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Game Theory Approach in Malaysia Palm Biomass Industry: Analysis

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In Malaysia, there are plentiful of palm biomass but not always these resources are fully utilised. In the perspective of biomass industry owner, there are three factors that affect the business decision, (i) constant and good quality supplies, (ii) process efficiency, (iii) market demand and price. The strategy considerations that respond to these factors are based on other players' competition, plantation output, mill output, logistics matter, government policy and weather. In order to model the real situation in a particular palm plantation area, game theory approach is used to analyse the best strategy of biomass industry owner. Since every players are act on their self-interest based on maximum profit, this is a non-cooperative game study. A case study is modelled on two industry players, two oil mills and two plantations. Nash equilibrium is achieved by analysing the best strategies that are the best responses to other parties in the scenario. By analysing this scenario using game theory approach, an optimal non-cooperative strategy can be derived. In future works, it can be applied into the decision support framework for the biomass industry management team.

1. Introduction

Oil palm industry is a significant economic backbone of Malaysia – it is currently the fourth largest contributor to the national economy, accounting for approximately 8 % of the country's GNI per capita and 6 % of Malaysia's GDP (Chang et al., 2014). As at December 2014, there are 5.39 million hectares of oil palm planted area in Malaysia, occupying nearly three quarters of the country's agricultural land, which is 14 % of the total land area of the country (MPOB, 2014). The entire area has produced 19.67 million tonnes crude palm oil in 2014 and accounted for 39 % of world palm oil production (MPOC, 2014). Being such a large agricultural sector in Malaysia, oil palm industry has simultaneously generated vast amount of surplus palm biomass waste, which has constituted approximately 85.5 % of biomass in the country, with an average of 53 Mt each year and is even projected to rise to 100 million dry tonnes by the year of 2020 (Umar et al., 2014). Generally, the solid biomass wastes come directly from oil palm plantations in the form of harvested trunks and pruned fronds, and also from the palm oil extraction mills, such as empty fruit bunch (EFB), mesocarp fiber and palm kernel shell (PKS). These biomass wastes are in turn being used either in plantations or mills. For instance, the fronds, trunks and EFB are often left in the plantations for mulching purposes or to be decomposed naturally as nutrient replacement, whilst mesocarp fibre and PKS are utilised in palm oil mill as in-house fuel for generating steam and energy. Given its abundant availability, oil palm biomass is particularly regarded as a valuable alternative for energy regeneration in Malaysia. There are a plethora of researches on the relevant field, such as the optimisation of biomass, in order to convert it into a variety of value-added products (Sabri, 2015).
This paper, notwithstanding, aims to veer in a new direction for the oil palm biomass industry to focus on the sustainable oil palm biomass procurement as a premise for further optimization process. It should be first recognized that despite of its vast availability nationwide, procurement of palm oil biomass at regional level is nonetheless a challenge for those external biomass processing plants. Stiff supply competition is

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inevitable especially for whom do not own plantations. They do not merely strive for local biomass supply for their own plants and business, but also facing competition from external buyers from different states who come to procure the biomass. Irregular biomass supply, which is contingent upon oil palm harvest cycle and yield, can further aggravate competition amongst the industry players (Umar et al., 2014). Additionally, the quality of biomass that is largely affected by surroundings moisture might considerably impact the subsequent process and cost before it can be utilised in the plant. BELCA (Lim and Lam, 2014) and BCI (Tang et al., 2014) methods can provide an insights of biomass material characteristics before it is ready for the plant. All of these aspects ought to be taken into consideration in measuring and identifying the best strategy to ensure sustainable palm biomass procurement.

2. Problem statement

Strengthening technology, process optimisation, supply chain optimisation and product market diversification are typically the main emphasis within oil palm biomass industry. From the perspective of biomass plant entrepreneurs in particular, these facets are deemed to be closely affiliated with the profitability. Intensifying technologies and equipment can undoubtedly improve the efficiency of new biomass processing technology to produce reliable and higher value products, yet it would at the same time incur higher cost on the production cycle (Klemeš and Varbanov, 2013). While process optimisation also aims to increase efficiency, its focus is primarily on enhancing existing process without adding to the cost and thus maximising profit. Supply chain optimisation emphasizes on the performance and improvement the supply chain structure and operation by looking into alternate sourcing, supply route management, regional collection hub positioning, and effective handling method, wherein cost is the key performance metric (Zhang et al, 2014). In fact, all of these technical approaches attempt to enhance their competence in their own sphere; yet they might not necessarily contribute to higher profit or to serve the plant owner best interest. Furthermore, considering that biomass is commonly considered of no economic value (Ani et al., 2015) while processing such by-products does incur production cost, transportation cost and storage cost (Sarma et al, 2015); therefore, entrepreneurs might not find it economically viable.

Above all, biomass industry is competitive, particularly in terms of security and sustainability of biomass supply. In order to gain a competitive advantage over the other competitors, recognition of their interests and moves are important to enhance leverage in getting the most cost-effective biomass supply (Krestschmer et al., 2014). Instead of merely focusing on increasing efficiency of processing biomass, it is equally crucial to shed light on sourcing strategy for effective procurement within such a competitive environment. Ultimately, strategic procurement would be a complement to the optimisation steps stated above and further enhance the overall efficiency.

3. Methodology

This paper adopts game theory approach in analysing Malaysia current competitive biomass industry, wherein multiple players are involved, often with conflicting objectives. In terms of procurement, they compete among each other to acquire the most cost-effective biomass supply and to maximise profit. Strategic form is the most appropriate method to analyse the above scenario. All possible strategies from every competitors are listed out while the outcomes for each possible combination of choices are also defined. The outcomes represent separate payoff for each competitor or also call player in terms of game theory. The payoff is a value to measure how likely a player prefers that outcome.

The formal representation of strategic game is:

a. A number of players involve,

$$i = 1, \cdots, n \tag{1}$$

b. A set of strategies for player *i*,

$$s = (s_1, \cdots, s_n)\ where\ s_i \in S_i\ for\ i = 1 \cdots, \tag{2}$$

c. A function,

$$\pi_i \rightarrow: S \rightarrow R\ for\ player\ i = 1, \cdots, n, where\ S\ is\ the\ strategy\ profiles\ set \tag{3}$$

$$player\ i^{'}\ s\ payoff = \pi_i(s) \tag{4}$$

After the strategic form of the players’ game has been constructed, the best strategy which gives the best response (favourable payoff) to other strategies is identified. Nash equilibrium is achieved if each of the players is making the best decision possible by taking into account the decision of opponents.

4. Case study

Case study is demonstrated in a particular oil palm plantation area which has two individual biomass processing plants. There are competing each other for biomass supply and market share. To further demonstrate the application of game theory in palm industry, a competitive environment criteria have been set up for the analysis which is short of biomass supply. Both players have to compete each other to survive in these tough situation. In order to countermeasure these challenges, optimal strategies (Naziri and Zaccour, 2009) need to be made by the players. In the worst case, lower competitiveness player is likely to be eliminated from the market (Sun et al., 2013).

Table 1: Palm biomass business strategy for low supply

Decision priority	Available strategy
1	Purchase all possible source from local market
2	External sourcing (same biomass from other area)
3	Alternative sourcing (different biomass)
4	Increase selling price
5	Production reduce
6	Production stop
7	Process change

The priority of strategy is made based on possible cost incur if it is executed by the team. The first priority has the least cost among others. However, first priority does not mean it is the best strategy apart from others. Without taking into account opponents’ decision, it is difficult to make the best decision. Therefore, the priority ranking of the strategy is for the simplicity of analysis. The analysis does not include all strategies together to avoid complication in decision making. The pay-off that are listed in each strategy combination are assumed to be the likelihood of players’ acceptable profit margin after including the possible cost and market share changes.

4.1 First step analysis for priority 1 and 2

The first two business options to countermeasure the low local biomass supply source are:

i. Procure whatever supply leftover from the local market.
   This would increase the supply pricing if both players are competing each other.

ii. Supply sourcing from external area.
   There are external, internal and network risks in supply chain (Mitkowski and Zenka-Podlaszewska, 2014) which are no guarantee of sourcing success, additional logistic and handling cost since from different area. In this current scenario, the success rate of sourcing is assumed high where the proximity of biomass sources are as close as possible (Sun et al., 2011).

Figure 1 shows the strategic game form of step 1 and the payoff of each strategy set. The achieved Nash equilibrium (Figure 2) is to do second sourcing from external area, no matter what is the opponent’s strategy. This can be explained since the local biomass supply is in shortage, there are no guarantee to fulfil the market demand even to procure every available supply in that area.

		Player 1	
	Strategy	**Purchase all**	**External procure**
Player 2	**Purchase all**	30 30	60 40
	External procure	40 60	50 50

Figure 1: Step 1 strategic game

		Player 1	
	Strategy	~~Purchase all~~	External procure
Player 2	~~Purchase all~~	~~30~~ / ~~30~~	60 / ~~40~~
	External procure	~~40~~ / 60	50 / 50

Figure 2: Step 1 dominance strategy

4.2 Second step analysis for priority 3 and 4

Continue from step 1, same type of biomass is unable to source from any other area (due to weather condition, harvesting period and logistic issue) and local available supply are out of stock due to the competition from previous step assumption.

Two available options to countermeasure this issue are (Figure 3):

i. Alternative supply source of different biomass.
   This might increase the cost of purchase (Dumortier, 2013), logistic, handling and process modification since this is a different properties of material.

ii. To avoid any further incur cost, maintain the current supply but increase the selling price.

Pricing increase would be the best solution (Figure 4) since no additional cost incurs and the additional profit margin can offset the possible demand decrease due to higher selling price.

		Player 1	
	Strategy	Alternative source	Increase pricing
Player 2	Alternative source	30 / 30	40 / 40
	Increase pricing	40 / 40	50 / 50

Figure 3: Step 2 strategic game

		Player 1	
	Strategy	~~Alternative source~~	Increase pricing
Player 2	~~Alternative source~~	~~30~~ / ~~30~~	40 / ~~40~~
	Increase pricing	~~40~~ / 40	50 / 50

Figure 4: Step 2 dominance strategy

4.3 Third step analysis

Based on step 1 and 2, possible strategies are external sourcing (same type of biomass) and selling price increase (Figure 5). The best solution among these two is to increase the product selling price (Figure 5) which yield for an acceptable payoff for both players. This can be explained there are no additional cost incur if this decision is made. Again, the only risk that might happen is the possibility of demand decrease due to price changes. However, this would be the best case scenario since the supply from local area is limited, no point for any player if the demand is increasing. This is only matter if either player can get external sourcing successfully with all the possible risks are being overcome especially biomass harvesting and transportation issues. These two factors contribute 29 % and 18 % of total capital cost separately (You and Yue, 2014).

After the best strategy has been identified (Figure 6), further optimisation can be applied to it. For this strategy there are two possible sub-options. First, supply chain optimization by as utilising a satellite biomass plant (Brammer and Rogers, 2009) to reduce the biomass transportation cost. Second, the biomass can be transformed into higher efficiency material as energy pack (Lam et al., 2014). These can be used to negate the effect of demand decrease due to selling price increase.

	Strategy	Player 1 External procure	 Increase pricing
Player 2	External procure	40 40	40 30
	Increase pricing	10 30	50 50

Figure 5: Step 3 strategic game

	Strategy	Player 1 ~~External procure~~	 Increase pricing
Player 2	External procure	~~40~~ 40	40 30
	Increase pricing	~~10~~ 30	50 50

Figure 6: Step 3 dominance strategy

4.4 Further explanation on priority 5, 6, 7 strategy

Strategy 5, 6 and 7 are not included into above game analysis. These 3 strategies are not common action to be taken by the management team. Stopping production cycle means no income while the process equipment are depreciated day by day. Furthermore, no output from the plant will give chance to opponent to monopoly the whole market shares. This is a total negative payoff to the player and this option is the least favourable. If the player choose to reduce the production rate to conserve supply source also results in a negative impact as it will decrease the commitment to the market demand. Again, it let the opponent to have the chance to monopoly the local market. However during lower production rate, service and maintenance of the plant can be carried out. There is an additional 10 % of operating expenses (PPC Renewables, 2012) incurred but in the sense of long term strategy, this is advisable although it does not make any profit margin at that moment. It has a short term risk and long term benefit need to be balanced out. Last strategy would be process change to cope with new type of biomass processing. This is not an encouraging option as if setup a new plant would cost a lot. Even for the cheapest option, co-firing plant (IRENA, 2012) would cost $ 600 /kW for only equipment itself. This consider a new investment and should run a detail business profiling. In the case of co-firing plant where the player can retrofit (Cuellar, 2012) the process for different biomass also cost $ 640/kW/y compare to direct ($ 150 /kW/y) and indirect ($ 139 /kW/y) co-firing. This results a higher fitting cost. Therefore, it is the last resort for the player as this may consider coming out from market and re-enter again in a brand new start.

5. Conclusions

Palm biomass business is a value added sector in the existing palm-related industry; the management policy is tend to be cost-orientated. Against this backdrop, game theory offers some of the most comprehensive and sophisticated tools in analysing and modelling a better strategy within a competitive biomass business environment through gaining insights into competitors' objective and interest, as well as their psyche (Bhattacharya, 2013). By structuring an analogous situation to identify appropriate and feasible strategy, further engineering optimisation can then be targeted on the specific strategy. Rather than optimising the whole process cycle, it emphasizes specifically on key areas and thus is more effective on decision making without wasting time and resources, and can even achieve rapid payback.

6. Future works

Further analysis can be carried out to explore more options of strategy. Payoff of the strategy can be improved by incorporate practical real-life scenario figures. In this light, typical supply chain and process optimisation can be applied to that strategy. Results or outcomes can be compared to evaluate the performance of optimisation, and also feasibility and efficiency of the chosen strategy.

Additionally, more factors can be adapted to the strategy analysis such as supply uncertainty risk management (Shabani et al., 2014) and natural environment factors. Thus, multi-criteria (Sogut and Aplak, 2013) would complement the decision making process of biomass industry owner.

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