

Impact of Various Palm-Based Biodiesel Blend Mandates on Malaysian Crude Palm Oil Stock and Price: A System Dynamics Approach

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Abstract

With an increasing concern over world population, energy security, volatile fuel prices and rising in greenhouse gas emissions, many countries are considering to a more friendly alternative fossil fuels. United States and also the European Union has already introduce of legislation mandating the use of biofuels in the energy mix. This action has stimulated the demand for vegetable oils. Malaysia is currently the largest palm oil exporter and the second largest producer after Indonesia has launched her palm-based biodiesel blending mandate of 5 percent (B5) in year 2011. However the mandate has not been implemented nationwide. Thus, this study, therefore seeks to contribute to our understanding of the impacts of various blend mandates specifically B5, blending mandate of 7 percent (B7) and blending mandate of 10 percent (B10) on the Malaysian crude palm oil market stock and price. A system dynamics model was developed for the Malaysian palm oil industry which provides a framework to understand the feedback structure and how changes in various blend mandates impact the behaviour of the crude palm oil stock and price. This research suggests that increasing the blending rate is not a favourable policy, although it managed to decrease the crude palm oil stock to the targeted level but it does not contribute to palm-based biodiesel industry production due to loss in terms of profitability because of high crude palm oil prices.

Keywords: demand, palm-based biodiesel mandate, price, supply, system dynamics

1. Introduction

Malaysia's palm oil industry has succeeded to be a powerful force in the global oils and fats economy over a few decades of year. Currently, Malaysia is the largest exporter and second producer of palm oil after Indonesia with an annual export value accounting to RM63.4 billion in year 2014 (MPOB, 2014). Palm oil is widely demanded by various industries like food, cosmetic, pharmaceutical, and also recently has ventured into the energy sector as a feedstock for biodiesel.

The continuous volatility and the prospect of depletion of supply in the future of world crude oil, have forced energy dependence economy in the advanced countries to seek for alternative energy, in the form of biofuel such as ethanol and biodiesel. The Kyoto Protocol is another push-factor towards biofuel demand. The protocol sets targets for industrialized countries and the European Community to reduce the greenhouse gasses (GHG) emissions. Hence the seeds for biofuel demand were planted worldwide.

Mandatory measures such as introducing legislation and subsidies were used as a start for biodiesel. A number of countries have numerical targets for domestic consumption or production of biofuels. Brazil and United States (U.S.) have backed their industries with a variety of supportive policy measures especially for the use of ethanol.

For instance, the U.S. is targeting 20 percent of ethanol to be blended with gasoline by 2030. The targets set by the European Union (EU) Biofuels Directive increased from two percent in 2005 to 5.75 percent by 2010 for biodiesel. By 2020, 10 percent of all conventional motor fuels in the EU will be replaced with biofuels. All these mandates were supported with massive subsidies and non-tariff protection by the U.S. and EU (Arshad, 2008).

In the case of The Association of South East Asian Nations (ASEAN) countries, mandates and investment plays an important role to boost the sector. The Indonesian government plans to replace 10 percent of its petroleum consumption with biofuel by 2020 while Thailand, supports the domestic sugar and cassava producers has mandated two percent biodiesel to be blended with diesel since February 2008 and also an ambitious 10 percent ethanol mix in gasoline starting in 2007. For a similar reason, two percent blend of biodiesel has been used in Philippines to support coconut growers.

In Malaysia, biodiesel blending mandate was launched in 2011 in the federal administration capital of Putrajaya. This was followed by Malacca on July 1, Negeri Sembilan on August 1, Kuala Lumpur on September 1 and Selangor on October 1. However the mandate has not been launched nationwide. The mandate requires diesel to contain 5 percent of biodiesel (B5). The implementation of B5 blending mandate will help to boost the production of palm-based biodiesel. With the consumption of the diesel of around 10 million per annum, approximately 500,000 tonnes of Crude Palm Oil (CPO) will be used as the feedstock for palm-based biodiesel production (Yahaya et al., 2006). This move is not only to response to the alternative fuel demand but also the opportunity for the palm oil industry to leverage on the excess stock and help to increase CPO price. In other words, biodiesel industry acts as a good buffer to support price in the case of oversupply of CPO (Hanim, 2014). The implementation of B5 mandate will enforce government to fix the CPO volume yearly even though in the reality the palm-based biodiesel producer will only produce biodiesel when the CPO price is lower than RM2000 per tonne. Furthermore, Lopez and Laan (2008) states that in the period of high CPO price, palm-based biodiesel producers may sell CPO in its crude form to leverage on its high price rather than producing POB at loss (Lopez & Laan, 2008).

This study, therefore seeks to contribute to our understanding of the impacts of various blend mandates specifically B5, B7 and B10 impact on the Malaysian crude palm oil market stock and price. Thus, a system dynamics model was developed for the Malaysian palm oil industry which provides a framework to understand the feedback structure and how changes in various blend mandates impact the behaviour of the crude palm oil stock and price.

The remainder of the paper is organized as follows: the next section briefly reviews the literature on previous studies on palm oil industry especially on the biofuels. The methodology used for examining the market variable behaviour is in Section 3. Section 4 is the results and analysis and finally some conclusions are presented in the last section.

2. Literature Review

There are many studies has been modelled in the Malaysian palm oil industry using econometric models. A study by Ramli et al., (2007) on the impact of palm-based biodiesel demand on palm oil price was the first attempt to include biodiesel demand in the price equation by using time varying parameter. Another study by Shri Dewi et al., in 2011 analysed the link between biodiesel demand and Malaysian palm oil market by using econometric method using annual data for the period 1976-2008 (Shri, Arshad, Shamsudin, & Hameed, 2011a). This study included the role of stationarity and cointegration as a prerequisite test before proceeding to the simultaneous equation estimation procedure. Further, Shri Dewi et al. in 2011 have extended the study by examining the link between biodiesel demand, petroleum prices and palm oil market (Shri, Arshad, Shamsudin, & Yusop, 2011b). The impact of biodiesel demand on the Malaysian palm oil industry by using simultaneous equations approach was done by Shri Dewi et al. in the same year (Shri, Arshad, Yusop, Shamsudin, & Alias, 2011c). In terms of biofuel impact studies using system dynamics models mostly focused in EU and U.S. (Bantz & Deaton., 2006; Papachristos & Adamides 2012; Franco, Ochoa, & Florez, 2009). However, there is also a study by Hidayatno et al. in Indonesia (Hidayatno, Sutrisno, Zagloel, & Purwanto, 2011) and Yahaya et al. in Malaysia (Yahaya, Sabri, & Kennedy, 2006). Both of the studies in Malaysia examine the biodiesel, crude palm oil and petroleum price linkages.

In terms of biofuel mandate impact studies in Malaysia, Shri Dewi et al. in 2014 examined the impact of B10 on the Malaysian palm oil market using structural econometric models (Shri Dewi, Ali, & Alias, 2014). The study indicates that counterfactual simulation of an increase from B5 to B10 predicts a positive increase (23.31 per cent) in palm oil domestic consumption, 109.3 per cent decrease in stock, 0.07 per cent increase in domestic price of palm oil and a marginal (0.05 percent) increase in production. FAPRI (2007) examined that the increase

in biofuel mandate to the level specified in Energy Saving Act of 2007 through 2015 resulted in a 2.6 billion gallon average increase in U.S. ethanol use in 2015, relative to the baseline. Most of the increase is supplied by an increase in production of U.S. corn-based ethanol. The mandate also leads to an increase in the producer prices for ethanol to generate the required level of ethanol supplies. The estimated increases are small in early years, as the required changes in ethanol supplies are modest relative to the baseline. The increase in corn demand results in higher corn prices, with the increase relative to the baseline reaching USD0.20 per bushel (6.6 percent) by 2015. Meanwhile, in soybean market, the mandate increases the demand for soybean oil to make biodiesel. This in turn reduces domestic demand for soybean meal. The net effect of the reduction in soybean production and the changes in product markets increases soybean price. Higher soybean prices, in turn contribute to reduction in soybean domestic use and export. In 2015, domestic soybean reduces by 14 million bushels relative to the baseline, while export reduces by 32 million bushels.

Birur et al., in 2007 concludes that development in the U.S. EU biofuels market with the 5.75 percent biofuel mandate, were likely had significant and lasting impact on the global pattern of agricultural production and trade (Birur, Hertel, & Tyner, 2007). Anderson and Coble (2010), investigated the potential impact of ethanol mandates on equilibrium corn prices and quantity, which focused on how the mandates influence market participant expectations. Results showed that due to the stochastic nature of supply and demand shocks, even a mandate that was technically nonbinding can have substantial impact on corn prices and quantities through the mandate's impact on the price responsiveness of demand from ethanol sector. Results suggest that on average for the simulated outcomes, the price response associated with the Renewable Fuels Standard (RFS) mandate was about 6.5 percent greater with the elasticity of -2.75 than with the elasticity of -1.75.

Acheampong et al. studied the impact of biofuel mandates and switch grass production on hay markets (Acheampong, Dicks, & Adam, 2010). The RFS mandates will require 36 billion gallons of ethanol to be produced in 2022, 16 billion gallons of which is to be produced from cellulosic feedstock. To meet the mandate, it is estimated that 24.7 million acres would be used to produce 109 million tonnes of switch grass in 2025. Since the majority of these acres likely would be converted from land currently producing hay, cattle production will be reduced. Thus the chronological impact of biofuel mandates on cattle market were linked by hay production and price.

To date, little research has specifically addressed various blend of biodiesel mandate impact in the Asian context especially in Malaysia with the exception by Shri Dewi et al., (2014) where only focuses on B10 mandate impact. We will incorporate these factors into our analyses. Finally, we are unaware of any studies using more recent data in a system dynamics models to examine the mandate impact on the Malaysian crude palm oil market especially on the stock and price.

3. Methodology

3.1 The Concept of System Dynamics

System dynamics rooted from the invention of industrial dynamics by J. Forrester in 1961 (Forrester, 1961). Since then, it has been developed and used to model complex systems that entail variables and its inter-relationship with each other. It promotes and facilitates the analysis process of non-linear relationship of variables in a complex system. The main advantage of system dynamics is its feedback. There are two main feedbacks that becomes the core structure of system dynamics: positive and negative feedback. Positive feedback impose a reinforce loop, where one variable effect will increase the effect of another variable. Negative feedback on the other hand imposes a balancing feedback, where one variable effect will balance out the effect of another variable (Sterman, 2000). System dynamics emphasize the importance of overall dynamics trends such as exponential, asymptotic and oscillation in explaining a system.

In system dynamics, there are two important diagrams: the causal loop diagram (CLD) and stock and flow diagram (SFD). CLD are drawn to capture the qualitative model at the beginning of the modelling process. It helps in projecting the cause and effect relationship and feedback among variables. Variables are linked by arrows with appropriate polarity based on their relationship and show the direction of influence. Positive polarity exhibits a direct influence, while negative polarity exhibit inverse influence.

SFD is drawn after completing CLD. Unlike CLD, SFD conjures the actual dynamics of the system. It consists of stock variable, flow variable, auxiliary variable and link as its main build. Stock variables (also known as accumulation or state or level) show the state of the system at one particular time. Flow variables determine the value of stock, where net flow (difference between inflow and outflow of a stock) will cause the value of stock to increase or decrease. Auxiliary variables are calculated from other variables within the system, which specifies the decision rules that carries information between system components. The connections between the variables

were established through links. Links act as a connector in the form of arrow defining the connection and control between the variables in the system.

3.2 Model Conceptualization and Data

A generic structure of commodity model has been presented in Sterman (2000), adopted from Meadows (1970) which includes key variables such as supply, demand, price and profitability. This is a good reference in developing other commodity market model. The underpinning concepts of the structure is that demand depends on price and price depends on the availability of products in inventory, while the inventory is depending on the demand. The same concepts are applicable in the palm oil commodity system.

In this study, a system dynamics model has been constructed to help in understanding the impact of various blend mandates (B5, B7 and B10) towards Malaysia crude palm oil stock and price. Figure 1 shows the CLD of this study. There are two balancing loops B1 and B2. The balancing loop B1 represents the supply and demand loop. As CPO stock is accumulated from CPO production and CPO import, it will be depleted with the increase of total CPO demand. Low CPO stock will increase CPO price, which in turn will decrease the total CPO demand. Low total CPO demand will increase the CPO stock and the cycle continues.

The balancing loop B2 represents the palm-based biodiesel (POB) profitability loop. High CPO price will result to high POB production cost, which in turn will lower the POB profitability. Low profitability will lower the CPO demand for POB demand and total CPO demand. Lower total CPO demand will increase CPO stock and subsequently decrease back the CPO price, and the cycle continues. Note that CPO demand for POB is determined by POB mandate imposed by government. Note also that POB profitability is affected by the increase of crude oil price.

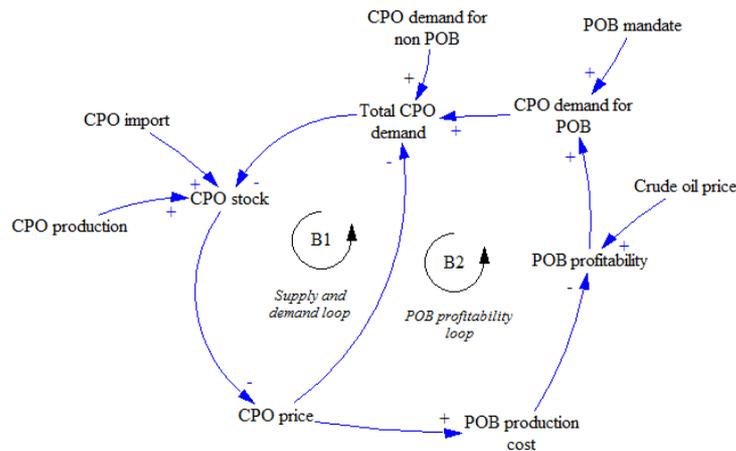


Figure 1. Causal loop diagram of the study

Secondary data from Malaysian Palm Oil Board (MPOB), Department of Statistics of Malaysia and various published sources were used for model construction and validation. The simulation covers the period of 2000-2020.

3.3 Model Formulation

After constructing CLD, the SFD was built to enable further analysis on model dynamics and experimenting different policy scenarios. The SFD constructed in this study is consisting of three sub-models: supply and demand, POB demand and POB profitability.

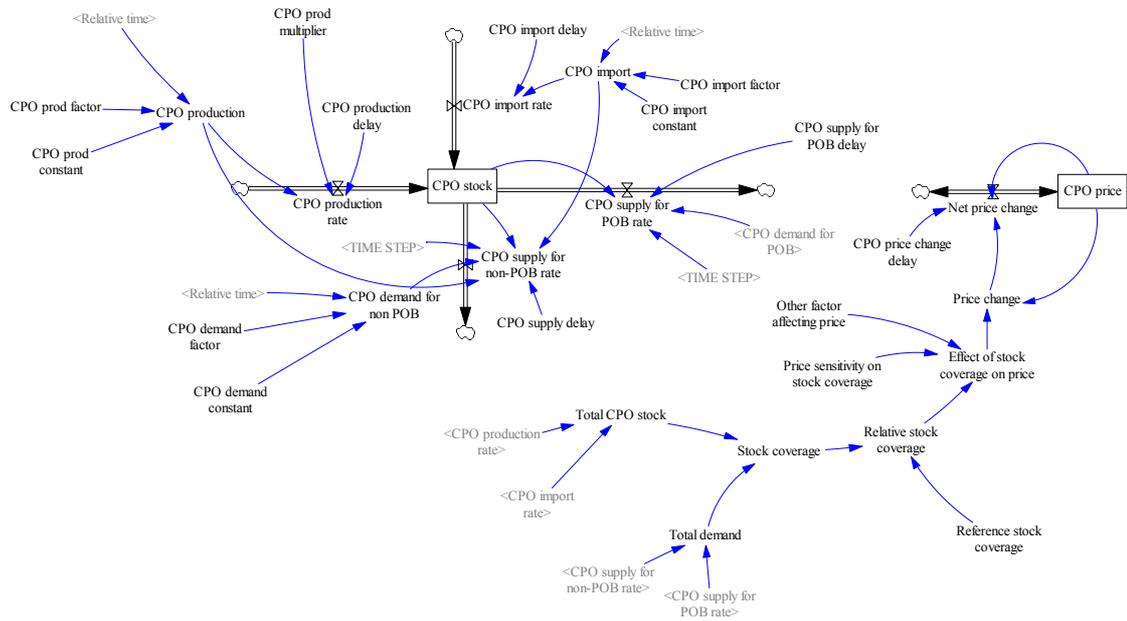


Figure 2. Supply and demand sub-model

Figure 2 shows the supply and demand sub-model. There are 29 variables and 2 stock in this sub-model. *CPO stock* is the accumulation of CPO, with *CPO production rate* and *CPO import rate* as its inflows, and *CPO supply for POB rate* and *CPO supply for non POB rate* as its outflows as per Equation 1.

$$CPOstock = INTEG \left(\begin{matrix} CPOproductionRate + CPOimportRate - \\ CPOsupplyForPOBrate + CPOsupplyForNonPOBrate, CPOstock_0 \end{matrix} \right) \quad (1)$$

We also have *CPO price* modelled in the form of stock in this sub-model. *CPO price* is the accumulation of net price change overtime (refer Equation 2). The agent of change in price is the *stock coverage*. *Stock coverage* or inventory coverage is the ratio of existing inventory level to consumption (Sterman, 2000). When stock coverage is higher than *reference stock coverage* (average value according to historical data), the price will be decreased and vice versa. Note that *effect of stock coverage on price* is affected by *price sensitivity on stock coverage* and *other factor affecting price*. *Price sensitivity on stock coverage* indicates the level of sensitivity of CPO price with the change of *stock coverage*. *Other factor affecting price* is other possible factor (like price of soybean) that may affect the CPO price trend but is not being explicitly modelled in this study, but instead being represented in a constant value.

$$CPOprice = INTEG(Net PriceChange, CPOprice_0) \quad (2)$$

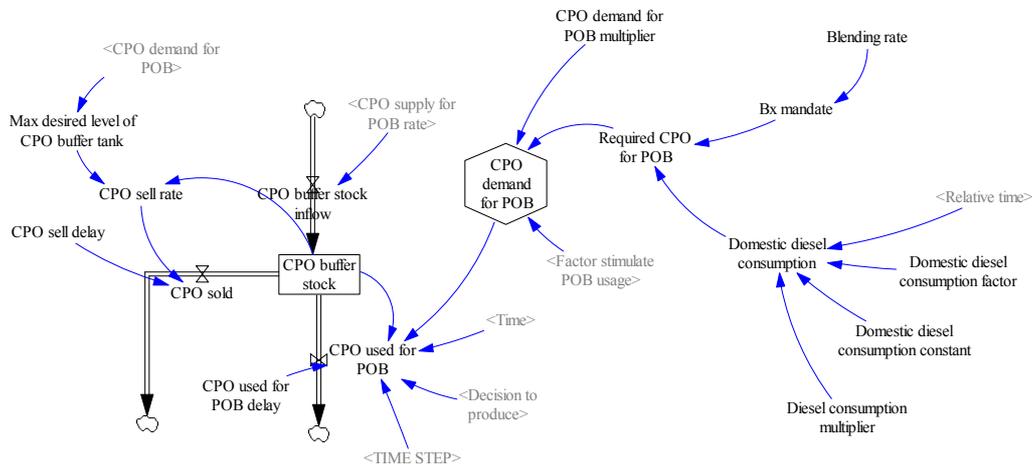


Figure 3. POB demand sub-model

Next, is the POB demand sub-model (refer Figure 3). This sub-model consists of 16 variables and 1 stock. In the POB demand sub-model, the compulsory purchase of CPO will be stored in *CPO buffer stock* (refer Equation 3). *CPO buffer stock* will be utilized either through the production of POB during the profitable period; or will be sold when the price of CPO is high (Lopez & Laan, 2008). In the profitable period, *CPO used for POB* will utilize the *CPO buffer stock* to produce POB according to the demand. Note that CPO used for POB is affected by *decision to produce*. *Decision to produce* determines the profitable period for POB producer to produce POB and will be explained further in the next sub-model. *CPO demand for POB* is mainly determined by the *Bx mandate* imposed by the government at certain *blending rate*. Current implemented blending mandate is B5, which means 5 percent of palm oil will be blended with 95 percent of petrol diesel. Required CPO for POB is then calculated by multiplying the *Bx mandate* with *domestic diesel consumption*.

$$CPObufferStock = INTEG(CPObufferStockInflow - CPOusedForPOB - CPOsold, CPObufferStock_0) \quad (3)$$

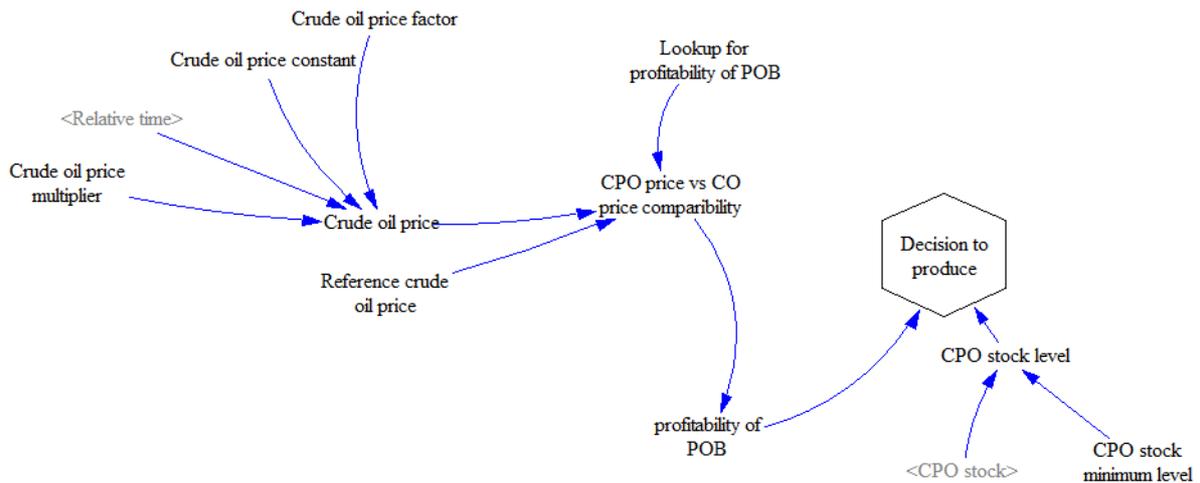


Figure 4. Profitability of POB sub-model

Figure 4 shows the profitability of POB sub-model. This sub-model elaborates further the *decision to produce* variable. *Decision to produce* indicates the suitable period for POB producer to produce POB. It is determined by two factors, which are the *profitability of POB* (Lopez & Laan, 2008) and *CPO stock level* (Hanim, 2014) as

per shown in Equation 4.

$$\text{DecisionTo Produce} = f(\text{profitabilityOfPOB}, \text{CPOstockLevel}) \quad (4)$$

Profitability of POB is affected by the *CPO price vs crude oil (CO) price comparability*. *CPO price vs CO price comparability* indicates that various combination of CPO and CO price will result in variants of POB profitability (as per reported in past studies and compiled by Lopez and Laan (2008)). Figure 5 shows the table lookup for profitability of POB. Any CPO price at a particular crude oil price that falls below the line is deemed as profitable, while CPO price above the line is assumed as non-profitable for POB production. Generally, lower CPO price and higher CO prices combination will lead to higher POB profitability. *CPO stock level* on the other hand indicates the feasible POB production period when the CPO stock level is more than the *CPO stock minimum level*. It is reported that the aim of POB production is to reduce the domestic palm oil inventory to below 1 million tonne annually to control the CPO prices (Hanim, 2014). Thus it can be concluded that the CPO stock level should be below 1 million tonne and above the *CPO stock minimum level* (we do not want the stock to be completely zero, thus small margin like 50,000 tonne will be set as *CPO stock minimum level*).

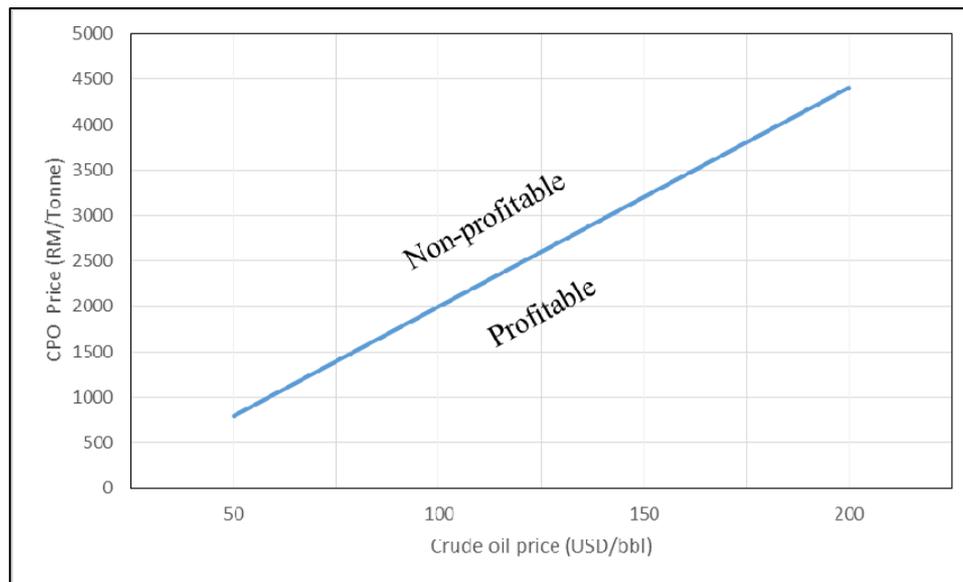


Figure 5. Table lookup for profitability of POB (Taken from Lopez & Laan, 2008)

4. Results and Analysis

4.1 Model Validation Results

Validation test is an important pre-requisite test to ensure that the constructed model is robust enough and sufficiently reliable in representing the real system. We have conducted two most important tests on our model. The first test is the unit test. Unit test is crucial for dimensional consistency of the model. Vensim™ built in unit test has been used for unit test and the model shown no error in terms of dimensional consistency (refer Figure 6).

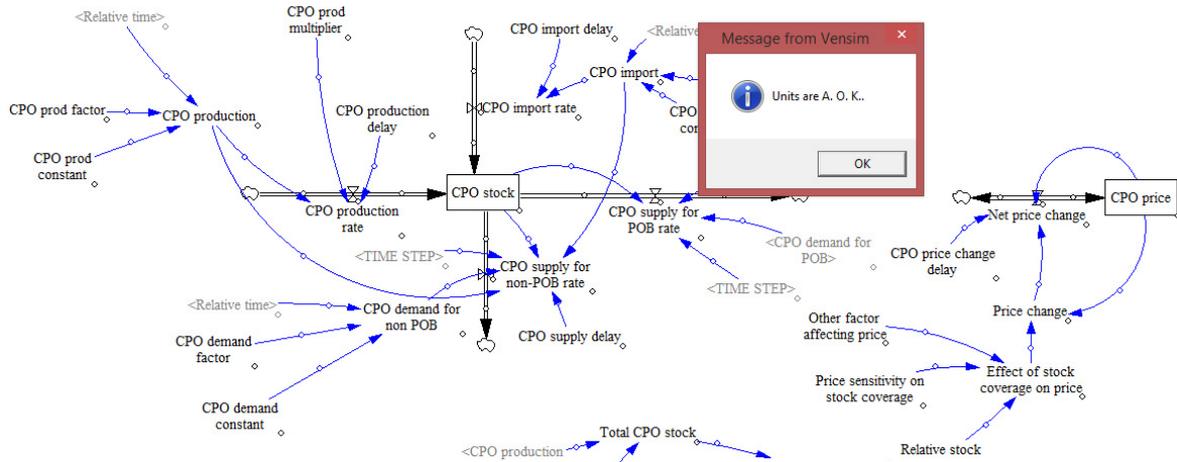


Figure 6. The model unit test

The second test is the integration behavioural test. Test is performed by changing the delta time (dt) for integration time step. It is expected that a particular stock behaviour does not change significantly when time step is reduced. As the overall behaviour pattern for all stocks in the model are almost identical as per Figure 7, 8, and 9 for every tested time step, the model has passed the integration test.

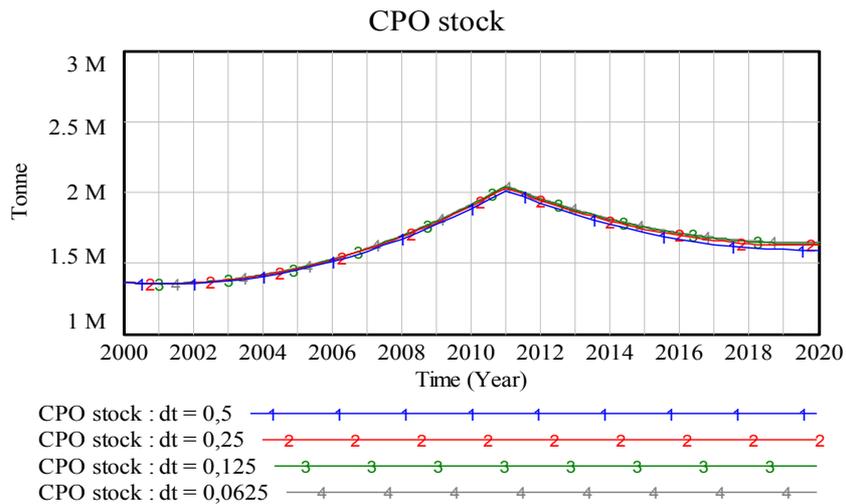


Figure 7. CPO stock for various time step value

Figure 10 shows the *CPO stock* for all tested scenarios. Compared to the baserun, increasing the blending rate has resulted to the depletion of *CPO stock*. Blending rate of 7 percent and 10 percent has both successfully decreased the *CPO stock* level below 1 million tonne by year 2020 as targeted (Hanim, 2014). This is due to the increase in *CPO demand for POB* as per Figure 11. By increasing the blending rate to 10 percent, the *CPO demand for POB* recorded an increase of 100 percent, which is coincide to the finding by Shri Dewi et al., (2014) that stated a 109 percent increase in *CPO stock* for POB production with B10 mandate in their simulation.

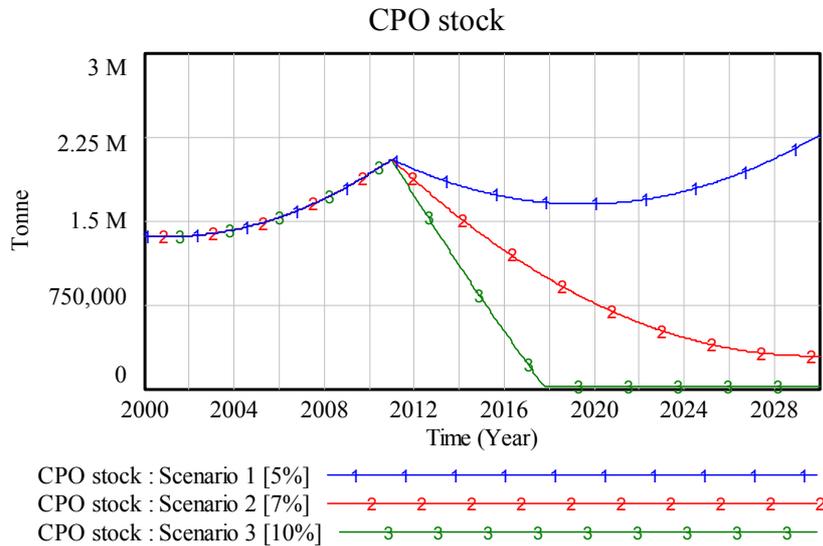


Figure 10. *CPO stock* for all tested scenario

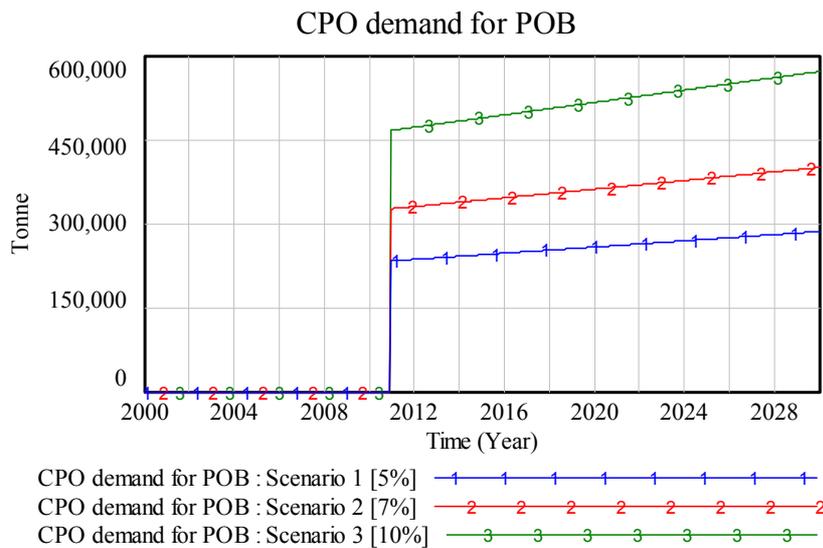


Figure 11. *CPO demand for POB* for all tested scenarios

With the decrease of *CPO stock*, *CPO prices* have responded in an increasing trend as per shown in Figure 12. Note that the higher the blending rate, the steeper the slope of *CPO prices* become. By increasing the blending rate to 10 percent, approximately 0.075 percent increase in *CPO prices* is recorded. This finding also similar to the finding by Shri Dewi et al., (2014) that recorded 0.07 percent of *CPO prices* increment with B10 mandate.

This study tend to look at POB profitability from general view to see the impact of various biodiesel blending mandates on CPO stock and price. However, it is arguable that other factors like capital cost, production cost and return of investment has to be incorporated for more accurate analysis of biodiesel industry profitability. Thus in the future, we will include the life cycle cost and sensitivity analysis using SD approach to investigate further the impact of various blending mandates on POB profitability. We also will incorporate government subsidies as a variable in our model and simulate the important role of this variable towards the Malaysia palm oil industry in our future research.

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