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Palm Oil Industry: A Review of the Literature on the Modelling Approaches and Potential Solution

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Abstract. Palm oil industry plays an important role as a backbone to the economy of a country, especially in many developing countries. Various issues related to the palm oil context have been studied rigorously by previous researchers using appropriate modeling approaches. Thus, the purpose of this paper is to present an overview of existing modeling approaches used by researchers in studying several issues in the palm oil industry. However, there are still limited numbers of researches that focus to determine the impact of strategy policies on palm oil studies. Furthermore, this paper introduces an improved system dynamics and genetic algorithm technique to facilitate the policy design process in palm oil industry. The proposed method is expected to become a framework for structured policy design process to assist the policy maker in evaluating and designing appropriate policies.

INTRODUCTION

In the world's oil and fats market, palm oil is one of the important commodity. Palm oil production by major producers like Malaysia and Indonesia ensure its global supply. There is a complex system underlying the supplies of palm oil in the world market. The process of supplying palm oil involves a huge interrelated value-added process. This includes the palm oil plantation, the palm oil production, palm oil local distribution and export. In each process, there are directly- and indirectly-related variables that influence the behavior of system. Changes in the industry dynamics are rather sensitive due to the presence of feedback process among the several key players in the industry. As such, it is difficult to understand and to analyze the palm oil industry due to its complex nature. Furthermore, due to the complexity of the industry, the impact of certain policies on the industry is often misleading and unpredictable.

The challenge faced in order to study issues in complex system has long been a premise of discussion among researcher. Various analytical methods have been developed in an attempt to resolve this problem. Contextually, different approaches are required to handle different issues. For instance, forecasting method is widely used for prediction purposes while simulation model deals with issues at operational level. This paper reviews several modeling approaches which have been used in the palm oil industry. In conducting the review, this study adapted the review processes as discussed in [1]. The authors formed a panel consist of experts to discuss the appropriate search terms relating to varies issues in palm oil study. The papers were initially selected based on the following generic keywords of palm oil issues. Furthermore, the decision also was made by the panel to use more specific keywords in searching an appropriate articles related to the available modeling methods specific to econometrics, system dynamics, discrete-event simulation, agent-based modeling and combination method. The searched database includes published journal articles, organizational reports, conference proceedings and news headlines. At the end of this paper, we also proposed an integration of methods to facilitate the policy design process in palm oil industry.

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This paper proceeds with the review of individual and integrated modelling approaches applied in various palm oil studies. The following section explains the proposed methodology that is applicable to the Malaysian palm oil study. The final section presents the conclusion and recommendation for future research.

INDIVIDUAL APPROACHES

A wide variety of estimation techniques were employed in palm oil market researches. Its aim is to understand the market behavior and to forecast the future outcome of this industry. The most two popular methods of modelling are econometrics and simulation.

Econometrics

Economics researches have extensively employed econometrics method for forecasting. Forecasting model helps to understand the system and to estimate the value of unknown variables. Its ultimate purpose is to facilitate the system improvement process. By application, econometrics is a method of analyzing and explaining relationship between variables in the economic model. Furthermore, it helps to forecast the future value of dependent variable on the basis of cause-and-effect relationship between variables. Econometrics model can be divided into classical and modern econometrics. Classical econometric uses single equation and simultaneous equations, while modern econometric shows the link between present and past values of time series variables [2].

Generally, there are quite a number of researches using econometric model. However, studies relevant to the case of Malaysian palm oil industry are still limited. For instance, [3] developed a palm oil market model using econometrics method to examine the factors that affect palm oil prices. [4] used the same method to construct a Malaysian model of palm oil market to identify the important factors affecting the industry. Furthermore, [5] investigated the impact of CPO imports liberalization from Indonesian to Malaysian market. They used econometric method to recommend imports of CPO from Indonesia and to address the excess refining capacity issues. Nonetheless, [6] use econometrics method to study the effect of crude oil price on the trend of palm oil short term price in year 2013.

There are several studies that focus on the biodiesel sector of Malaysian's palm oil industry. [7] use econometrics method to explore the options which could help to reinforce the biodiesel industry and highlight the issue of over-capacity in the industry. Simultaneously, [8] analyze the link between biodiesel demand and Malaysian palm oil market using annual data for the period 1976-2008. This study includes the role of stationarity and cointegration as a prerequisite test before proceeding to the simultaneous equation estimation procedure. Furthermore, [9] extended the study by examining the link between biodiesel demand, petroleum prices and palm oil market. She also studied the impact of biodiesel demand on the Malaysian palm oil industry by using simultaneous equations approach [10]. Finally, [11] use econometrics method to examine the impact of biodiesel blend mandate (B5) on the Malaysia palm oil market.

In short, the econometrics method varies. It depends on the type of estimation technique employed. Some of the econometrics studies that have been published are summarized in Table 1 below. The table is restricted to studies that focus on various palm oil and biodiesel issues regardless the practice of countries.

TABLE 1. Econometrics analysis of Malaysian palm oil and biodiesel issues

Palm oil industry			
Reference	**Econometrics Estimation Technique**	**Description**	**Finding**
[3]	Two Stage Least Squares (2SLS)	Develop the palm oil market model to examine the factors affecting palm oil prices.	Finding indicates that the important determinants of palm oil prices are stock levels, total consumption and world economic activity.
[5]	Non-linear Two Stage Least Squares (N2SLS)	Investigate the impact of CPO import liberalization from Indonesia on the industry.	The liberalization of imports of CPO from Indonesia is one of the ways to overcome excess refining capacity in Malaysia.
[4]	Two Stage Least Squares (2SLS)	Describe a national model of the Malaysian palm oil market and to identify the important factors affecting the Malaysian palm oil industry.	Result shows the importance of Malaysian economic activity, the exchange rate and world population that affect the palm oil industry.
[6]	Autoregressive Distributed Lag (ARDL)	Review the relationship between crude palm oil prices and stocks and its short term applications on the trend of palm oil price in 2013.	The result provides a strong evidence long-run equilibrium relation between crude oil price, its stock level and the crude oil prices.
Palm oil based biodiesel sector			
[7]	Ordinary Least Squares (OLS)	Explore options which could help to reinforce the Malaysian palm biodiesel industry and examine the impact of palm methyl ester (PME) production and biodiesel mandate implementation program on CPO prices.	Biodiesel industry is still not viable as producers cannot fully recover from the depreciation in their operation due to the problem of overcapacity.
[8]	Two Stage Least Squares (2SLS)	Describe the important factors affecting Malaysian palm oil industry, and formulating the Malaysian palm oil market model.	Biodiesel demand has a positive impact on Malaysia palm oil domestic price. Significant growth in biodiesel demand is important in explaining the Malaysian palm oil price determination.
[9]	Two Stage Least Squares (2SLS)	Examine the relationship among world petroleum prices, biodiesel demand, and palm oil prices in Malaysia	Biodiesel demand has a positive impact on the Malaysian palm oil domestic price. Thus, significant growth in biodiesel demand is important in explaining Malaysian palm oil price determination.
[10]	Two Stage Least Squares (2SLS)	Examine the impact of biodiesel demand on the Malaysian palm oil industry.	A sustained increase in biodiesel demand predicts a positive increase in palm oil exports for non-biodiesel, domestic palm oil price and production.
[11]	Two Stage Least Squares (2SLS)	Examine the effect of biodiesel blend mandate (B5) on the Malaysian palm oil market.	Biodiesel blend mandate (B5) significantly affects domestic demand.

Despite its advantage, the econometrics modeling has its downturn. Looking at the previous researches, this type of study depends heavily on historical data to construct the model. It can be concluded that these models are developed when the changes to the system has been made. Due to the requirement of extensive data, data limitations may hamper the flexibility of the econometric model. Furthermore, econometrics model tends to ignore feedbacks from other variables, which is important since it disturbs the system's equilibrium especially in long-run. The modeler focuses on enhancing the ability of the model to reproduce the real behavior of the system in the past, rather than the representation of the actual structure of the system [12]. Finally, it is difficult to involve other person with limited mathematical background in the model construction, especially for group modeling process. It is also difficult to interpret the result especially if the analysis is done for clients with lack of knowledge in econometrics method.

Simulation Model

If econometrics method required extensive data and profound analytical skills, simulation model offers a more user-friendly platform. In operation research (OR) field, simulation model can be grouped into three methods, namely discrete event simulation (DES), system dynamics (SD), and agent-based modeling (ABM). A common characteristic of these models is they offer a user-friendly visual interface rather than plain mathematical formulas. It helps to facilitate the modeling process experimentation especially for non-expert personnel. However, these methods have their own distinctive characteristic.

Generally, DES models work to process a series of discrete events. DES shows the sequences of each event in a discrete time at a certain point of changes [13]. Due to its advantage, it has been widely used in areas of operational or tactical level, focusing on the process in organizations such as production of products. Interestingly, this method has been widely applied in various fields of studies for over forty years [14]. However, the major setback of DES is that it is not suitable to model the complex system behavior in a wider perspective, as the core strength of DES focuses on the process in the system [14].

SD is different than DES as it focuses more on the flows around network rather than the individual behavior of entities [15]. SD is best in facilitating the process of understanding the complex system with the inclusion of feedback process for the purpose of finding opportunities to improve weaknesses. Additionally, SD helps the modeler to identify and understand the key factors that influence the system behavior. The identified factors will then assist the modeler in experimenting with the different type of interaction against the system. This is why it has been extensively used to improve the public policy, by identifying the common question that might appears in an organization [16]. However, there are concerns in modeling using SD, since the modeler has to clearly define the problem to avoid over-simplification and misleading analysis of the model. Another limitation of SD is that the modeling process may become over complicated in modeling huge system with too many complex scenarios [17].

ABM is the most recent simulation method, particularly useful in modeling the system behavior with autonomous and interactive abilities [18] [19]. The model is made up of autonomous agents that follow a series of predefined rules to achieve their objectives whilst interacting with each other and their environment [15]. Despite its superiority, there is one major practical issue. It is known that ABM looks at a system at the micro-level of its constituent units. Thus, when the process attempts to model a huge system, simulating all units can be extremely computer-intensive and time-consuming [19].

In the context of palm oil industry, only few studies have been found in the literature that employed simulation method. Table 2 compiles some of the simulation-based researches relevant to palm oil issues.

TABLE 2. Simulation-based studies on various palm oil issues

Reference	Simulation model	Description	Findings
[20]	System dynamics	Examine the impact of biodiesel growth on palm oil industry and examine the linkages between palm oil, petroleum and biodiesel.	Palm biodiesel profitability vary at certain price of crude palm oil (CPO) and crude oil.
[21]	System dynamics	Identify the variables that affect the growth of U.S. biodiesel industry.	Diesel and biodiesel price influence the growth of the U.S. biodiesel industry. Both are dependent on the demand of its counterpart.
[22]	System dynamics and econometrics	Examine the impact of biodiesel demand on the Malaysian's palm oil industry	Changes in biodiesel growth rate can affect export and the whole system variables.
[23]	System dynamics	Develop a comprehensive sustainability model and analyse the effects of government policy for stimulating biodiesel industry.	Accomplishment of a sustainable biodiesel production within target and time frame is possible without releasing the subsidized price of diesel fuel and further direction from the government.
[24]	System dynamics	Analyse the future trends of crude palm oil exports and processed palm oil under new export duties.	With low CPO export duties - CPO domestic price, profitability of plantation owners, immature crop, mature crop, total planted area, production and exports of CPO increase. However, exports of process palm oil decrease.
[25]	Agent-based modeling	Develop models that offer a workable algorithm to seek optimum weight level of underlying factors while calculating utility added value that satisfy palm oil supply chain as a whole.	The negotiation between all actors in palm oil supply chain need to consider overall supply chain sustainability while conducting pairwise negotiation.
[26]	Discrete event simulation	Measure value added of CPO that is processed by palm oil downstream industry.	It is more valuable if palm oil downstream industries are able to produce finished product to the end customer. The simulation result can construct supply chain configuration in order to support decision making process.
[27]	System dynamics and Agent-based modeling	Identify areas of improvement in the sustainability of Malaysia palm oil industry	The output of the models of each tier (for example the mill and refinery models) must be linked in order to have significant result.

Based on the reviews, it is shows that SD has been used regularly compared to other simulation model methods. All the researches focus on seeking system improvement by looking at the bigger perspective. DES and ABM are also employed in modeling palm oil industry, but it focuses more on the micro-level analysis. For instance, [26] used DES to measure the value added of CPO processed by palm oil downstream industry. In this study, the palm oil mills production process was simulated using DES. On the other hand, ABM is used by [27] to model the palm oil mills and refinery process in order to find areas of improvement. Likewise [25] used ABM to model palm oil supply chain in order to seek optimum weight level of underlying factors while calculating utility added value.

General comparison for these three methods has revealed the suitability of SD to be applied for macro-level policy evaluation. Nonetheless, the purpose of this study have no requirement of micro-level entities analysis which are being offered by DES or ABM. Furthermore, the policy design process intended in this study is looking at the broad view of the system.

INTEGRATED APPROACHES

Albeit its potential to resolve issues in complex system, the simulation model does have its limitations when it comes to policy design process. This has urged the modeler to combine the simulation model with other modeling method to gain better performance of the system. For example, [22] combine econometrics with SD approach to analyze the economic impact of increasing the biodiesel demand on the crude palm oil production, demand and prices. [26] combine DES with supply chain operational reference (SCOR) model as a set of key performance indicators to evaluate the simulation performance. [27] on the other hand, integrate SD and ABM methods to simulate the behavior of different entities and interactions in the plantation, mill and mill-refinery models of the Malaysian palm oil industry.

A general comparison of these models shows that SD is more appropriate to model a complex system and policy evaluation in a broader perspective. However, SD alone is insufficient for policy design process. Even though SD is effective in modeling complex system, the method only represent the real system in the structured form and effort to improve the system can only be done by changing the key variables in the system per se. As a result, the modeler applies the traditional approach of parametric or structural changes on the model on a trial-and-error basis for policy design process [28]. However, intuitive ability of modeler to produce an acceptable policy options is restricted to the traditional approach. Hence, more analytic and structured approach to replace the traditional trial-and-error approach should be developed [29]. In short, other method is needed to complement SD modeling ability when it comes to designing policies.

System Dynamics and Optimization

Modeling is an appropriate approach towards better understanding of the system's behavior. In the context of palm oil industry, it is crucial to design policies for the industry so as to achieve its target performance. Hence, a structured policy design process is needed to ensure the achievability of the desired target performance. However, it is known that in a complex system, changes in one variable may inversely affect the behavior of other variables. For instance, rapid expansion of plantation land may incur high capital investment and result in over-supplied of palm oil production. As discussed earlier, an integration of method is vital for policy design purpose, and optimization is one of the preference approaches.

Optimization method has long being recognized to assist the decision making and policy design process related to the ultimate solutions within given set of constrains to pursue the objective. Many studies have employed these optimization methods in various field of studies, and it has been proven effective to improve the quality of decisions [30] [31] [32] [33]. However, some limitations on optimization method, particularly on its inability to be applied in complex systems have sparked interest on integrated approach such as SD optimization [17].

In SD, optimization contributes to identify the best solution by searching ultimate range of parameter values for policy improvement [34]. With the ability of SD to model a complex system, embedded optimization complement and enable it to overcome the weakness posed by other optimization method. Some researchers have expanded SD optimization by integrating it with meta-heuristics optimization like genetic algorithm (GA) to further improve its optimization ability. Table 3 compiles the studies on the integration of SD and GA that are published in journals and conference proceedings.

TABLE 3. SD and GA integration methods.

SD and GA integration			
Reference	**Simulation model**	**Description**	**Findings**
[35]	System dynamics and genetic algorithm	Demonstrates the use of genetic algorithm optimization with system dynamics models.	The process of transforming STELLA models to C++ code is hard and tedious. It requires a programming expert to do so.
[34]	System dynamics and genetic algorithm	Proposes the synthesis of two analytical approaches to support decision making in complex systems.	Solution is compared in pair-wise manner using dominated and non-dominated criterias.
[36]	System dynamics and genetic algorithm	Presents the idea of integrating system dynamics and genetic algorithm with the aid of multi criteria objective function evaluator.	The integration of system dynamics and genetic algorithm is difficult, and some process has to be done manually
SD and GA with other methods			
[37]	System dynamics and genetic algorithm with neural network	Propose a policy design method for system dynamics models based on neural network and genetic algorithm.	The SD model has to be converted to neural network model before it could be integrated with genetic algorithm.
[38]	System dynamics and genetic algorithm with 2D pattern algorithm	Develop support tool that can be used for pattern-based parameter search, which may be utilized in model identification, validation and policy analysis stages.	The numeric features of the desired pattern is lacking in terms of its objective function of the search algorithm. It only focuses on pattern seeking rather than numerical values.

Past studies that combined SD and other modeling methods like GA have become the subject of many researches. It has shown promising outcomes in assisting policy design process. However, some weaknesses have been identified. Firstly, the SD model needs to be converted into hard code like C++ or neural network model in order to integrate the model with GA. This can be tedious and time consuming process, especially for huge and complex model even for a person with good programming background. Secondly, the SD and GA optimization can only be optimized by minimizing or maximizing an objective function without considering the specific time constraint. However, in a real world application, policy makers may want to design policies with specific values and at specific time constraint. Current SD and GA integration is not able to fulfil this requirement.

THE PROPOSED METHODOLOGY

In depth, this study proposed a structured policy design process by integrating SD and GA optimization approaches with some improvements. The proposed methodology will be applied in the context of Malaysian palm oil industry to solve some of the critical issues pertinent to its productivity. The novelty of this study lies in the proposed integration methods which offer an added flexibility in policy design process (as compared to SD-GA and SD-GA-Pattern based). The proposed method can set any policy target within any specified time line, thus adding more flexibility in policy design process.

The general framework for this study is presented in Figure 1. It starts with defining the problems and determining the variables for the studied subject. After adequate data collection, SD model is developed and subjected to validation test to ensure the reliability of the model. Simultaneously, the objective function for GA is identified and formulated based on policy requirement. The completed model will then be simulated and integrated with well-configured GA optimization process in the optimization loop.

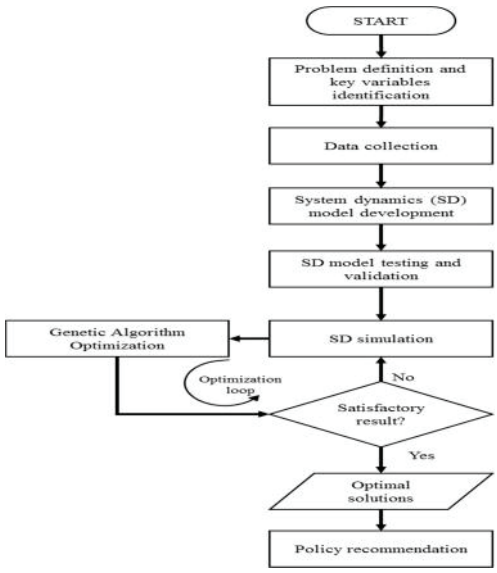

FIGURE 1. General framework of modelling approach based on system dynamics with genetic algorithm methods

This study proposed a structured policy design process that consists of two main phases. The first phase involves process to understand the industry behavior through the development of SD model. Then, the second phase offers the platform to evaluate and experiment on the various policies interaction on the industry behavior through the integrated approach. The core strength of the proposed method is that the forecasting concept is applied on SD platform, while GA optimization helps to achieve the best solution for policy experimentation and recommendation.

CONCLUSION AND FUTURE RESEARCH

This study proposed an improved SD and GA hybrid method in facilitating the policy design process in Malaysian's palm oil industry context. However, this is only the preliminary stage of our ongoing research. Thus, more work is required to deal with the issues highlighted. Next, the relevant information will be collected thoroughly since the validity of information is crucial before the model could be developed. From the managerial perspective, findings from this research will assist the Malaysian Palm Oil Board (MPOB) stakeholders in planning and formulating an appropriate policy to reach a better prospect on palm oil industry in Malaysia.

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