Model of Price Stabilization In Staple Food Distribution Using Game Theory: Comparative Study

Danis Eka Prasetya Wicaksana, Muhammad Hisjam, Yuniaristanto, Wahyudi Sutopo

***Abstract*— There is a big problem in stabilize staple food distribution price. The unstable price occurs due to disparity of supply and demand between the harvesting period and planting period. An instrument of indirect market intervention has been created by previous research using buffer stocks system integrated in warehouse receipt system. The model used in previous research could be used to determine the decision variables such as number of staple food to be stored in warehouse receipt system. This paper proposes a new approach by using game theory model. Game theory model is chosen to simplify model due to less constraint required so that it can be used easier. The model is used to illustrate the transaction between the producer and government agency. The result of the model is compared with previous model to find the compatibility of the model. The result shows that in the same condition the game theory model can simulate the constructed model in stabilize the staple food price. In addition, the staple food game theory model can illustrate supply chain system of staple food distribution.**

***Index Terms*— game theory, price stabilization, staple food, supply and demand, supply chain**

I. INTRODUCTION

Staple food distribution such as sugar has been a problem for some countries include Indonesia. The biggest problem is unstable price due to unstable quantity of supply of the commodity. Quantity of supply of staple food commodity makes a seasonal graph in a supply demand relationship. The quantity will be rising in harvesting season and it will be declining in planting season. It is assumed that the demand of the staple food commodity is relatively stable along year. So that there will be a supply surplus in the harvesting time and there will be shortage in planting time.

In the shortage condition the distributor (wholesaler) can manipulate the price of commodity due to excess of demand as demand law said that the higher demand will make a higher price. The wholesaler can buy the commodity at lowest purchasing price and sell it to consumer at highest buying price. It causes consumer losses and moreover will make government struggle to provide sufficient staple food with rational price. And the easiest way to fulfill the lack of supply is to import the commodity.

Some intervention to the market has been created in the past years. Sutopo et. al. [1] proposed a mathematical model for an instrument of indirect market intervention (IMI) to obtain a price stabilization for staple food commodity in Indonesia. It took the sugar market for a case study. The paper used buffer stock model in warehouse receipt system (WRS) and recommended a new entity called BLUPP (*Badan Layanan Umum Penyangga Pangan*), a public service institution for staple food buffer stock. The model used to determine how many amount of commodity should be deposited in BLUPP to keep the price stabilization.

In the model, the author used a deterministic data to construct and simulate the model. At the end of the paper the author recommend game theory model to describe the transaction between entities involved. This paper proposes a new model for the same case using game theory model. Game theory model is selected to illustrate the non-deterministic condition. The model will be simulated with the same data used in that paper. Then the two models will be compared to see the compatibility of the models.

II. LITERATURE REVIEW

This paper mainly refers to Sutopo [1], and Sutopo et. al. [2] about buffer stocks model to ensure the price stabilization in seasonal staple food commodity. WRS system used in that paper develops a buffer stocks model to encourage the IMI programs. Price stabilization program and price supporting program are the programs in IMI model for staple food commodity. The result of two programs was evaluated by analytical model. In this paper, the IMI programs will be evaluated with a constructed game theory model. The result of the evaluation then will be compared between game theory model and analytical model. Compatibility of the model will be known from the result. Figure 1 shows the framework of the idea in this paper.

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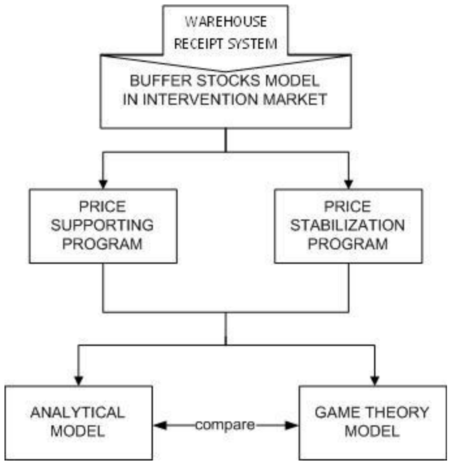

Figure 1. Framework of Idea

A. *Buffer Stock Model*

Buffer stock is stocks to muffle the uncertainty of producer's quantity [1]. Buffer stocks model have been used for several researches in obtaining price stability. Many approaches have been used to built a buffer stocks model such supply-demand approach, location-allocation approach and inventory system approach.

This paper uses supply-demand approach to build the model of buffer stocks. The buffer stocks model based on supply-demand approach have been built by some researcher [1], [3–9], [14]. Athanasioua et. al. [9] found that buffer stocks scheme will keep the commodity supply in to the equilibrium supply and will be corresponding to make a closed-loop system. The approach is shown in figure 2.

The code E, E' and E'' show the equilibrium in normal condition, surplus of supply condition and lack of supply condition. It is shown that the price will be rising when the quantity is fallen (right graph). The intervention with buffer stocks model will return the quantity supplied into normal equilibrium. So that the price will return to normal price (left graph).

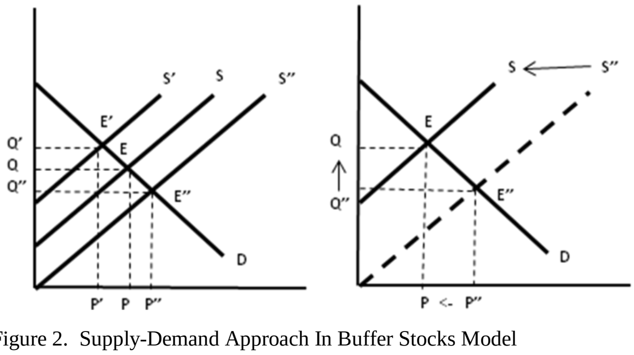

Figure 2. Supply-Demand Approach In Buffer Stocks Model

B. *Game Theory*

Game theory is one of non deterministic tools that can be used to illustrate the price stabilization system. The first application used the game theory analysis is done by Antonie Cournot in 1838 in the study of duopoly. Then the game theory model is developed by researchers and have an own field in 1944. It is noticed by Nuemann and Morgenstern publication. Since 1970s game theory drive a revolution in economic theory [10-11].

Game theory model uses a pay-off matrix to solve the problem between two entities. Each of entities has their own business and has several strategies to obtain their objectives. Each strategy will influence the other entity for each opponent strategy. Minimax-maximin criteria is the most way used to determine the best strategies for each entity. Figure 3 shows the flowchart in solving the game theory model.

Nowadays many policies are constructed by some actors and consequently have an evaluation data method and approach [12]. One of evaluation method is analytical method that used in [1]. Due to game theory is a method that capable to solve the situations of conflict and competition [13], this method will be used for analyzing buffer stocks model in warehouse receipt system as government policy.

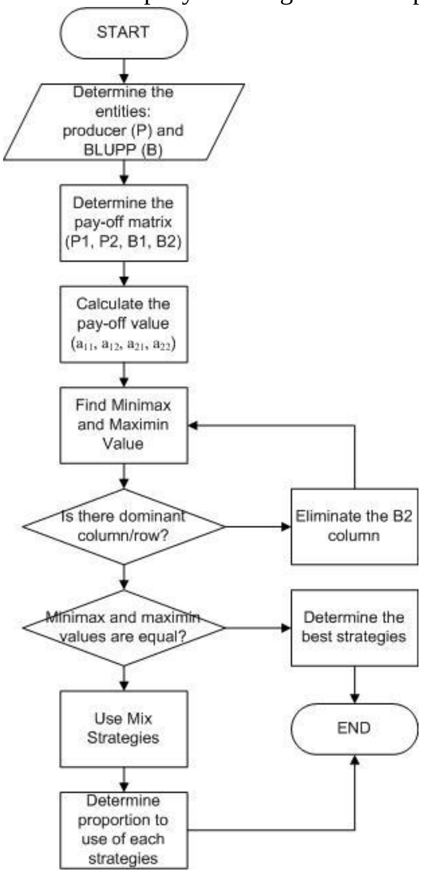

Figure 3. Solving Game Theory Problem Flowchart

III. Method and Modeling System

The methodology of this paper refers to Sutopo [1] in construct a mathematical model for an indirect market intervention (IMI) instrument in Indonesia. There are several assumptions used in the paper: staple food can be stored, no damage occurs during storage, planning horizon is 12 months (t_0 – t_{12}) and begin with harvesting season. A timeline assumption which divides the planning horizon into 4 periods with their each characteristics given in table 1.

TABLE 1
LIST OF TIMELINE ASSUMPTION

	p_1 ($t_0 - t_3$)	p_2 ($t_4 - t_6$)	p_3 ($t_7 - t_9$)	p_4 (t_{10}–t_{12})
Season	harvest	harvest	Plant	plant
Production	normal	booming	none	none
Consumption	stable	stable	stable	stable
Availability	sufficient	surplus	sufficient	shortage

Sutopo et. al. [1]

Several addition assumptions used to construct the game theory model. There are three entities involved in the model, they are producer, BLUPP (government) and consumer. Three entities have their own business. Best strategy selection based on minimax and maximin strategy. The wholesaler does not import commodity to fulfill the shortage.

In this model there are two strategies for each entity. These are the strategies for each entity and the symbol.

P1 : Producer only sell the product to BLUPP
P2 : Producer also sell the product to consumer
B1 : BLUPP save supply from farmer
B2 : BLUPP does not save supply from farmer

The data in this paper are gained from Sutopo [1]. New model will be used to simulate the condition and find total quantity to be stored in BLUPP. Then the result will be compared to check the compatibility of the model. Figure 4 shows the method to solve the problem.

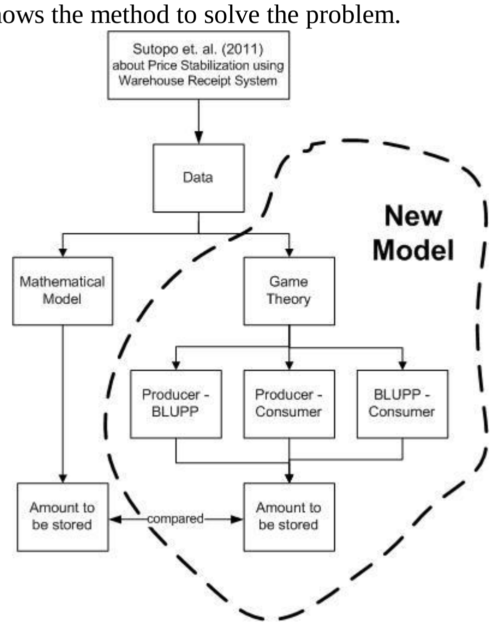

Figure 4. Methodology

While the pay off matrices for game theory model are shown in table 2, 3 and 4.

TABLE II
PRODUCER AND BLUPP PAY OFF MATRIX

Producer	BLUPP	
	B1	*B2*
P1	a_{11}	a_{12}
P2	a_{21}	a_{22}

In a_{11} the BLUPP buy all the staple food production for producer to be stored in warehouse receipt system. In a_{12} the BLUPP does not buy any staple food production and the producer do not sell any product. In a_{21} the BLUPP buy the surplus of staple food product after the producer sell the product directly to consumer as demand schedule. In a_{22} the BLUPP does not buy any product but the producers sell some product directly to consumer as demand schedule.

Some criteria are used to compare between the analytical model and game theory model. First point is the parameter result, total producer benefit. Parameter result is the main goal of the model. Second point is the ease to solve the model. Ease of the model is used as the criteria because the model will be implemented. The analytical model uses Lingo as solving software, while the game theory uses Microsoft Excel as solving software. Third point is the complexity of the model. Complexity shows the reliability of the model.

IV. Result and Analysis

Sutopo [1] calculated some decision variables such as total buffer stocks, import quota and staple as warehouse receipt (WR) guaranteed based on Indonesian staple food production and consumption data in 2010. Same data will be used to calculate the effectiveness of the model based on total producer benefit (TB^P). Calculation of TBP use the same formulation used by Sutopo [1] with a little modification in accordance with the condition in staple food game theory model.

Here are the parameters and variables to calculate the total producer benefit:

TB^P = total producer benefit
t_k = beginning of IM periods for producer
t_j = beginning of IM periods for consumer
Q_t^{PB} = amount of producer and BLUPP transaction in period-t
P_t^{pl} = producer selling price in period-t
P_t^{sl} = consumer buying price in period-t
Q_t^{OP} = amount of staple food purchased by BLUPP in the price support program
c_p = production cost per unit
c_d = distribution cost per unit
q_t^s = supplies of staple food in period-t
q_t^d = demand of staple food in period-t

The total producer benefit is calculated by summing the revenue from BLUPP in price support program and price stabilization program then subtracted by total production cost. The formulation is shown in formula (1). Especially for a_{21} and a_{22} condition the producer revenue added by consumer purchasing. The formulation for a_{21} and a_{22} condition is shown in formula (2).

$$TB^P = \sum_{t=1}^{t_k} Q_t^{PB} P_t^{pl} + \sum_{t=tk}^{t_x} Q_t^{OP} P^{min} - \sum_{t=1}^{6} c_p q_t^s \qquad (1)$$

$$TB^P = \sum_{t=1}^{t_k} Q_t^{PB} P_t^{pl} + \sum_{t=tk}^{t_x} Q_t^{OP} P^{min} - \sum_{t=1}^{6} c_p q_t^s + \sum_{t=1}^{12} q_t^d P_t^{sl} \qquad (2)$$

Formulation (1) and (2) are subjected by:

$$p_t^{pl} = \begin{cases} p_0^{p0} - c\ln(q_t^A), if\ p_t^{pl} \geq CI_p, \forall_t = 1, \ldots, t_k \\ P^{min} = p_0^{p0} - c\ln(q_t^{A^*}), otherwise\ \forall_t = 1, \ldots, 6 \end{cases} \qquad (3)$$

$$p_t^{sl} = \begin{cases} (p_t^{p0} + c_d) - d\ln(q_t^d), if\ p_t^{sl} \leq CI_c, \forall_t = 1, \ldots, t_j \\ P^{max} = (p_t^{p0} + c_d) - d\ln(q_t^{d^*}), otherwise\ \forall_t = 1, \ldots, tj \end{cases}$$

$$t_k = \{1, \ldots, 6\}, t_j = \{7, \ldots, 12\}, P^{min}, P^{max}, Q_t^{OP} \geq 0 \qquad (4)$$

In formula (3) there are several conditions for producer selling price and consumer buying price. Formulas in the first row are used in free market condition. This condition happened in a_{12} and a_{22} from constructed game theory model. Formulas in the second row are used in intervention market. This condition happened in a_{11} and a_{21} from the constructed model.

The data to calculate the total benefit are shown in table 3 and table 4. The supply and demand units are in thousand tons.

In a_{11} condition BLUPP buy all staple food production from the producer, so that Q_t^{PB} will be equal to q_t^s in each period. In a_{12} condition BLUPP do not interfere the market, so that they do not buy any staple food production and Q_t^{PB} is equal to 0. This condition is same with a_{22} condition.

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While in a_{21} BLUPP buy staple food production but the producer also sell the staple food as demand schedule, so that Q_t^{PB} is equal to q^s subtracted by q^d.

TABLE III
DEMAND AND SUPPLY SCHEDULE

	t_1	t_2	t_3	t_4	t_5	t_6
q^s	240	480	480	550	630	470
q^d	200	230	230	260	280	280
	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}
q^s	0	0	0	0	0	0
q^d	260	230	240	240	240	210

Sutopo [1]

TABLE IV
PARAMETERS

c_p	c_d	P^{P0}	CI_p	CI_c	c	d
6,500	400	7,000	6,900	7,500	3	9

Sutopo [1]

The producer revenue from BLUPP in the price support program is equal to 0 because in period 7 until period 12 there is no any staple food production that can BLUPP bought. In other words, the Q_t^{OP} is equal to 0. This condition is happen for all condition in constructed game theory model. While the total production cost for all conditions is equal because the amount of staple food produced is constant for each condition.

In a_{21} and a_{22} there is special condition that producer sells their production to consumer. It assumed that total amount of producer sold to consumer is equal to demand schedule. This special condition make a_{21} and a_{22} have different formula. The formula for a_{21} and a_{22} is shown in formula (2).

Data calculation by the formulas gives a pay off matrix as shown in table 5.

TABLE V
GAME THEORY RESULT BETWEEN PRODUCER - BLUPP

Producer	BLUPP (IDR)	
	B1	*B2*
P1	1,143,978	-3,055,000
P2	2,065,564	-7,497, 945

The functions of the constructed game theory model are to minimize BLUPP cost and maximize producer benefit. To obtain the functions, the model use maximin-minimax model to solve the problem. Due to intervention market system that used in Sutopo [1], *B2* column is eliminated because it use free market system, beside one of the column is to dominant to other column so that only one column is used. Table 6 shows the solved problem using minimax-maximin model.

From the table 6 minimax value for BLUPP is 2,065,564 and the maximin value for producer is 2,065,564. Due to same value for minimax and maximin value in this model, there is a saddle point between BLUPP and producer. The saddle point happen when BLUPP use strategy 1 and producer use strategy 2 with the game point or total producer benefit (TB^P) is 2,065,564.

TABLE VI
MAXIMIN AND MINIMAX VALUE

Producer	BLUPP *B1* (IDR)	Minimal value
P1	1,143,978	1,143,978
P2	2,065,564	2,065,564
Maximal value	2,065,564	

In Sutopo et. al. (2011) total producer benefit is calculated with a mathematical model in intervention market condition. In that paper the TB^P is 1,162,397. While in this paper the TB^P is 2,065,564. Game theory model gives more benefit than the model used in Sutopo [1]. But the producer condition in Sutopo [1] is different with the condition in this paper. In this paper the producer sell the production to consumer as demand schedule and sell the surplus to BLUPP. While in Sutopo [1] all the staple food production is sold to BLUPP.

For the same condition, the TB^P in this paper is 1,143,978. Little bit different with the result in Sutopo [1]. The comparison between the results is shown in table 7.

TABLE VII
RESULT COMPARISON

1	TB^P (Sutopo [1])	IDR 1,162,397
2	TB^P – Game Theory Model Condition 1	IDR 1,143,978
3	TB^P – Game Theory Model Condition 2	IDR 2,065,564

From the table above the result in row 1 and 2 has a little different. So that game theory model is compatible to be used in solving price stabilization problem based on the result. Based on the ease of use the analytical model has more advantage than game theory model. Use of Lingo as operational research solving problem software simplifies the analytical model. While in the new model it is more difficult because the calculation must be done manually with Microsoft Excel aid. Moreover, use of Lingo gives an advantage to analytical model in complexity and accuracy due to automatically calculation. Game theory model consider less constraint in the model. But the game theory has an advantage that it can be used to illustrate more condition and transaction in one calculation process. Table 8 shows the comparison between the analytical model and game theory model.

TABLE VIII
MODEL COMPARISON

Criteria	Analytical Model	New Model
Parameter Result (TB^P) (IDR)	1,162,397	1,143,978
Ease of Use	More advantage due to use of Lingo	More difficult due to manually calculation
Complexity	More constraint involved, more accurate	Less constraint involved, less accurate

V. CONCLUSION

A staple food game theory model has been developed in accordance with buffer stock model integrated in warehouse receipt system for solving the problem of staple food supply chain distribution. Relationship between two players, producer and government agency (BLUPP), has been built in a two players - pay off matrix. The mathematical model conducted in previous research is used in this paper to calculate the parameter of the model (total benefit). Then the both model will be compared to find the compatibility of the new model.

The result shows that in the same condition the staple food game theory model can simulate the constructed model in stabilize the staple food price. But based on the ease of use and complexity, analytical model have more advantage due to use of Lingo as problem solving software. In addition, the game theory model can illustrate more condition in staple food price stabilization problem.

It is necessary to develop the staple food game theory model to solve the price stabilization problem. Addition entities involved in the model can be the development of the model proposed. Consumer and distributor can be added in the model to illustrate all the transactions that possible to be happened in the problem. Use of Lingo software as problem solving software can be another alternative to develop this paper.

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