A Buffer Stocks Model for Stabilizing Price of Commodity under Limited Time of Supply and Continuous Consumption

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Abstract. Staple foods, in developing countries especially in Indonesia, have extremely volatile among harvest and planting season caused by inelastic of supply-demand and price disparity. When a staple food is shortage in market, it will trigger crisis of economics, political and social because it concerns with food security. This paper develops a buffer stock model for stabilizing price of commodity under limited time of supply and continuous consumption. The performance criterion of model will consider financial loss of producer, consumer and government side when market is interfered by price-stabilization program and price-support program simultaneously. The price fluctuation will be stabilized by market operation where buffer stocks are bought from domestic and import supply point. This paper provides a price band policy that attempts to bound domestic price variation between a set of upper and lower bounds on the level of domestic prices. We consider three sets of problems reflecting different three prices elasticity from 4 period of supply and demand. Numerical examples are found to be consistent with empirical estimates regarding the relationship price elasticity with price band and with government budget for the agenda of assisting household to assure availability a staple food with enough amounts at rational prices.

Keywords: buffer stocks, price band, stabilization, limited time of supply, staple foods.

1. INTRODUCTION

At agricultural commodity market, staple foods (such as rice and sugar), in developing countries especially in Indonesia, have extremely volatile caused by inelastic of supply-demand and price disparity (Reiner and Treka, 2004; and Susila & Sinaga, 2005). The staple foods will trigger crisis of economics, political and social for the reason of food security when they shortage in market (Heidhues, 1976; Knudsen & Nash, 1990; Smith, 1997; dan Brennan, 2003). Government has obligation to assure availability of enough staple foods, for amount, qualities, peaceful, flatten and at reasonable price. Government also concerns with availability, accessibility, vulnerability (stability and reliability) and sustainability of staple foods for people. Government should maintain the stability of food market through market intervention. Government has several stabilization schemes for instance a buffer stocks policy.

The policy of buffer stocks will be complex because it is influenced by commodity types, supply-demand characteristics and trade regulation. The basic function of such a buffer stocks policy is to store a certain amount of the commodity in boom periods, when the price is low, and to release a certain amount of the stored commodity in bust periods, when the price is high. Undoubtedly, there has been a lot of research over the past decades in particular field, for examples Arzac (1979), Newbery and Stiglitz (1981) and Brennan (2003).

This paper concerns with price stabilization for a single-commodity by buffer stocks for example sugar’s commodity. It is assumed that commodity cannot be replaced by substitution products but it is consumed continuously in a year. This commodity has highly fluctuation of selling price in a year (ISO, 2005; Susila & Sinaga, 2005 & Susila, 2006). However, time supply of commodity is limited by several factors such as period of harvest and planting season; production factors, distribution factors and trade regulation. Total of domestic supply is lower than national demand (Isma’il, 2001, + : Corresponding Author
The supply will be fulfill by imported commodity when domestic supply is insufficient. The quanta and period of import commodity is regulated by Government (Mardiyanto et al., 2005). The relevant system illustrated the relationship among structural aspect and research’s object, is shown in Figure 1. The structural aspect consists of three components as follows; government or regulator, consumer, and producer. Regulator conducts buffer stock planning program, procurement planning program, inventory management program, and market operation planning policy (Nur Bahagia, 2004).

![Figure 1: Overview of System Relevant](image)

This research begins with the mapping of previous models which are related with the price stabilization using buffer stocks. Based on the mapping result, this paper determined reference model to solve a phenomenon of price stabilization for staple foods. The development of mathematical frameworks to investigate the effects of policy interferes in competitive markets has been addressed by several authors.

Labys (1980) and Edwards & Hallwood (1980) have developed model based on econometric to determine the amount of commodities which must be stored by the Government, then the amount of releasing stocks to stabilize prices could be determined. The decision variables of the both models are their parameter value of functions when equation of econometric is proposed. These two models are evaluated by amount of government expenses as performance criterion.

Nguyen (1980) proposed a simple rule for the buffer stock authorities to stabilize both price and earnings in all circumstances, except when market is instable. This model is wholly supply-induced and price elasticity of demand which is greater than or equal to unity. Thus, this model aims to secure producer from loss of arising out.

Brennan (2003), Jha & Srinivasan (2001), and Newbwy & Stiglitz (1982) developed the model buffer stocks supply considering yield price balance at price band policy. The models consider an assurance to producer and consumer welfare by aegis of government interferences, but the models have not considered budget relative with the food price stabilization.

Then, Jha & Srinivasan (2001) have considered the variation of supply from domestic and global market. However, Jha & Srinivasan (2001) did not consider the effectiveness of buffer stocks budget. They also do not consider the financial losses of consumer side as impact of market intervention. Another paper, Athanasia et al (2008) present a Cobweb Model with supply increasing according to certain a piecewise linear supply function. Athanasia et al (2008) also proposed naive expectation to test effect of governmental interferences, related to scheme supply of reserve in weakening price fluctuation a commodity.

According to the mapping result above, no models had developed yet to protect financial loss of 3 structural components as performance criterion of model simultaneously. This model is concerned with availability and price stability of staple foods but this should put considerable optimal financial burden for producer, consumer, and government. In this paper, the price fluctuation will stabilize with market operation where buffer is bought from domestic and import supply point. We extend
Cobweb model as the basic model to determine amount of buffer stocks considering the limited commodity domestic production in convergence to market equilibrium. To solve this problem, the first step is developed a mathematical model based on Athanasiou et al (2008) model as reference, and then solve the model based on a piecewise linear S-shaped supply function and takes into account the constraints which must be satisfied by the stockpiling quantity.

This paper is organized as follows. In Section 1, we propose the background of our research. We then discuss several special cases of the model, in which objective of price stabilization are placed only on government side, only on consumer side, or only on producer side. In Section 2, we provide the description of complicated problem when we will develop a mathematical framework. In particular, the existence of commodity problem and uniqueness of performance criterion need a new buffer stocks model. In Section 3, we propose a new buffer stocks model addressed to answer the existence of commodity problem and uniqueness of performance criterion. We introduce an algorithm for the computation of the equilibrium. We then apply in Section 5 three numerical examples to analysis price elasticity of supply. Section 6 summarizes and concludes.

2. PROBLEM DESCRIPTION

Staple foods in Agricultural market are far from being perfectly competitive. The short-run supply for this commodity is even more inelastic than the long-run supply. At harvests season, when excess supply or market surplus, market price is falling. Government can use regulatory force to prevent anyone from selling or buying at a lower price. A price-support program is designed to maintain price at levels higher than the market price. This price floor helps some producers or farmers but it hurts others.

At planting season, when shortage supply or market minus, there is excess demand where customers want more of commodity. Market price will rise to get equilibrium. Government can use regulatory force to prevent anyone from selling or buying at upper price. A price-stabilization program is designed to maintain price at level lower than the market price. This price ceiling helps some consumers.

Price-support and price-stabilization program above, or price band policy, is designed to keep prices equilibrium at a range of lower-upper price. Price band policy is give benefit both consumers, who get reached of price, and producers, who get proper price to maintain their agriculture industry. Government policy tends to reflect consumer-producer’s interests but governmental budget must be as low as possible. The following costs are required by government: purchase of buffer from import when domestic supply is shortage to cover national demand and spent budget as cost of storage.

According to the explanation above, this paper extends a buffer stocks model to determine price band policy. This model will consider financial loss of producer, consumer and government side simultaneously as performance criterion. The development of mathematical frameworks to determine a price band policy in oligopoly market is become complicated due to conflict of interest in relation between Government-Producer-and-Consumer. At Figure 2 is presented relationship of price band policy with the three structural aspects.

![Fig. 2: Price Stabilization Problems](image)

3. MODELING FRAMEWORK

In this section, we present a modeling framework. This model is developed based on two categories of assumption. There are the market equilibrium assumptions and the system of government interference assumptions.

Setting market equilibrium assumptions:
(i) Competition between and among consumers and producers sets off equilibrium process
(ii) Unique equilibrium of market supply and demand when equilibrium price \( p^* \) is price at which quantity supplied = quantity demanded. Equilibrium quantity \( q^* \) is quantity corresponding to equilibrium price.
(iii) Price volatility is short run problem. Prices generally decline immediately during harvest season, and then gradually increase during planting season.
(iv) Staple foods which studied can be stored and no damage happened during stored.
(v) Supply of domestic production is inflow to market under specific uniform function and distribution time can be disregarded. Demand is under uniform cost in a year.
The system of government interference is depicted in Figure 3 as follow:

(i) Supply of domestic production to market assumed can be differentiated as 4 periods as follows:
- the early of harvest season \([t_0, t_1]\) where market demand is equal to market supply;
- the end of harvest season \([t_1, t_2]\) when supply is bigger than demand;
- the beginning of planting season \([t_2, t_3]\) when no supply form production; and
- the end of planting season \([t_3, t_4]\) when supply is shortage.

(ii) Total of domestic supply point during harvest season \([t_0, t_2]\) is lower than national demand.
(iii) Import supply is regulated by Government. No lead time is calculated when Government purchase commodity from import.
(iv) Government has stocks into 2 (two) classification: government buffer stocks and government market operation stocks.
(v) Government interference market by price-support program when supply is bigger than demand; and by price-stabilization program when supply is shortage.

Fig. 3: Framework of Modelling

4. MODEL DEVELOPMENT

The modeling framework is illustrated at Figure 3. The model developed in this paper use the following notation (Table 1):

<table>
<thead>
<tr>
<th>Table 1: Notation</th>
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<tr>
<td><strong>Index:</strong></td>
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<tr>
<td>( t )</td>
</tr>
</tbody>
</table>

| **Parameters:** |
| \( P_0 \) | Cost of Good Sold of commodity. |
| \( P_t \) | Price equilibrium in period, \( t \). |
| \( P^i \) | A purchase cost per unit of item from import. |
| \( P^f \) | Price equilibrium in period of free market. |
| \( Q^S_t \) | Amount of supply’s commodity in period \( t \). |
| \( Q^D_t \) | Amount of demand’s customer in period \( t \). |

| **Decision Variables:** |
| \( Q^G_t \) | The beginning buffer stocks |
| \( h \) | A holding cost per unit in stock per unit of time. |
| \( SS \) | A minimum stock is required by government. |
| \( T \) | Length of time periods. |
| \( Q^O_t \) | Amount of market operation in period, \( t \). |
| \( Q^I_t \) | Amount of imported commodity. |
| \( P_{Min} \) | Minimum limit price. |
| \( P_{Max} \) | Maximum limit price. |
| \( TC^{P,E,G} \) | Total expected loss cost by Stakeholders |
First let consider the simple one-commodity market model, it is only governed by the quantity demanded of the commodity \( (Q^D) \), the quantity supplied of the commodity \( (Q^S) \), and its price \( P_t \). This paper is assumed that price change only determined by the supply price functions because demand is relatively stable during a year (inelastic). Translated into mathematical statements, the model can be written as:

\[
P_t = a - bQ_t^S, \quad a > 0; 0 < b \leq 1 \tag{1}
\]

Where \( a \) is constants, \( b \) is point price elasticity of supply; then \( a \) and \( b \) should be the mutually independent parameters. Given this notation, we can formulate the objective function is minimizing combination producer, consumer and government financial losses side.

(i). Producer side

When the early of harvest season \([t_0, t_1]\) period, supply is appropriate with demand. Market price is indicate equilibrium of supply and demand. Producer will get advantage which is equal to differences sell market between costs of good sold (COGS) times with the amount of supply. When the end of harvest season \([t_1, t_2]\), supply will be excess then the prices equilibrium will decline immediately. Without price support, producer will be harmed because price will tend to lower than the Cost of Goods Sold. Government intervenes by a price floor. It is minimum limit price \((P_{min}^f)\) to prevent producer sell at a lower price. Translated into mathematical statements, the objective function for producer can be written as:

\[
TC^P = (P_{f1}^f - P_0)Q_1^S + (P_0 - P_{min}^f)Q_2^S \tag{2}
\]

(ii). Consumer side

Since the government interference market equilibrium — the end of harvest season \([t_1, t_2]\) period, supply is bigger than demand — through purchase excess supply as a buffer stock, it will be hurt consumer. The market prices will grow up closes to the minimum limit price \((P_{min}^b)\). Consumer is harmed equals to difference among the real price when no interventions with the minimum limit price multiple the amount of total consumer demand. Government intervenes by a ceiling price when the end of planting season \([t_3, t_4]\) period. It is maximum limit price \((P_{max}^b)\) to prevent consumer sell at an upper price. Consumer will get beneficial equals to difference among the real price market without intervention with the maximum limit price multiple the amount of demand. This statements are:

\[
TC^C = -(P_{min}^b - P_2^b)Q_2^D + (P_{f2}^b - P_{max}^b)Q_4^D \tag{3}
\]

(iii). Government side

No budget needed by government if market intervention is not conducted. Since market intervention, government expenses budget to reduce amount of domestic supply in surplus period to purchase of commodity from import in shortage period and to store a buffer stocks during a planning horizon. Government will purchase commodity at the minimum limit price when surplus period. Government will purchase commodity from import at the global price when shortage period. Government will get revenue from market operation equal to a buffer stocks release to market multiple with the maximum limit price. Translated into mathematical statements, the objective function of government can be written as:

\[
TC^G = (P_{min}^bQ_2^D + P_{max}Q_4^D - P_{max}Q_4^G) \tag{4}
\]

4.1. Objective Function

Price band policy is give beneficial both consumers who get reached of price and producers who get proper, price to maintain their agriculture industry. However, Governmental budget could be minimally. Given the equilibrium behaviour shown in equation (1)-(4), we can formulate the objective function as follows:

\[
TC^{P.C.G} = TC^P + TC^C + TC^G
\]

\[
= (P_{f1}^f - P_0)Q_1^S + (P_0 - P_{min}^f)Q_2^S
\]

\[
- (P_{min}^b - P_2^b)Q_2^D + (P_{f2}^b - P_{max}^b)Q_4^D
\]

\[
+ (P_{min}^bQ_2^D + P_{max}Q_4^D - P_{max}Q_4^G) \tag{5}
\]

The formulation as a Mixed Linier Integer Programming Model is as follows:

\[
\text{Min } TC^{P.C.G} (P_{min}^b, P_{max}^b, Q_2^D, Q_4^D, Q_4^G) \tag{6}
\]

(a). Price band policy Constraints

The following constraints enforce the price equilibrium is under control at lower-upper price.

\[
P_{min}^b = a - b(Q_2^S - Q_2^O) \tag{7}
\]

\[
\overline{P_2} < P_{min}^b < P_{f1}^f \tag{8}
\]

\[
P_{max}^b - bQ_4^O < a - bQ_4^S \tag{9}
\]

\[
\overline{P_3} < P_{max}^b < P_{f2}^f \tag{10}
\]
The constraints achieve the following:

(7) is the supply price function where existing supply is reduce by government.

(8) express a minimum limit price constrains that stated by government only used to intervenes at the end of harvest season \([t_1, t_2]\).

(9) is maximum limit price function constrain, supply price function where existing supply is smaller than existing price.

(10) ensure that maximum limit price that stated by government is not harming the previous period.

(b). Supply-demand Constraints

The following constraints enforce the total supply is adequate to fulfill the total demand in each period.

\[
Q^s_2 - Q^o_2 \geq Q^d_2 \\
Q^s_4 + Q^o_4 \geq Q^d_4 \\
Q^i + \sum_{t'=1}^{t} Q^s_{t'} \geq Q^d_{t'} + \sum_{t'=1}^{t} Q^o_{t'}
\]

The constraints achieve the following:

(11) ensure that remains of supply constrain when government purchase amount of buffer stocks in surplus period \([t_1, t_2]\) must be bigger than the current demand.

(12) is maximum limit price function constrain, supply price function where existing supply is smaller than existing price.

(13) ensure that total national supply and total import are bigger than total national demand and government buffer stocks.

(c). Market Clearance Constraints

The following constraints enforce the supply is adequate of the demand in each period.

\[
Q^o_0 + Q^o_2 - Q^o_4 + Q^i \geq SS \\
- Q^o_2 + Q^o_4 - Q^o_4 + Q^i = 0 \\
Q^o_t, Q^o_i, Q^i, P_{\text{Min}}, P_{\text{Max}} \geq 0
\]

The constraints achieve the following:

(14) express a minimum of government buffer stocks.

(15) express the market clearing condition of government buffer input and output.

(16) ensure that all variables cannot be negative.

The optimal solution can be obtained by solving the mathematical programming above. We provide an algorithm to solve the problem that description above. The computation technique is summered in the following algorithm:

(i) Calculate initial price for each supply condition as price equilibrium without intervention.
(ii) Input model equation (5) until (16) into LP-ILP software i.e. WinQSB or Microsoft Excel Solver 8.0.
(iii) Calculated objective function use optimization software.
(iv) Determine each stakeholder costs based on Min. TC

5. NUMERICAL EXAMPLE AND ANALYSIS

In this section we present numerical example and analysis to evaluate the total stakeholder loss costs. We considered three sets of problems reflecting different three price elasticity from 4 period of supply and demand. The parameters used for the computational example is presented in Table 2 and Table 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_t )</td>
<td>( a - bQ^s_i )</td>
</tr>
<tr>
<td>( P_0 )</td>
<td>5.60</td>
</tr>
<tr>
<td>( P_f^1 )</td>
<td>( a - bQ^o_1 )</td>
</tr>
<tr>
<td>( P_f^2 )</td>
<td>( a - bQ^o_2 )</td>
</tr>
<tr>
<td>( P_i )</td>
<td>5.75</td>
</tr>
<tr>
<td>( h )</td>
<td>0.20</td>
</tr>
<tr>
<td>( SS )</td>
<td>20 %</td>
</tr>
<tr>
<td>( T )</td>
<td>4</td>
</tr>
</tbody>
</table>

For given parameter values, we processed to determine decision variables use LP-ILP software. The results are shown in Table 4.

Using the parameter assumptions outlined in Table 2 and Table 3, the rational price band policy was estimated. A comparison of decision variables with three different price elasticity of supply respectively 0.20; 0.25; and 0.30; are shown in Table 4. Three set of prices band policy has been estimated by the proposed model. Each of prices band has difference range, respectively 3.00, 4.20 and 5.10. High
fluctuation between \( P^{\text{ass}} \) and \( P^{\text{ass}} \) is explain the effect of limited time supply on harvest season.

**Table 4:** Computational results with three different price elasticity of supply

<table>
<thead>
<tr>
<th>Decision Variables</th>
<th>(Unit)</th>
<th>( a=0.20 )</th>
<th>( a=0.25 )</th>
<th>( a=0.30 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P^{\text{Min}} )</td>
<td>IDR/unit</td>
<td>6.00</td>
<td>5.25</td>
<td>3.90</td>
</tr>
<tr>
<td>( P^{\text{Max}} )</td>
<td>IDR/unit</td>
<td>9.00</td>
<td>9.50</td>
<td>9.00</td>
</tr>
<tr>
<td>( Q^c )</td>
<td>(Units)</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
</tr>
<tr>
<td>( Q^g )</td>
<td>(Units)</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>( Q^e )</td>
<td>(Units)</td>
<td>5.00</td>
<td>8.00</td>
<td>8.00</td>
</tr>
<tr>
<td>( Q^r )</td>
<td>(Units)</td>
<td>20.00</td>
<td>23.00</td>
<td>23.00</td>
</tr>
</tbody>
</table>

A government buffer stock equals to 10 units in each variation of price elasticity of supply. Government purchases commodity from domestic supply, respectively 5.00, 8.00, and 8.00 units. Government should purchase 25.00 units commodity from import market where 10.00 units among of imported stored as a government buffer stocks in the beginning of time period. Further more, Government should release buffer in minus period, respectively 20.00, 23.00, and 23.00 in each variation of price elasticity. It can be noted that inelastic price of supply \((b \rightarrow 0)\) has smaller band price than elastics \((b \rightarrow 1)\). Further more, demand of buffer stock under elastics price is bigger than inelastic price.

This paper presented a comparison free market between interferences market. An analysis beneficial of government interference to producer and consumer is depicted in Table 5. The losses of consumer and producer in free market are calculated by assumption that market price is based on average supply in a year.

It can be noted that inelastic price of supply \((b \rightarrow 0)\) needs smaller governmental budget than elastics \((b \rightarrow 1)\). Table 5 also depicts the value of beneficial impact to system, respectively 94.00, 141.25, and 179.50. This proposed model is proven to reduce the effect of free market to consumer and producer. Since price of commodity is extremely volatile hence the government interference has beneficial for producer and consumer significantly.

**Table 5:** A comparison free market versus interferences market

<table>
<thead>
<tr>
<th>Price Elasticity of Supply</th>
<th>( a=0.20 )</th>
<th>( a=0.25 )</th>
<th>( a=0.30 )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Free Market</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Producer</td>
<td>27.00</td>
<td>-54.25</td>
<td>-135.50</td>
</tr>
<tr>
<td>(b) Consumer</td>
<td>-95.00</td>
<td>-130.75</td>
<td>-166.50</td>
</tr>
<tr>
<td>(c) = (a)+(b) P + C</td>
<td>-68.00</td>
<td>-185.00</td>
<td>-302.00</td>
</tr>
</tbody>
</table>

It can be noted that a market consequence of a targeted price band rationing scheme based on the price support and price stabilization has results for consumer and producer welfare significantly with is ability to provide food security. An important point addressing this proposed model is to contribute quantitative approach of buffer stocks mechanism for the agenda of assisting household to assurance availability of staple food with enough amounts at rational prices.

6. CONCLUSION

This paper provides a buffer stocks model for stabilizing price of Commodity which have extremely volatile among harvest and planting season. The price band policy attempts to limit price fluctuation in between a set of upper and lower bounds to achieve the volatility targeted by Government. We have further mentioned the inclusion of the price band, volatile targets and the amount of buffer stocks. The findings are summarized in Table 4. Table 5 give an overview of a comparison free-market versus intervention-market, with abbreviations listed parameters in Table 2 and 3. This proposed model is focused on price elasticity, limited time of supply and the interest of stakeholders.

A proposed model has significant effect to enhance the beneficially for minimizing financial loses loss of producer, consumer and government. When supply is inelastic, the financial losses are relatively smaller than elastic. From the point of view of food security objectives, government intervention plays a major part the following three points are important: (i) a buffer stocks provide the price stabilization for overall beneficially both producers and consumers; (ii) a proposed model is able to obtain the buffer stocks program, and (iii) the revenue of price intervention is intended to induce an equivalent reduction in the fluctuations of total market revenue.
This paper has certain limitation that should be overcome in order to provide in deep analysis on the function of buffer stocks. Ongoing research is dedicated to include more realistic price stabilization policy using the parameters relevant to the Indonesia sugar market. Then, further research will focus on others characteristic of dynamic buffer stock problems, such problems include the heterogeneous of supply-demand points, the spatial price equilibrium as impact of multi location, the location-allocation of government buffer stocks in multi-location cases, and the probabilistic distribution of supply-demand function.

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REFERENCES


Isma’il, N.M. (2001). Improvement of Industry Competitiveness National Sugar as Step to Free Competition. *Institute for Science and Technology Studies Journal, II*, pp. 3-14. *(Published in Indonesia).*


Khudori (2002). Restructuring Industrial of National Sugar. *Usahawan* No. 03 Th XXXI, pp. 3-6. *(Published in Indonesia).*


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