A game-theoretic model to select suitable rubber policy

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Abstract. In this study, we used a game theoretic modelling technique to analyze the governmental policies by collecting natural rubber related data to create a model in order to select the policies that suit Thai rubber’s stakeholders. After the model has been created, we used sensitivity analysis to capture the uncertainties of parameters such as the success probabilities of the policies and the rubber price. The results from the game theoretic model show that there are two policies that should be selected by the government which is the policies that support the increase of natural rubber consumption by 10%-15%. However, in order for the government to optimally select these policies, the success rate of the policies needs to be at least 30%. Otherwise, none of the policies should be selected. Regarding the policy to support Tier-1 entrepreneurs, since the increase in demand by implementing this kind of policy is fairly small, the policy should not be chosen. The policy for Tier-2 companies owned by the local farmers should be supported when the chance of selling the products is more than 35%.

1. Introduction
After the rise of the rubber price to its highest in 2011, the price has gone down ever since. There were strikes several times among the rubber farmers to ask for government’s subsidy in the price. Providing subsidization may help absorbing farmers’ expenses in a short run, but the government also explores some other potential solutions. The government also allocated several funding for several projects to support Thailand rubber farming situation. This includes soft loan projects for rubber processing business and the projects to help adding value to the natural rubber for business own by the local farmers.

To our knowledge, there has not been any research study focusing on applying a game-theoretic model to identify suitable governmental policy for rubber farming. In other countries, there have been numerous studies regarding to establishing game-theoretic models to study governmental policies. Most of the studies have been focusing on strategic decision in protection against terrorism ([11], [2], [3], [4] and [5]). The mentioned references are focusing on establishing a game-theoretic model for budget allocation against terrorism. Other studies such as Azaiez and Bier [6] use game theory to model resource allocation problem in terms of the reliability system. Brown et al. [7] study the optimal allocation on the US infrastructure.
2. The Proposed Model

There are 3 stakeholders in the game. The first one is the policy maker who needs to select the optimal rubber policies from the list of the available policies. The second player is the small and medium entrepreneurs in Thailand who process natural rubber to final products such as rubber gloves, condoms, rubber products from mould pressing, etc. We call this player the Tier-1. The third player is the companies who process natural rubber and supply the products to companies in the Tier-1. We call this player the Tier-2. The Tier-2 companies are mostly owned by the local farmer coops except for the latex company which is usually owned by a private investor.

The policy maker needs to make a decision about which policies to select (can be more than one) and how much to provide the budget for each product type under the budget constraint and the constraint that all farmers need to have the income that pass the poverty line.  

The policy maker’s objective function is shown below. In Equation (1), it is assumed that the estimated increase in the income (represented by the parameter $p_{ijk}$) cannot be fully achieved since it needs to be multiplied by the success probability of the policy and the portion of budget allocated.

$$\max_{j \in T_1 \cup T_2} \sum_{i=1}^{N_j} \sum_{k=1}^{10} (p_{ijk} y_{ijk} \tau_{ijk} - b_{ijk}) x_{ijk}$$

subject to the following constraints:

$$\sum_{j \in (T_1 \cup T_2)} \sum_{k=1}^{N_j} b_{ijk} x_{ijk} y_{ijk} \leq Z$$

$$(f_i (r + h x_{ij}) - ((c_{il} - g l) a_i)) \geq W, \forall l$$

$$y_{ijk} \leq x_{ij}, \forall i, \forall j, \forall k$$

$$\sum_{k=1}^{N_j} \tau_{ijk} = 1, \forall i, \forall j$$

$$x_{ij} \in \{0,1\}, \tau_{ijk} \geq 0, \forall i, \forall j, \forall k$$

$y_{ijk}$ = The success probability in achieving the goal estimated by the government from the implementation of project $i$ to player type $j$ who produces product type $k$

$p_{ijk}$ = The estimated increase in income from the implementation of project $i$ to player type $j$ who produces product type $k$

$\tau_{ijk}$ = The decision variable regarding to the portion of budget to implement policy $i$ to player type $j$ who produces product type $k$

$b_{ijk}$ = The cost of implementing project $i$ to player type $j$ who produces product type $k$

$x_{ij}$ = The decision variable of the policy maker to select project $i$

$y_{jjk}$ = The decision variable of the type $j$th player who produces product type $k$ to follow the policy of project $i$

$Z$ = The total budget

$f_i$ = The amount of natural rubber per rai produced by farmer of size $l$

$r$ = The rubber price (Baht per kg)

$g_l$ = The governmental subsidy for natural rubber production cost per rai

$a_i$ = The average plantation area (in rais) of farmer size $l$

$W$ = Thailand’s poverty threshold

$i$ = The policy index, $i = 1, 2, \ldots, 10$

$j$ = The index for the Tier-1 and Tier-2 players where $j \in T_1$ is for Tier-1 players and $j \in T_2$ is for Tier-2 players

$k$ = The index for players who are processing product type $k$

$l$ = The index for the farmers’ sizes

$N_j$ = The number of product types for Tier-1 or Tier-2 player.
During the time that the research study was conducted, there were ten available policies to select as shown in Table 1. From Table 1, since policies 4 and 7 are too broad and vague, we exclude these two policies from our study (i.e., \( x_4 = 0 \) and \( x_7 = 0 \)). Moreover these two policies require relatively small amount of budget, hence it does not affect the optimal solution. Also in Equation 3, farmers’ sizes are assumed to be small, medium, and large.

The Tier-1 or Tier-2 player \( j \) has the following objective function. In Equation (8), it is assumed that the production capacity is increased by the portion of budget allocated to product type \( k \).

\[
\text{max} \sum_{k=1}^{N} \sum_{i=1}^{10} e_{ijk} d_{ijk} \gamma_{ijk} \tau_{ijk} x_{ijk}
\]

subject to the following constraint
\[
d_{ijk} + \sum_{i=1}^{10} [q_{ijk} d_{ijk} \gamma_{ijk} \tau_{ijk}] x_{ijk} \leq V_{ijk} + \sum_{i=1}^{10} (V_{ijk})_x y_{ijk}, \forall j, \forall k
\]
\[
y_{ijk} \in \{0,1\}
\]

\( e_{ijk} \) = An estimated increase in profit per unit after implementing policy \( i \) to player type \( j \) who produces product type \( k \)

\( q_{ijk} \) = The percentage of increase in demand after implementing policy \( i \) to player type \( j \) who produces product type \( k \)

\( d_{ijk} \) = Initial demand of player type \( j \) who produces product type \( k \)

\( V_{ijk} \) = Initial capacity of player type \( j \) who produces product type \( k \)

Table 1. The list of the available policies

| No.   | Policy explanation                                                                                                                                                                                                 |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.    | A project to increase the working capitals for Tier-2 companies who were processing natural rubber to latex                                                                                                         |
| 2.    | A project to provide soft loans to increase capacity for Tier-1 companies who were processing natural rubber to final products such as tires, rubber gloves, and rubber bands                                             |
| 3.    | A project to provide soft loan to increase capacity for Tier-1 companies own by the local coop who were processing natural rubber to Tier-2 products such as rubber sheets and rubber blocks.                        |
| 4.    | A project to support farmers to earn side incomes                                                                                                 |
| 5.    | A project to subsidize partial cost of agricultural supplies (fixed amount per rai)                                                                                                                            |
| 6.    | A income subsidization project (fixed amount per rai)                                                                                                                                                           |
| 7.    | A project to support farmers to earn side incomes based on the sufficiency economy philosophy                                                                                                                |
| 8.    | A project to revise the natural rubber market structure (with the aim to increase rubber demand by approximately 10%)                                                                                               |
| 9.    | A project to reduce 400,000 rais of rubber plantation area                                                                                                                                                    |
| 10.   | A project to setup the rubber process plant with the goal to increase rubber demand by 15%                                                                                                                    |

3. Results and Discussion

The model is solved and sensitivity analysis is applied due to several uncertain parameters. These parameters are assumed to have ranges from the relatively estimated low values to the relatively estimated large values.

The rubber price is assumed to range from 10 Baht per kg to 150 Baht per kg. Other model parameters such as the plantation cost, the production capacity, and the plantation areas are also assessed. There are a total of 11,520 scenarios to run from the ranges in Table 2. The results are shown in Figure 1. The figure above shows the percentage that each policy is chosen for each rubber price ranging from 10 Baht per kg to 150 Baht per kg. The result shows that policy 10 is chosen the most followed by policy 8. Other policies are not optimal to be selected. The result also shows that when the rubber price is increased, policies 8 and 10 are even more attractive.
Figure 1: The percentage that the policies are chosen for each rubber price ranging from 10 to 150 Baht per kg

Another result also shows that when the rubber price is below 42 Baht per kg, policy 5 or 6 is also chosen to raise farmers’ income so that their income passed the poverty line. Policies 1 and 2 are not optimal since these will only increase demand in a specific industry. If the benefit from policies 1 and 2 is increased (by increasing the demand significantly or by increasing the value of the final product), these two policies will then be attractive. Policy 3 is not optimal since the success probability to increase its demand is estimated to be between 10%–30%. If this success probability is increased to be more than 35%, then we can start to see the potential of this policy. Policy 9 is never selected since this does not affect the objective value of the policy maker (since the model is run for only one period).

4. Conclusion
The finding in this study provides a stepping stone for the Thai government in terms of the selection of rubber policies. Previously, the chosen policy has been mostly ad hoc based on the rubber price. Rubber farming policy selection should be more strategic in a long run. Strategic decision making should be a new trend of policy selection in Thailand, not only for rubber supply chain but also for any other agricultural product supply chain.

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