of model selection revealed that REM was appropriate for data analysis. Therefore, the REM equation of the NR world production model was regressed.

It proved that NR price and total planted area of NR were having a positive relationship with NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar which was statistically significant at $\alpha = 0.01$ level respectively. Furthermore, panel cointegration test showed that there was evidence of the presence of cointegration among variables in the model. Granger causality test results showed that there were two unidirectional causal relationships in the model which were (1) SMR20 price Granger caused NR production and (2) NR production Granger caused total planted area of NR at $\alpha = 0.05$ level respectively. Lastly, model evaluation of NR production model showed that Ln model was the best model with satisfactory and valid forecasting performance by having the lowest value of RMSE, MAE, MAPE and Theil's U statistics.

Apart from that, in the NR consumption model, the maximum consumption in the 4 major consuming countries was 9591.6 thousand tonnes and the minimum consumption was 968 thousand tonnes. Both the independent variables namely the NR price and NR stock were having a weak negative correlation with NR consumption. Moreover, unit root tests results suggested that variables were stationary at Ln and first difference level. Test results of model selection revealed that REM was appropriate for data analysis. Therefore, the REM equation of NR consumption model was regressed.

REM equation indicated that in the four major NR consuming countries (China, India, Japan, USA), NR price and NR stock were having negative relationships with the NR consumption which were statistically significant at $\alpha = 0.05$ and 0.10 level respectively. Panel cointegration tests also showed that there was statistical evidence of the presence of cointegration among variables in the NR world consumption model too. Besides, it was found out that there was 1 unidirectional causal relationship running from NR consumption to NR stock at $\alpha = 0.01$ level. Lastly, the model evaluation revealed that Ln model was having the lowest value of RMSE, MAE, MAPE and the Theil's U statistic, which implied that the model was valid and satisfactory in forecasting performance.

Lastly, in the NR SMR20 price model, data of the recent 10 years showed that the maximum price of NR SMR20 was about 5560.8 USD/ton and the minimum price was only 1090.5 USD/ton. Results of correlation test revealed that NR production and Shanghai NR price were having a moderate and strong positive correlation with the NR SMR20 price respectively; NR consumption, real exchange rate and SR price were having a weak and moderate negative correlation with the NR SMR20 price respectively. Unit root tests results revealed that all the variables only became stationary after first differencing which were all I(1). Cointegration rank tests results proved that there was existence of cointegration in the model which was statistically significant at $\alpha = 0.05$ level. Since all the models were I(1) and cointegrated, VECM was performed for the next step.

Cointegration equation of NR SMR20 price model revealed that only Shanghai NR price and SR price were having long-run cointegrated relationship with NR SMR20 price. On the other hand, VECM equation showed that NR world production, world consumption, Shanghai NR price and SR price were having short term relationships with NR SMR20 price, but not the NR production, consumption, real exchange rate and crude oil price.

Furthermore, results of Granger Causality test revealed that there were eight unidirectional and two bi-directional causal relationships in the model. Eight unidirectional causal relationships were (1) Shanghai NR price granger caused NR SMR20 price; (2) NR production granger caused Shanghai NR price; and (3) Crude oil price granger caused NR production; (4) NR consumption granger caused real exchange rate; (5) Crude oil price granger caused NR consumption; (6) Shanghai NR price granger caused SR price; (7) real exchange rate granger caused crude oil price and (8) crude oil price granger caused SR price.

Two bi-directional causal relationships were running between (1) NR SMR20 price and SR price; and (2) NR consumption and NR production. Last but not least, model evaluation was also conducted. Results indicated that Ln model was the valid and satisfactory in forecasting performance with the lowest value of RMSE, MAE, MAPE as well as the Theil's U Statistic.

5.2 Implication of the Study

Overall, this study provided the findings on the development of NR production, consumption and price models in selected ASEAN countries as well as the world market, as stated as the general objective of this study. For NR production, the results of the study could contribute to government policy implementation especially on NR producing countries which the NR industry is one of the contributors to economic growth. To avoid the continuous falling of NR production, the government should take action to resolve it. For instance, the government could provide training to rubber and smallholders of NR in the rural areas and appropriate education on the importance of NR market to the country. Agricultural infrastructure and facilities should also be provided by the government to them to encourage the production of NR.

Moreover, results can contribute to the stability and sustainability of NR production if governments take appropriate actions on the issue, which is the falling of NR production. For example, the government could provide grants or funding to NR farmers and smallholders to further encourage them to stay in NR industry and perform better than before. Other than that, commissions or incentives could also be given to them based on the volume of the production. By that, it could urge the farmers and smallholders to work harder by ensuring the continuous production of NR. Also, it could avoid them from switching to other crops such as palm oil and cocoa which would even worsen the NR industry.

For NR consumption, the outcome of the study would contribute to NR consuming countries as a reminder or alarm for them to look into the issue of overconsumption of the NR. Due to the favorable price and the rising of the automobile industry, NR has been highly consumed as compared to SR. Eventually, the rising of NR consumption and falling of NR production has enlarged the gap between these two factors and it happens the imbalance of production and consumption in NR market. As consuming countries, such as China and India, the government should take this as a serious matter as it affects the NR market in the world. Instead of consuming a high volume of NR, the government could invest in the new plantation and replantation areas in their own countries, but not only invest in other SEA countries. Although the outcome of the expanded plantation areas might not contribute to a lot of the volume since China is a four-season country, but still it will help to reduce the gap of consumption surplus in the industry.

On the other hand, for the price of NR, the results could contribute to the policymakers in both the producing and consuming countries. Firstly, they could truly understand what the real factors behind the price of NR in recent years are. Results show that only NR production, consumption, Shanghai NR price and SR price are important and significant in the past 10 years. It could contribute to the speculative fund investors in the NR future exchange market. As China is the biggest consumer and also a rising economy in the world, it will bound to have an impact on the NR market, either directly or indirectly. Consumers or investors are now clearer to the relationship between NR world price and Shanghai NR price where these two prices are moving together in the same direction while NR world

price tends to follow the trend of Shanghai's future market. In fact, this is a very new variable that is being investigated in the same field as there is very little precedence before this study. Therefore, one of the contributions of the outcomes could be the contribution to the literature.

Moreover, the insignificance of real exchange rate and crude oil price also provides an understanding to the readers and to contribute to NR markets. It tells us that in the recent 10 years, the NR market has started to change its historical behavior where real exchange rate and crude oil price are always significant when it is to be included in the price model of NR. However, perhaps due to the sampling period of the study, they are insignificance in this case. Although it does not comply with the theory, however, it rather reflects the real situation that is happening in the NR market. High volatility and fluctuating currency exchange and world oil price have messed up the theoretical relationship between them. Therefore, related bodies or the government of both producing and consuming countries should take note of the issue that NR market has been unstable especially in recent years. What the old theory says could not explain the physical world after all.

5.3 Limitation of the Study

There are bound to have some limitations of the study in every research. In this study, the first constraint is the limitation and availability of data. For instance, in the NR production model (panel data model), the independent variables are the NR prices and total planted area of NR in the five producing

countries (Thailand, Indonesia, Malaysia, Vietnam, Myanmar). However, as mentioned in the theoretical review part in chapter 2.1.1, the study by Arunwarakorn *et al.* (2017) actually included rainfall and fertilizer price in the production model. In the case of this study, such factors are difficult and unable to collect for the data analysis. Such factors might be collected in Malaysia's context, but it is difficult to collect from other countries' data which may induce high cost and time-consuming. Therefore, independent factors are limited to several available variables.

Another reason for the selection of variables in different models is the significance of other variables. NR price could be affected by a lot of external factors other than its fundamentals. However, in the study, the independent variables of NR world price model are limited to NR world production, world consumption, Shanghai NR price, real exchange rate, crude oil price and SR price. Previous studies that investigated the price factors of NR included other factors such as SICOM, TOCOM. However, for this study, not every factor mentioned above was significant after running the data analysis. To ensure the overall performance of the model, insignificant variables have been dropped, and eventually come out with the current model in this study.

Apart from that, the insignificance of some of the variables in the models could be due to the data sampling period, which is one of the limitations of the study too. The sampling period of both of the panel data models (NR world production and consumption models) are annual data from 2004 to 2017. The reason is that instead of monthly or quarterly data, only annual data is available

to be collected for both producing and consuming countries. Besides, some of the variables are only collectible from 2004 onwards, therefore, to ensure the consistency of the sampling period of both models, all of the data was collected from 2004 onwards to 2017 (the latest available data).

Moreover, another limitation of the study is that the number of models and equations in this study might cause confusion for the readers. This study consists of only three models: two panel data models (NR world production and consumption models) with two REM equations; one time series models of VECM (NR world price model) with one cointegration equation and one VECM equation. Throughout the contents, readers may get confused about the models and equations. On top of that, only NR world production and consumption models are analyzed by using panel data analysis but NR world price model is analyzed by using VECM analysis. This is also one of the study gaps in which this study performs panel data analysis on NR models where there were very little precedents in the literature.

5.4 Recommendation for Future Study

There are a few recommendations which can be suggested for future studies. Firstly, future studies can increase or extend the sampling period for the data analysis. As mentioned in the previous section, this study has only employed annual data of 14 years for panel data analysis and monthly data of 10 years for the time series model of VECM, which was due to the availability of data. As such, if possible, future researchers may try to collect data for more

years and bigger sample size to further increase the accuracy of the analysis. Moreover, future studies can also try to add other appropriate variables in the models. Some factors were insignificant in this study which could be due to the sampling period too. By extending the sampling period and increasing the sample size, other appropriate variables such as the aforementioned crude oil price, fertilizer price, SICOM (Singapore) and TOCOM (Japan) NR prices could be considered to add to the model for further enhancement. In this case, these variables might be statistically significant.

Furthermore, in terms of forecasting, this study only conducted model evaluation tests on the three world models by studying the value of RMSE, MAE, MAPE and Theil's U statistics. A future study could employ other forecasting methods such as historical simulation of an ex-post forecast to check for both the simulated and actual data are similar. Besides, researchers could also apply the ex-ante forecast for the future forecasting of the NR economy in a particular country, or in the world market. The ex-ante forecast could be conducted for the future 10 or 20 years for the NR production, consumption and price which provides more information to the government, policymakers or speculative fund investors. Besides, other forecasting methods such as Autoregressive Integrated Moving Average (ARIMA), Multivariate Autoregressive Moving Average (MARMA) could also be performed in future studies, and then compared the methods to find out the most powerful or significant forecasting tool that could be practiced in the rubber economy.

Recommendations on research methodology for future studies can be provided. One of the research methods which is the simultaneous equation could be employed in this kind of study where production and consumption were investigated. For instance, studies by Arunwarakorn *et al.* (2017) and Khin & Thambiah (2015) conducted simultaneous equation analysis to study the NR market. They formulated a supply equation and a demand equation which both of that consist of NR price as one of the independent variables.

Khin & Thambiah (2015) estimated the NR price simultaneous equation by equalizing the supply and demand equations and then compared to the VECM equation of NR price in terms of its forecasting accuracy. Arunwarakorn *et al.* (2017) used the predicted factors in the simultaneous equation to forecast the equilibrium price of NR from 2017 to 2026. According to Gujarati & Porter (2009), a normal unidirectional cause-and-effect relationship is not meaningful, because there is always a two-way or simultaneous relationship between the dependent variable and the independent variables (or some of the variables). Thus, a simultaneous-equation model is better when it lump a set of variables together, so that it can be resolved simultaneously by the remaining set of variables. Therefore, such methods could also be employed by future studies.

5.5 Conclusion

In a nutshell, this chapter is the last chapter of this thesis. It concluded the whole study in several sections. Firstly, a summary of the previous chapters was discussed. The background of the NR market, the problem statement and

the general objective were stated in the section. Besides, theoretical and literature reviews of this study were also mentioned. After that, the major findings (chapter IV) were summarized and discussed. In this section, the results of the panel data and VECM models were revealed with discussion as well as the rejection or acceptance of the hypotheses in the particular models.

Moreover, the implication of the study was delivered. This study could contribute to the government policy implication, the improvement of the livelihood of farmers and smallholders as well as the business and organization that were related in the NR industry. On the other hand, the limitations of the study would be the number of models and equations involved might cause confusion to the readers. The sampling period and selection of variables in the models had caused insignificancy in the models.

On top of that, some recommendations for future researchers were provided for the enhancement of future studies in the NR industry. Future researchers could extend the sampling period and try to involve more relevant variables in the models. Besides, they could also employ some forecasting methods, both historical simulation and future forecasting to further explain the future trend of the NR market. Lastly, in terms of research methodology, future researchers could employ other research methods such as simultaneous equations.

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