A Buffer Stocks Model for Stabilizing Price of Staple Food with Considering the Expectation of Non Speculative Wholesaler

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Abstract — **This paper is a study of price stabilization in the staple food distribution system. All stakeholders experience market risks due to some possibility causes of price volatility. Many models of price stabilization had been developed by employing several approaches such as floor-ceiling prices, buffer funds, export or import taxes, and subsidies. In the previous researches, the models were expanded to increase the purchasing price for producer and decrease the selling price for consumer. Therefore, the policy can influence the losses for non-speculative wholesaler that is reflected by the descending of selling quantity and ascending of the stocks. The objective of this model is not only to keep the expectation of both producer and consumer, but also to protect non-speculative wholesaler from the undesirable result of the stabilization policy. A nonlinear programming model was addressed to determine the instruments of intervention program. Moreover, the result shows that the wholesaler behavior affects the intervention costs.**

Index Terms **Buffer stocks, Price stabilization, Nonlinear programming, Wholesaler behavior.**

1 INTRODUCTION

The price volatility of commodity has been greatly became a problem in the staple food distribution system. The shortage of staple food around the world has been affecting the economics, political and social crisis because of food security reason [1]-[3]. Price stabilization policy is an intervention in the market in order to reduce price volatility. The international organization and domestic governments have tried numerous ways to stabilize price for example by implementing the quota systems, commodity agreements, marketing boards, compensatory funds, and price hedging on futures markets [4]-[9]. However, it is only a small number of these mechanisms have entirely succeeded [10]-[15]. This situation forced the domestic governments to stabilize the prices by using appropriate local solutions.

In the last few years, there were many models of price stabilization developed by each country using several approaches such as floor-ceiling prices [16], [17], buffer funds [18]-[22], export or import taxes [23]-[25], and subsidies [26]-[28]. In the developing countries, it is common that governments stabilize the price using both export/import taxes and subsidies approaches. However, these create a policy dilemma since these countries signed the general agreement on trade and tariff (GATT). They must reduce the quantitative restrictions and tariffs. On the other hand, if the governments use State Trading Enterprises (STEs) to stabilize price using both floor-ceiling prices and buffer funds, it might be still allowed [10], [11]. Therefore, this study only focuses on how to develop a model based on the floor-ceiling prices and the buffer funds.

There were a number of researches had been conducted regarding to this issue. It came out with several models. The reduction of uncertainty on the supply side only by determining the buffer stocks schemes consist of time and amount of buffer's procurement were proposed by [29], [30]. The reduction of uncertainty on the supply side by deciding the buffer stocks schemes consist of the amount and price of procurement were developed by [31]-[37]. The reduction of uncertainty on the demand side by determining the buffer stocks schemes consist of the amount and price of procurement were addressed by [18]-[23], [26].

This research is trying to fill the research gaps. Meanwhile, it also comes up with the real problem of sugar price stabilization in the supply chain of sugar in Indonesia. The sugar price volatility was carried for some reasons as follow. First, based on supply-demand problem, the domestic supply is decreasing contrary to the increasing of the staple food consumption [38], [39]. Second, due to the periods of sugar cane crops, there is a great difference of staple food supplies between the harvest season and the planting season while the demand is relatively constant [40]-[42]. During the harvests season, the market price is falling down because of the excess supply (surplus). Conversely, in the planting season, the market price will rise because of the excess demand when the customer wants more. Third, it may be cheaper to obtain the staple food from foreign country than domestic. This situation are caused by several reasons such as a low level of sugarcane productivity per hectare, a low level of sugar mill/plant efficiency, and the price distortion in the global market [43]-[46]. Fourth, it is probably speculative action of wholesaler encourage the price volatility [47].

Due to some possibility causes of price volatility mentioned above, all stakeholders experience market risks [48], [49]. Producer is forced to sell staple food at lowest price during the harvest season. Consumer has to deal with the scarcity of staple food and the price hikes during the planting season. Non-speculative wholesaler suffers a larger procurement cost due to drop in selling quantity but raise in stocks. Government cannot maintain the food security to assure the availability of the staple food with enough amounts at the rational prices. The expectation of both the producer and the consumer is to obtain a reasonable price for their transaction with

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the wholesaler. The non-speculative wholesaler expects all stocks can be sold with reasonable profit. The government keeps away the crisis of staple food. This case study requires a buffer stocks model to answer the expectation of all stakeholders.

As in the papers cited above, none of the models is appropriate to solve the case study by considering the four possibility reasons of high price volatility. Furthermore, Supply Chain Management (SCM) may be able to solve it because the problems above can be seen as an integration of key business processes from the integrated system point of views that include people (government, producer, wholesaler and consumer), material (staple food), equipment (distribution channel/infrastructure), and energy (financial and information). The integration of key business processes is required to achieve the suitable economic results and to leverage benefits [50]-[52]. In this work, a strategic level of Supply Chain (SC) design problem is addressed, that is the decision on buffer stocks for stabilizing good's price. The buffer stocks schemes consist of planning, procurement, inventory, and operation program [53].

This paper is organized as follows. In Section 1, we propose the background of our research and describe the problems in real system. In Section 2, we construct the problem setting. In Section 3, we provide the methodology for solving the problem. In Section 4, we design the solution method and analysis. In Section 5, we deliver the summary and conclusion.

2 PROBLEM DESCRIPTION

In order to maintain the expectation of all stakeholders, the government can apply the buffer stocks schemes to sustain the market price on certain price band [54]. The relevant system of the problem is illustrated in Fig. 1. It consists of three main components namely single producer, single wholesaler, and single consumer as well as the government as regulator. The producer supplies the staple food to the market, and then the wholesaler distributes it to the customer. It is assumed that other products cannot substitute staple food. The total production is lower than the total consumption. Consequently, the import of staple food is permitted by the government to anticipate the market shortage. The government will use the buffer stocks schemes to intervene the market price when the market indicates a crisis. It is assumed that the price fluctuation as a single crisis indicator and the government has unlimited budgets.

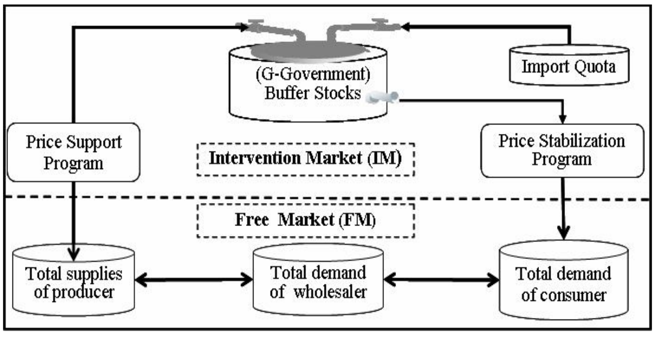

Figure 1. An overview of relevant system

In a free market **(FM)**, the theory of supply and demand states the selling price for producer and the buying price for customer. In the harvest season, the producer sells the staple food to the wholesaler, and then the consumer buys it from the wholesaler as much as his/her demand. In the planting season, since the wholesaler still has excess inventory, then the consumer can buy it as much as his/her demand. To illustrate the market situation, the planning horizon of supply-demand is differentiated as four periods (Table 1.).

Table 1. The market situation

Period	t_1	t_2	t_3	t_4
1 season	the early of harvest	the end of harvest	the beginning of planting	the end of planting
2 production	normal	booming	none	none
3 consumption	stable	stable	stable	stable
4 availability	sufficient	surplus	sufficient	shortage
5 purchasing price to producer	normal-lower	lowest	-	-
6 selling price to consumer	normal-lower	normal	normal-higher	highest

In an interventioned market (IM), the market price is not only determined by supply-demand forces, but also by the buffer stocks schemes forces. The buffer stocks schemes can be used by the government to support/stabilize the market price for both the producer and the consumer. In the harvest season, especially during the boom periods (period t1-t2), the government intervenes the wholesaler to increase the purchasing price for the producer by applying the Price Support Program. The government purchases staple food to increase the market price up to PMin (minimum purchasing price permitted by regulator). On the other hand, throughout the planting season especially in the bush periods (t3-t4), the government asked the wholesaler to decrease the selling price for customer by using the Price Stabilization Program. The government sells the staple food in to the market to reduce the market price to PMax (maximum selling price permitted by regulator).

The price support and stabilization program above, or price band policies, are designed to keep the market price at a range of lower-upper price. A buffer stock model must be able to determine the instruments which are required for market intervention program. The objective of this model is not only to keep the expectation of both the producer and the consumer, but also to protect the non-speculative wholesaler from the undesirable result of the stabilization policy. The decisions concern on the quantity and the price of buffer stocks schemes to interfere both the purchasing price and the selling price.

3 MATHEMATICAL FORMULATION

The condition of staple food distribution and all relevant data (costs, supply-availability-demand, and other factors) were collected from the historical data and appropriate forecasting methods. The notations in the formulation will be described and all of the cost parameters and decision variables are measured in Indonesia Domestic Rupiah (IDR).

Parameters:

c_p Production cost of producer per unit (IDR/tons)
c_d Distribution cost of wholesaler per unit (IDR/tons)
c_o Operation cost of government (IDR/tons)
c_h Holding cost (IDR/tons/year)
p_i Staple food price in the global market (IDR/tons)
c_i Import cost (IDR/tons)
q_t^s Supplies of staple food in period t (tons)
q_t^d Demand of staple food in period t (tons)
q_t^A Amount of staple food in the market in period t (tons)
q_t^C Amount of consumption of staple food in period t (tons)
p_t^{p0} Purchasing price to producer in the FM in period t (IDR/tons)
p_t^{p1} Purchasing price to producer in the IM period t (IDR/tons)
p_t^{s0} Selling price to customer in the FM in period t (IDR/tons)
p_t^{s1} Selling price to customer in the IM period t (IDR/tons)
a An asymptotic parameter of purchasing price function
b A natural logarithmic parameter of selling price function
CI_p Crisis indicator of purchasing price for producer (IDR/tons)
CI_c Crisis indicator of selling price for consumer (IDR/tons)

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Major decision variables:

P^{Min} Minimum purchasing price limit (IDR/tons)
P^{Max} Maximum selling price limit (IDR/tons)
Q^{OP} Staple-food purchased by the government (tons)
Q^{OR} Buffer stocks distributed by the government (tons)

Minor decision variables:

Q^{OI} Import quota (tons)
Q^{OG} Amount of government buffer stocks (tons)
Q^{PW} Amount of producer - wholesaler transaction (tons)
Q^{WC} Amount of wholesaler - consumer transaction (tons)

A mathematical formulation is proposed in this work to incorporate the expectation of all stakeholders based on recourse model with three stages. First stage, an analysis of historical transaction is tackled to elaborate the wholesaler behavior and depict the price function. Second stage, the price band polices are made subject to the restrictions imposed by the first-stage results. Finally, a model formulation is conducted by using appropriate programming methods.

3.1. Analysis of historical transaction

The historical data and appropriate analysis methods are used to depict the price function and the wholesaler behavior. An asymptotic curve is representing the historical data of the purchasing price function. Furthermore, the selling price function can be illustrated by a natural logarithmic curve. Based on the both price functions, the wholesaler behavior is differentiated in to two categories, speculative and non-speculative wholesaler. Speculator can push the market to be either a bull or a bear. It is reflected by the changes of the price functions at unreasonable rate. Hence, this study is only focus on the non-speculative wholesaler. Fig. 2 describes both the purchasing price rate and the selling price rate versus the amount of supplies/consumption for the non-speculative wholesaler by utilizing the actual transaction data in the FM.

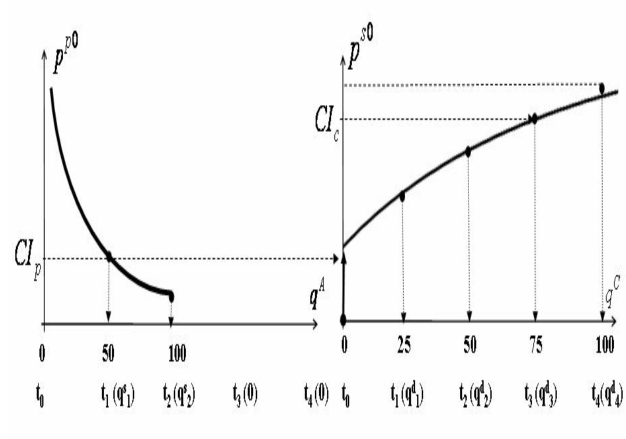

Figure 2. Market price rate versus amount of supplies/consumption

As shown in Fig. 2, an analysis of historical transaction can be used to propose a proportional function either the purchasing or the selling price function. The functions are as follow:

$$p_t^{p0} = \frac{a}{q_t^A}, \ 0 < q_t^A \le q_t^s, t = 1,2 \quad (1)$$

$$p_t^{s0} = (p_t^{p0} + c_d) + b\ln(q_t^C), 0 < q_t^C \le q_t^d, \ t = 1,...,4 \quad (2)$$

3.2. Price band policies

The price functions in Eq. (1) and Eq. (2) will be controlled by using the price band policies. When the amount of supplies/consumption is plentiful, actually both the producer and consumer experience the disadvantages transaction under the crisis indicator. Conversely, the non-speculative wholesaler is unsure to get a reasonable profit. The government can maintain the purchasing price at higher level than the crisis indicator by designing the price support program.

$$p_t^{p1} = \frac{a}{q_t^A}, when \ p_t^{p0} > CI_p, t = 1,2 \quad (3)$$

$$p_t^{p1} = P^{Min}, when \ p_t^{p0} \le CI_p, t = 1,2 \quad (4)$$

Furthermore, under Price Stabilization Program the government can control the selling price.

$$p_t^{s1} = (p_t^{p1} + c_d) + b\ln(q_t^C), when \ p_t^{s0} < CI_c \quad (5)$$

$$p_t^{s1} = P^{Max}, when \ p_t^{s0} \ge CI_c \quad (6)$$

Generally, the price band policy is only created to give benefit for both the producer and the consumer. In this paper, the model formulation considers the expectation of the non-speculative wholesaler to sell goods with the reasonable profit. All of the transaction between the producer and the non-speculative wholesaler will be ensured to be sold out.

$$\sum_{t=1}^{2} Q_t^{PW} = \sum_{t=1}^{4} Q_t^{WC} \quad (7)$$

The minimum purchasing price and the maximum selling price which are permitted by regulator will be resolved in order to protect the non-speculative wholesaler from the undesirable result of the stabilization policy (Fig. 3).

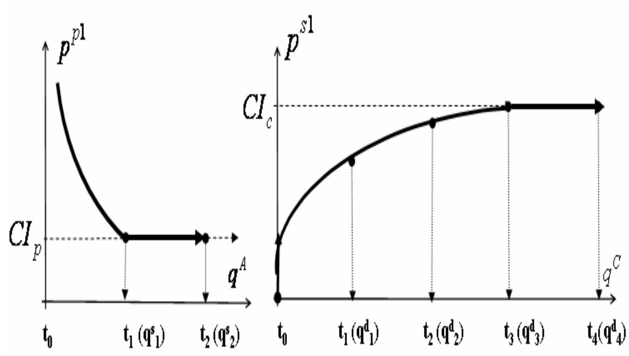

Figure 3. Determination of price band policy

3.3. Model formulation

Both the producer and the non-speculative wholesaler will get the reasonable profit when the market intervention had taken place. In contrast, both the customer and the government will spend money to buy the staple food and do the price intervention. For that reasons, the proposed-model will account the maximum benefit which could gain by the producer and the non-speculative wholesaler. All at once, it is also aimed to minimize the costs and the market risks for the customer and the government.

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i) performance criterian for each stakeholders

The total profit for producer (TP^P) is obtained from the difference between the total revenue and the total production cost. The total revenue (TR^P) is expected from the amount of staple food bought by the government (Q^{OP}) multiplied by the minimum purchasing price limit (P^{Min}) and the amount of staple food sold to wholesaler (Q_t^{PW}) multiplied by the current purchasing price (p_t^{p1}). The total production cost (TC^P) is obtained by multiplying the production cost per unit (c_p) and its production amount (q_t^s). Furthermore, the performance criteria for the producer can be expressed as:

$$\begin{aligned} TP^P &= TR^P - TC^P \\ &= \sum_{t=1}^{2}((Q^{OP}P^{Min} + Q_t^{PW}p_t^{p1}) - q_t^s c_p) \end{aligned} \tag{8}$$

The non-speculative wholesaler will get the reasonable profit because the government will protect it from the undesirable result of the stabilization policy (Eq. 7). The total profit of non-speculative wholesaler (TP^W) is calculated from the difference between the total revenue and the total cost (TC^W) such as procurement cost, distribution cost, and inventory cost in the IM condition. The total revenue for non-speculative wholesaler (TR^W) is computed by subtracting the total consumer's demand with the amount of buffer stocks when the market-operation is conducted; then the total revenue is obtained by multiplying the selling-price (p_t^{s1}) with the total sales (Q_t^{WC}). Total procurement cost (TC^W_{Proc}) is obtained from sum of the staple food bought from the producer at the purchasing price. Total distribution cost (TC^W_{Dist}) is measured from the multiplication of distribution cost per unit and the total consumer's demand of staple food. Total inventory cost (TC^W_{Invt}) is determined as the holding cost per unit in stock per unit of time multiplied by total of average inventory in a year. Therefore, the total profit for non-speculative wholesaler can be written as:

$$\begin{aligned} TP^W &= TR^W - (TC^W_{\mathrm{Proc}} + TC^W_{Dist} + TC^W_{Inv}) \\ &= \sum_{t=1}^{4}(Q_t^{WC}p_t^{s1}) - \\ &\quad (\sum_{t=1}^{2}Q_t^{PW}p^{p1} + \sum_{t=1}^{4}Q_t^{WC}c_d + \sum_{t=1}^{2}\frac{c_h}{4}Q_t^{PW}) \end{aligned} \tag{9}$$

In the IM condition, the consumer will spend money (TC^C) to fulfill its total demand at the selling-price between the wholesaler and the consumer during period t_1-t_3. During period t_4, the consumer bought the staple-food at the maximum price-limit when the market-operation is performed, and the rest of the demands will be purchased at the selling-price. Therefore, the total benefit for consumer is expressed as:

$$TC^C = \sum_{t=1}^{4}Q_t^{WC}p_t^{s1} + Q^{OR}P^{Max} \tag{10}$$

The Intervened Market Budget (IMB) is obtained from the total cost (TC^G) minus the total revenue (TR^G). The total cost consists of procurement cost, distribution cost, and inventory cost. The total revenue is gained from the multiplication between the amount of buffer stocks that is released to consumer and the maximum selling price limit. Total procurement cost (TC^W_{Proc}) is calculated from the amount of staple food bought by the government from the producer at the minimum purchasing price limit and the amount of staple food bought by the government from import at its purchasing cost. Total distribution cost (TC^G_{Dist}) is computed by multiplying the cost of market operation by the government and the amount of buffer stocks that should be released to the market. Total inventory cost (TC^G_{Invt}) is measured from the holding cost per unit in stock per unit of time multiplied by the total of government's average inventory in a year. Therefore, the Intervened Market Budget for the government can be stated as follows:

$$\begin{aligned} IMB &= (TC^G_{\mathrm{Proc}} + TC^G_{Dist} + TC^G_{Inv}) - TR^G \\ &= (Q^{OP}P^{Min} + (p_i + c_i)Q^{OI}) + Q^{OR}c_o + \frac{c_h}{4}Q^{OG} \\ &\quad - Q^{OR}P^{Max} \end{aligned} \tag{11}$$

ii) objective function

We develop a buffer stocks schemes for price stabilization to facilitate the expectation of stakeholders. The buffer stocks model therefore must attain two targets: maximize the benefit of the producer and the non-speculative wholesaler and minimize the total cost of consumer and government (Eq. 8-Eq. 11). The resulting objective function which includes the two objectives is finally expressed as follows:

$$Max.TP^P + TP^W - TC^C - IMB \tag{12}$$

iii) constraint sets

Constraints (13), (14) and (15) are introduced to ensure that the price equilibrium fulfills the expectation of the producer and the non-speculative wholesaler at the price support program.

$$q_t^A = a / p_t^{p1}, t = 2 \tag{13}$$

$$Q_2^{PW} = q_2^A \tag{14}$$

$$\sum_{t=1}^{2}q_t^s = \sum_{t=1}^{2}Q_t^{PW} + Q^{OP} \tag{15}$$

Constraints (16), (17) and (18) are addressed to ensure that the price equilibrium fulfills the expectation of the consumer and the non-speculative wholesaler at the price stabilization program.

$$q_4^C = e^f \tag{16}$$

$$f = (P^{Max} - (p_2^{p1} - c_d)/b) \tag{17}$$

$$Q_4^{WC} = q_4^C \tag{18}$$

We have to guarantee that the buffer stock schemes are not only adequate to hold the market-intervention program, but also to protect itself from the illegal import by considering constrains (19), (20) and (21). Finally, we have to make sure that none of the decision variables is negative by considering constraint (22).

$$Q^{OI} = \sum_{t=1}^{4}q_t^d - \sum_{t=1}^{2}q_t^s \tag{19}$$

$$Q^{OG} = Q^{OP} + Q^{OI} \tag{20}$$

$$\sum_{t=1}^{4}q_t^d = \sum_{t=1}^{4}Q_t^{WC} + Q^{OR} \tag{21}$$

$$P^{Min}, P^{Max} \geq 0 \tag{22}$$

4. SOLUTION METHOD AND ANALYSIS

In this section, we present the solution method, numerical examples and analysis to evaluate the expectation of stakeholders.

4.1. Solution method

The optimal solution can be obtained by solving the pre-emptive of the non-linear programming (NPL) above. The methodology to solve the proposed problem is described as follow:

- forecast all the parameters from the historical data,
- set the parameters of the market price function,
- predict the market price in the FM,
- formulate the objectives function in the IM,
- formulate all the constraints of the solution model, and
- solve the model by using NLP software i.e. Lingo v.9 [55].

4.2. Numerical examples and analysis

In order to illustrate the capabilities of the proposed-model, a numerical example has been done. The problem consists of hypothetic-parameters to reflect the data of Indonesian sugar market. Let $c_p = 58$, $c_d = 2.0$, $c_h = 0.5$, $c_O = 2.0$, $c_i = 3.0$, $p_i = 50$; $CI_p = 1.1c_p$ and $CI_c=1.38.c_p$ in appropriate units. Thus, the supply-demand parameters are shown in Table 2.

Table 2. Parameter of supply-demand

	t_1	t_2	t_3	t_4	Total
q_t^d	25	25	25	25	100
q_t^s	35	55	-	-	90

We consider two sets of problem. It is indicating by two sets of price function parameter (a; b) i.e. set 1 (4950; 3.9) and set 2 (5000; 4.0). The model was solved in Lingo software and the solutions are found by using the available methodology. The proposed-model estimates the decision variables in two set of price function parameter. Using the parameter assumptions outlined in Table 2, the proposed-model calculates both the decision variables (Table 3) and the performance criterian for each stakeholder (Table 4).

Table 3. A Computational of decision variables

	(Unit)	set 1	set 2
P^{Min}	IDR/tons	63.80	65.15
P^{Max}	IDR/tons	79.69	81.44
Q^{OP}	tons	12.43	13.25
Q^{OR}	tons	22.41	23.25

Two sets of price band policies have been produced by the proposed-model. Price-band schemes can be suggested respectively between 63.80-79.69 and 65.15-81.44 per unit. The mechanism of increasing price band is explained by the wholesaler behavior. It can be noted that the increasing of price function parameter will influence the performance criteria for each stakeholder.

Table 4. A Computational of performance criteria

	(Unit)	set 1	set 2
(TP^P)	Mill. IDR	522.00	643.54
(TC^C)	Mill. IDR	1,146.16	1,163.66
(TP^W)	Mill. IDR	7,969.77	8,143.00
(IMB)	Mill. IDR	1,368.38	1,441.71

Table 4 reports the results of the proposed-model regarding to the maximization of expected benefit for the producer and the non-speculative wholesaler; and the minimization of expected cost for the customer and the government. The market-intervention policy can be utilized to improve the profit for both the producer and the consumer. Therefore, the IMB is rising when the price function parameter is growing up.

5. CONCLUSION

This paper studies a buffer stocks model for price stabilization in the staple food distribution system. This model is not only to keep the expectation of the producer and the consumer, but also to protect the non-speculative wholesaler from the undesirable result of price band policy. By considering both the purchasing price function and the selling price function, it is shown that model is able to decide the minimum purchasing price limit and the maximum selling price limit simultaneously. A nonlinear programming model was addressed to determine the instruments of intervention program. The instruments concern on the quantity and the price of buffer stocks schemes in order to intervene the market price. Moreover, the result shows that wholesaler behavior affects the intervention costs.

This paper has certain limitations that should be overcome in order to provide a deeper analysis on the function of a buffer stocks schemes. There are some extensions from this work that could be derived to elaborate the model formulation such as considering the budget constraint, providing a volatility target (VT) options, and offering the Intervened Market Budget (IMB) options. Furthermore, in this paper, it is assumed that the model is appropriate with the direct intervention system using by the State Trading Enterprises (STEs). In the future, it probably significant to develop a model that is suitable with the indirect intervention system for instance by using the Warehouse Receipt System (WRS).

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