A Game Theory Model of Salt Price Stabilization Using Warehouse Receipt System

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A Game Theory Model of Salt Price Stabilization Using Warehouse Receipt System

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Abstract: In Indonesia, salt produced by farmers contributes 87.9% to the total national salt production. Unfortunately, the lack of quality of salt produced by traditional farmers is due to the problems of uncertain weather, salt processing technology; and lack of business insight makes it difficult for farmers' salt to compete with imported salt. This causes price volatility problems latility and fluctuating supply in the distribution system of salt in Indonesia. This study discusses the real problem of salt distribution with a case study in the largest salt-producing district in Central Java, namely the Pati Regency. The mathematical model uses a game theory approach that considers the warehouse receipt system (WRS) as a collateral management system of price support and price stabilization. The model involves two entities, including the farmers as commodity owners and the warehouse, who offer a collateral system with warehouse receipts. The game theory was used to analyze interactions between farmers and the warehouses in applying of the WRS. The farmers and warehouse strategies were developed based on the monopolistic and controlled wholesaler WRS schemes. The result shows that the proposed model can be applied to solve the distribution problem and can give a more promising outcome than its counterpart. Based on numerical examples, it can be concluded that monopolistic distribution of WRS scheme gives more benefits with a bigger payoff for both farmer and warehouse compared with a controlled wholesaler.

Keywords: farmers' salt; supply disparity; price fluctuation; warehouse receipt system (WRS); Game theory

1. Introduction

In Indonesia, national salt production is fulfilled by farmers and PT Garam, where farmer's salt contributes 87.9% to National production[1)]. Nonetheless, farmers' salt production still depends on the condition of weather that causes supply disparity and price fluctuation[2)]. Salt production will be abundant during the dry season which causes the price drop, but the price will increase during the wet season due to supply deficit and salt can't be produced[2)]. In addition to supply disparity, imbalance of stock and demand as a result of low quality salt has not yet provided significant added value for salt farmers[3)]. Salt from farmers is mostly absorbed for consumption needs and prices tend to be cheaper due to the quality doesn't meet the standard for industrial needs[3)]. The standard is associated with purchaser interests, health and safety, environmental protection, and it also has a potential for national company to have a competitive advantage[4)]. But, nowadays salt is not only used for consumptions and industrial purposes, but it has also the potential for battery cathode material so that salt has considerable opportunities in the future [5,6)]. In Indonesia, research of salt for sodium ion battery was developed by several academic institutions such as Sepuluh Nopember Institute of Technology, Parahyangan University, and Universitas Sebelas Maret[7)]. The research is in line with the Republic of Indonesia government program to accelerate the electric vehicle program based sustainablon battery for road transportation as mentioned in Habibie et al.[8)]. Using electric vehicle will produce less carbon emission than vehicle with internal combustion engine[9)]. This regulation hopefully can encourage Indonesian people to behave more sustainably, like people in developed countries such as Japan and Germany that has more consider sustainability in their decision[10,11)].

Sodium ion batteries are regarded as a promising next-generation energy storage device to replace lithium ion batteries (LIB)[12-14]. Research of cathode factory by using salt as raw material has potential opportunities for increasing value added of salt and farmer's welfare[15]. At this point, problem about imbalance of stock and demand can be minimized by the cathode factory plan solution.

Nonetheless, supply disparity and price volatility problem need to be discussed in order to give Farmer a longer period to sell his commodity due to price increasing. Pricing system in salt commodity is still using traditional way which is price and quality are determined by the wholesaler (buyer)[16]. Theoretically, to avoid income losses due to price drop during production time in dry season, farmers could delay sales of their produce[17]. However, most farmers do not have a strong bargaining power to withhold their harvested produce because they require cash flow to support their next farming investment[18]. Without government intervention, this problem would continue and give bad impact to the welfare of Farmer.

There are several models for direct market intervention (DMI) to tackle price volatility such as floor/ceiling price[19], buffer funds[20], export/import taxes[21], and subsidies[22]. However, many countries that involved in General Agreement on Trade and Tariff (GATT) must reduce DMI instruments to minimize barrier and quantitative restrictions in international trade[23]. To overcome this problem, several studies using The Law No 9 of 2011 about warehouse receipt system (WRS) with buffer stock scheme as indirect market intervention (IMI) instrument to conform to the GATT principles for intervened markets[24–26]. Warehouse receipt system enables farmers to deposit storable goods in exchange for a warehouse receipt (WR). Warehouse receipt is a document issued by warehouse operators as evidence that specified commodities of stated quantity and quality have been deposited at a particular location. This warehouse receipt can be traded, transferred, and used as loan collateral without any other collateral requirements[27]. At this point, implementation of WRS indirectly can increase bargaining power of Farmer. Based on Law of Ministry of Trade No 35 of 2016, there are 14 commodities that can be stored in WRS such as salt, grain, seaweed, coffee, and others.

Previous research has proven that warehouse receipt system (WRS) is able to maintain price stability of commodity with several distribution scheme such as monopolistic scheme and controlled wholesaler scheme [24,26,28,29]. Based on those research, it can be concluded that WRS scheme can be used as indirect market intervention model especially for agricultural commodities that experience supply disparity and price fluctuation. WRS model with monopolistic distribution scheme has been discussed in previous research for maintaining price stability in seasonal staple food and sugar commodity, where WRS facility is used by BLUPP as funding options to control price and supply of commodity[26,28]. WRS model with controlled wholesaler distribution scheme has been discussed for maintaining price stability in red onion commodity, where WRS facility is used by farmer as funding option to get money loan from Bank during the sales delay period [24,29].

Another research using game theory approach to analyze the interactions between entities that involved in price stability scheme. From those research it can be concluded that game theory can be used to describe and analyze interaction between entities and generates best solution to overcome supply disparity and price fluctuation[30–32]. Game theory is a mathematical modeling in analyzing conflict-of-interest situation, where rational players behave strategically[33,34]. Game theory is an important tool that helps to understand situation in which there is strategic interaction among the decision makers[33,34]. However, those research which using game theory to maintain price stability still not considered the probability of win-win solution from non-zero sum games[30–32]. This research tries to address a gap that currently exists in several literatures by analyzing the suitable WRS application to maintain salt price stability using game theory approach to generates a win-win solution for entities that involved. Type of game that will be used in this research is non-zero sum games which can generates a win-win solution for entities that involved in the game by finding the nash equilibrium of the game. Strategies from entities will be built from the WRS application interaction of monopolistic and controlled wholesaler distribution scheme.

2. Methods

Case study of this research was conducted in Pati Regency which the biggest region of salt production in Mid Java. Research begins by collecting and building hypothetical data on supply and prices as the basis for forming the price function. After price function is formed, then continued with the determination of players and game strategies. Interactions in the game are built based on the application of monopolistic and controlled wholesaler WRS scheme. Type of game that will be used in this model is non-cooperative and non-zero sum games which can generates win-win solution for entities that involved in game by finding the nash equilibrium of the game[35].

There will be two players in this game theory model. The first player is Farmer which has three strategies such as sales delay with collateral management system (S1), sales delay without collateral management system (S2), and price support system (S3). The second player is Warehouse which has 2 strategies such as sales delay system (S1) and price support system (S2). From those combination of strategies there will be generated several interactions such as WRS application of monopolistic distribution scheme, WRS application of controlled wholesaler distribution scheme, and without WRS application. Every interactions will have 2 payoffs output for each players, where those payoffs are made by calculating the profit from each players.

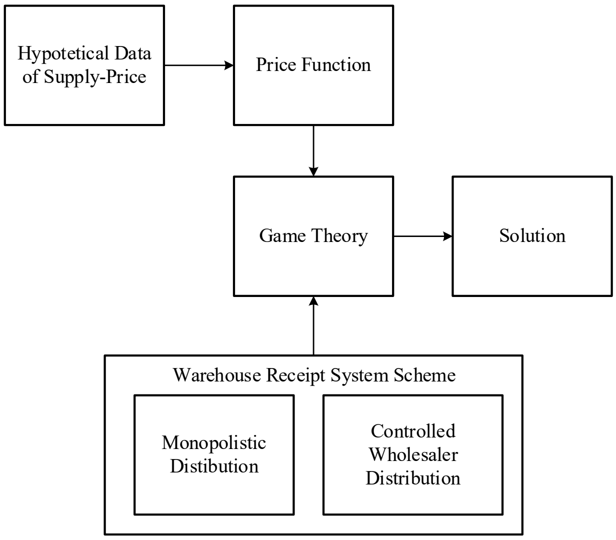

Figure 1. Research Approach

Table 1. Payoff Matrix

Farmer	Warehouse	
	S1	S2
S1	$a_{11} = (\mu_{F11}, \mu_{W11})$	$a_{12} = (\mu_{F12}, \mu_{W12})$
S2	$a_{21} = (\mu_{F21}, \mu_{W21})$	$a_{22} = (\mu_{F22}, \mu_{W22})$
S3	$a_{31} = (\mu_{F31}, \mu_{W31})$	$a_{32} = (\mu_{F32}, \mu_{W32})$

μFxy is payoff for Farmer and μWxy is for Warehouse, where x is the strategy of farmer and y is strategy of Warehouse. WRS application of controlled wholesaler distribution scheme is denoted by the interaction in a_{11} and a_{21} where the differences between those interactions is in Farmer decision of loan collateral action. WRS application of monopolistic distribution scheme is denoted by the interaction in a_{32}. Other interactions in a_{12}, a_{22}, and a_{31} describing the condition when WRS is not applied. Payoffs of each players are calculated from the total revenue and deduced by total cost.

In this model, supply controls is used for price stability mechanism either by farmer or warehouse. In monopolistic distribution scheme (Figure 2), warehouse is proposed to be the sole party to control supply of commodity in free market by using warehouse receipt system as alternative source of funding. Indirect intervention in this model is performed by government by covering 80% of loan interest from Bank in order to increase other entity's desire to take loan using warehouse receipt system cause of the small interest. This indirect intervention is also applied to controlled wholesaler distribution scheme (Figure 3). However, warehouse receipt system facility is used by farmer as alternative source of funding in order to get fresh money to fulfill their production cost each month, where warehouse is used by farmer to store their commodity as a party who saved commodity during sales delay period and created warehouse receipt for farmer. This WRS model tries to control price of commodity by controlling supply of commodity in free market. This model uses price and supply equilibrium concept to maintain price stability of commodity.

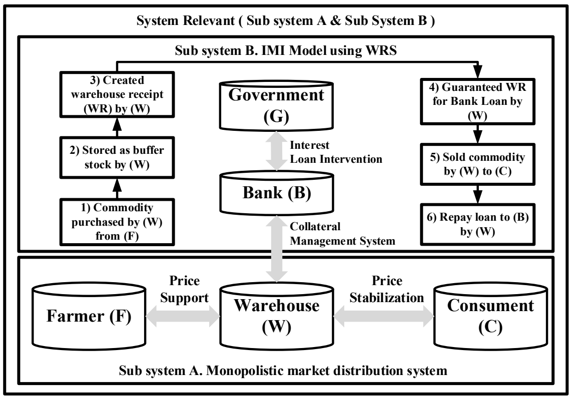

Figure 2. Relevant System of Monopolistic Distribution

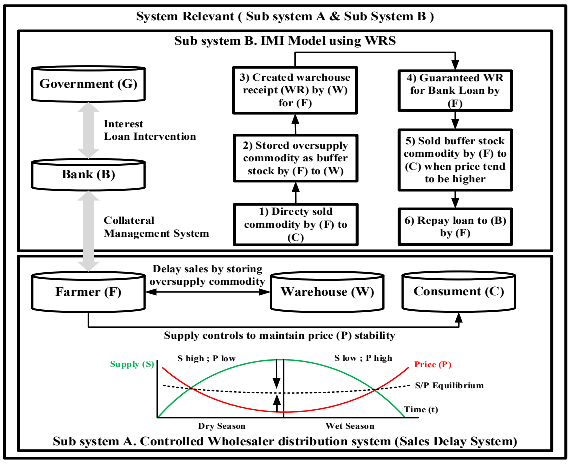

Figure 3. Relevant System of Sales Delay System

In this paper, the data set used to test the model is collected from a case study at Pati Regency, including:

- salt production between 2013-2016;
- the proportion of Pati salt potency in National;
- monthly salt price between 2013-2016; and
- historical data from the amount of WRS-salt sold by farmers or warehouses during the wet season

3. Result and Discussion

Price function is formed using hypotetical data of supply and price which is built from data of Pati salt production between 2013-2016, proportion of Pati salt potency in National, and monthly salt price of Pati regency between 2013-2016. Then, hypotetical data is analyzed using trendline in microsoft excel to see the suitable function which can described the pattern of data.

From result of the trendline analysis that was tested on several functions such as linear, logarithmic, exponential, and polynomial, it shown that the largest coefficient determination ($R2$) was found in logarithmic function of 0.8281 which indicates that the logarithmic function is suitable for describing the supply and price data pattern.

Figure 2 shows the logarithmic function as a price prediction function on this model. From the equation of the price function in figure 2, the variable x represents the amount of supply that affects the price, then the values of 3601,5 and 254,9 as the price function constants. One of each constants is negative and depends on the amount of supply which means price will drop if supply is high and the opposite. The notations used in the development model of game theory are as in Table 2.

Table 2. Notation of Model

Notation	Meaning
S_t^P	Revenue of farmer from selling salt during dry season (IDR)
S_t^{WR}	Revenue of Farmer from selling salt after sales delay period (IDR)
RS_t^{WR}	Profit shares from sales of WR commodity (IDR)
C_t^P	Total of production cost (IDR)
Ca_t^{WR}	Total of WR administration cost (IDR)
LI_t^{WR}	Money loan from Bank (IDR)
LR_t^{WR}	Loan repayment (IDR)
h_t^{WR}	Holding cost (IDR)
TR_t^P	Revenue of farmer from selling salt to warehouse (IDR)
TR_t^{WC}	Revenue of warehouse from selling salt to consumer (IDR)
C_t^{FW}	Total of purchasing cost (IDR)
Q_t^S	Amount of supply when WRS is not applied (IDR)
Q_t^{WRS}	Amount of supply when WRS is applied (IDR)
P_F	Price floor (IDR/Kg)
i_{RG}	Interest of loan (%)
C_{WR}	WR administration cost from Bank (%)
P_t^{P0}	Market price at the farmer level in period t when WRS is not applied (IDR/Kg)
P_t^{P1}	Market price at the farmer level in period t when WRS is applied (IDR/Kg)
P_t^{S1}	Selling price of salt from Warehouse to consumer (IDR/Kg)
C_P	Production cost per Kg of salt (IDR/Kg)
Ps	Profit shares of WR commodity sales for Farmer (%)
Q_t^d	Amount of demand (Ton)
Q_t^P	Amount of salt production (Ton)
Q_t^{WR}	Amount of salt that guaranteed to the WRS (Ton)
Q_t^{wro}	Amount of WR commodity that sold to consumer (Ton)
Q_t^{wrh}	Amount of stored WR commodity in warehouse (Ton)
Ch_{WR}	Holding cost (IDR)
Q_t^{FW}	Amount of salt that bought by warehouse from farmer (Ton)
a	Constants function of market price at the farmer level
b	Constants function of market price at the farmer level
μ_{Fxy}	Payoff for farmer (IDR)
μ_{Wxy}	Payoff for warehouse (IDR)

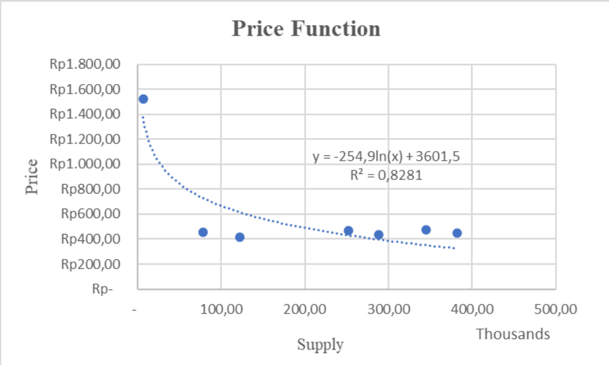

Figure 4. Price Function

After price function is formed, then continued the calculation of the player's payoff which is carried out from the interactions that occur in the game.

WRS Application of Controlled Wholesaler Distribution Scheme

In this interaction Farmer has 2 option such as using and not using the warehouse receipt as collateral to get money loan from Bank during the sales delay period that shown in a_{11} and a_{21}. These following equations below are the elements that formed the performance criterion to calculate payoffs of Farmer and Warehouse in this interaction.

a. Farmer's revenue from selling salt during dry season
$$S_t^P = \sum_{t=1}^{6} P_t^{P1} \times Q_t^d \tag{1}$$
b. Farmer's revenue from selling salt after sales delay period
$$S_t^{WR} = \sum_{t=7}^{12} P_t^{P1} \times Q_t^{wro} \tag{2}$$
c. Profit shares from WR commodity sales
$$RS_t^{WR} = \sum_{t=7}^{12} (1 - Ps) \times S_t^{WR} \tag{3}$$
d. Production cost
$$C_t^P = \sum_{t=1}^{6} C_P \times Q_t^P \tag{4}$$
e. WR administration loan cost
$$Ca_t^{WR} = \sum_{t=1}^{6} C_{WR} \times P_F \times Q_t^d \times plafon \tag{5}$$
f. Money loan from bank
$$LI_t^{WR} = \sum_{t=1}^{6} P_F \times Q_t^{WR} \times plafon \tag{6}$$
g. Loan repayment
$$LR_t^{WR} = LI_{t-6}^{WR} \times (1 + i_{RG})^6 \tag{7}$$
h. Holding cost
$$h_t^{WR} = \sum_{t=1}^{12} Ch_{WR} \times Q_t^{wrh} \tag{8}$$

Warehouse's payoff of both interaction in a_{11} and a_{21} is calculated by this following equation.
$$\mu_{W11}, \mu_{W21} = RS_t^{WR} - h_t^{WR} \tag{9}$$

Farmer's payoff in a_{11} is calculated by this following equation

$$\mu_{F11} = S_t^P + S_t^{WR} - RS_t^{WR} - (C_t^P + Ca_t^{WR} - LI_t^{WR}) - LR_t^{WR} \quad (10)$$

Farmer's payoff in a_{21} is calculated by this following equation

$$\mu_{F21} = S_t^P + S_t^{WR} - RS_t^{WR} - C_t^P \quad (11)$$

WRS Application of Monopolistic Distribution Scheme

In this interaction Farmer will sell his salt to Warehouse in dry season. Some salt that bought from Farmer will be sold by Warehouse to Consumer during the dry season and some of them will be used by Warehouse as the buffer stock to fulfill demand in wet season. WRS facility is used by Warehouse as collateral to get money loan from Bank. This interaction is called monopolistic distribution because Warehouse is the sole party that regulates the distribution of commodities in the market.. These following additional equations below are the elements that formed the performance criterion to calculate payoffs of Farmer and Warehouse in this interaction.

a. Farmer's revenue from selling salt to warehouse
$$TR_t^P = \sum_{t=1}^{6} P_t^{P1} \times Q_t^{WRS} \quad (12)$$
b. Farmer's revenue from selling salt to consumer
$$TR_t^{WC} = \sum_{t=1}^{6} P_t^{S1} \times Q_t^d + \sum_{t=7}^{12} P_t^{S1} \times Q_t^{wro} \quad (13)$$
c. Purchasing cost
$$C_t^{FW} = \sum_{t=1}^{6} P_t^{P1} \times Q_t^{FW} \quad (14)$$

Farmer's payoff in a_{32} is calculated by this following equation

$$\mu_{F32} = TR_t^P - C_t^P \quad (15)$$

Warehouse's payoff in a_{32} is calculated by this following equation

$$\mu_{W32} = TR_t^{WC} - (C_t^{FW} + Ca_t^{WR} - LI_t^{WR}) - LR_t^{WR} - h_t^{WR} \quad (16)$$

Without any WRS Application

In this interaction there won't be any application of WRS because each players choose strategies that not match between each other which shown in a_{12}, a_{22}, a_{31}. Payoff for Warehouse in this interaction will be equal to 0 because there is no involvement of Warehouse in this interaction ($\mu_{W12} = \mu_{W22} = \mu_{W31} = 0$). Payoff for Farmer is calculated from total revenue from selling salt to Consumer during the both seasons without any sales delay and deduced by total of production cost which shown on this following equation.

$$\mu_{F12}, \mu_{F22}, \mu_{F31} = \sum_{t=1}^{12} P_t^{P0} \times Q_t^d - \sum_{t=1}^{6} C_P \times Q_t^P \quad (17)$$

Constraint

$$Q_t^{WRS} = \begin{cases} Q_t^P, t = 1, \dots, 6, dry\ season \\ Q_t^d, t = 7, \dots, 12, wet\ season \end{cases} \quad (18)$$

$$Q_t^S = Q_{t-1}^S - Q_{t-1}^d + Q_t^P, t = 1, \dots, 12 \quad (19)$$

$$P_t^{P0} = a - b \ln Q_t^S \quad (20)$$

$$P_t^{P1} = a - b \ln Q_t^{WRS} \quad (21)$$

$$P_t^{S1} = P_t^{P1} \times (1 + profit) \quad (22)$$

$$Q_t^{WR} = \begin{cases} Q_t^P - Q_t^d, t = 1, \dots, 6, for\ farmer \\ Q_t^{FW} - Q_t^d, t = 1, \dots, 6, for\ warehouse \end{cases} \quad (23)$$

$$Q_t^{wrh} = Q_{t-1}^{wrh} + Q_t^{WR}, t = 1, \dots, 12 \quad (24)$$

$$Q_t^{FW} = Q_t^{WRS}, t = 1, \dots, 6 \quad (25)$$

$$Q_t^{wro} = Q_t^d, t = 7, \dots, 12 \quad (26)$$

Equation (18) is used to determine quantity of supply during dry and wet season when WRS is applied. Equation (19) is used to determine quantity of supply during both seasons when WRS is not applied. Equation (20) is used to predict salt price when WRS is not applied. Equation (21) is used to predict salt price when WRS is applied. Equation (22) is used to calculate selling price of the Warehouse to Consumer. Equation (23) is used to determine the quantity of salt that guaranteed to the WRS by Farmer and Warehouse. Equation (24) is used to calculate the amount of stored salt in warehouse every month. Equation (25) is used to determine the amount of purchased salt by Warehouse from Farmer. Equation (26) is used to determine the amount of WRS-salt that sold by Farmer or Warehouse during wet season.

Table 3. Salt Production and Demand (x1000 ton)

Month	Jan	Feb	Mar	Apr	Mei	Jun
Q_t^P	19	19	19	19	19	19
Q_t^d	8	8	8	8	8	8
Month	Jul	Aug	Sep	Oct	Nov	Des
Q_t^P	0	0	0	0	0	0
Q_t^d	8	8	8	8	8	8

Table 4. Calculation Parameter

a	b	P_F
3601	254.9	950
Ch_{WR}	plafon	C_{WR}
95	70%	0.5%
i_{RG}	C_P	P_S
0.5%	584.11	85%

Then continued the trial of the payoff calculation using hypotetical data and parameters in table 3 and 4. Payoff is calculated separetely for each players and conditions. Result of the payoff calculation for each players is shown in the following table.

Table 5. Payoff Calculation Result (x 1,000,000,000)

Farmer	Warehouse	
	S1	S2
S1	$\mu_{F11} = IDR\ 40.8$ $\mu_{W11} = IDR\ 6.2$	$\mu_{F12} = IDR\ 21.4$ $\mu_{W12} = IDR\ 0$
S2	$\mu_{F21} = IDR\ 42.4$ $\mu_{W21} = IDR\ 6.2$	$\mu_{F22} = IDR\ 21.4$ $\mu_{W22} = IDR\ 0$

S3	$\mu_{F31} = IDR\ 21.4$ $\mu_{W31} = IDR\ 0$	$\mu_{F32} = IDR\ 58$ $\mu_{W32} = IDR\ 11.1$

Constructed game theory model is aimed to calculate and analyze the highest benefit (payoff) of both players from the interaction of the game. The application of controlled wholesaler distribution WRS scheme which is denoted by interactions a_{11} and a_{21} gives IDR 40,8 billions to Farmer if he chooses to get money loan from Bank and IDR 42.4 billions if he chooses not to take money loan from Bank. The application of monopolistic distribution WRS scheme which is denoted by interaction a_{32} gives IDR 58 billions to Farmer. Other interactions which is denoted by interactions a_{12}, a_{22}, and a_{31} gives IDR 21.4 billions to Farmer by means Farmer will get lower benefit if WRS is not applied. Besides that, Warehouse has 3 several options of payoff such as IDR 6.2 billions and IDR 11.1 billions if WRS is applied and IDR 0 billions if WRS is not applied by means Warehouse will get higher benefit if WRS is applied. Then to find the solution of this non-zero sum games type, nash equilibrium will be used to replace the concept of saddle point in zero-sum games [29]. Game iteration will be used to find nash equilibrium (NE) for the solution of the game. First iteration is carried out by Farmer to find which strategy that provides the highest payoff when Warehouse chooses S1.

$$\boldsymbol{\mu_{F21}(IDR\ 42.4)}^* > \mu_{F11}(IDR40.8) > \mu_{F31}(IDR21.4)$$

The second iteration is still carried out by Farmer to find which strategy that provides highest payoff when Warehouse chooses S2.

$$\boldsymbol{\mu_{F32}(IDR\ 58)}^* > \mu_{F12}(IDR21.4) = \mu_{F22}(IDR21.4)$$

The third, fourth and fifth iterations are carried out by Warehouse to find which strategy that provides highest payoff for Warehouse when Farmer chooses S1, S2, & S3.

$$\boldsymbol{\mu_{W11}(IDR\ 6.2)}^* > \mu_{W12}(IDR\ 0)$$
$$\boldsymbol{\mu_{W21}(IDR\ 6.2)}^* > \mu_{W22}(IDR\ 0)$$
$$\boldsymbol{\mu_{W32}(IDR\ 11.1)}^* > \mu_{W31}(IDR\ 0)$$

From the iteration of the game, 2 nash equilibria (NE) are obtained which are indicated by the (*) mark in the payoff value of each players. Nash equilibria (NE) in this game are found in the interaction of WRS application with controlled wholesaler distribution scheme without any collateral loan (a_{21}) and interaction of WRS application with monopolistic distribution scheme (a_{32}).

To obtain a single solution, the game is expanded by using extensive form game and backward induction method. From table 5, Farmer eliminates S1 because it is dominated by S2. From figure 3 analysis starts from bottom (the last player). Warehouse chooses S1 strategy when Farmer chooses S2 strategy, so the interaction goes up. Warehouse chooses S2 strategy when Farmer chooses S3 strategy then the interaction goes up. The final decision is carried out by Farmer to choose between S2 and S3 strategy that provide highest payoff. Result of the game shows that S3 strategy of Farmer and S2 strategy of Warehouse provides highest payoff for each players. It can be concluded that WRS application of monopolistic distribution scheme which is denoted by interaction a_{32} is sensible for the solution of the game

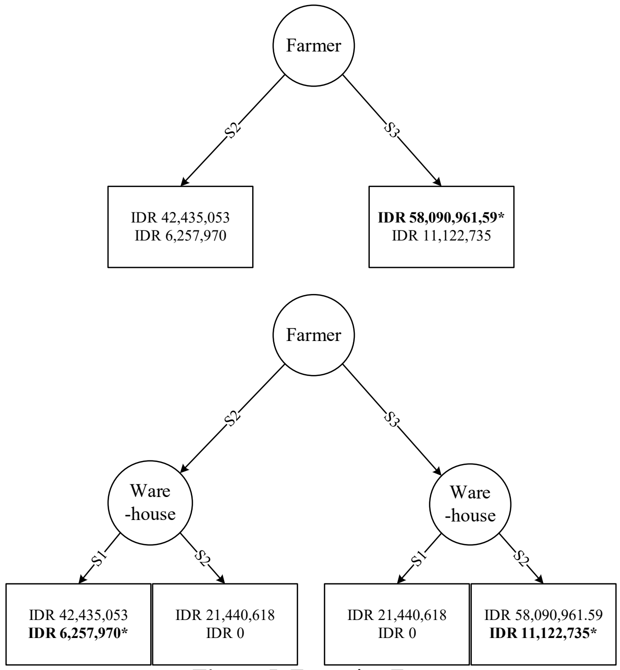

Figure 5. Extensive Form

Based on the numerical examples, it can be concluded that monopolistic distribution of the WRS scheme gives more benefits with a bigger payoff for both farmers and warehouses compared with a controlled wholesaler. This model also can be compared with the previous model of Wardayanti et al (2017) [32]. which proposed a game theory model for stabilizing the price of chili. In the case of chili, the model is more suitable for addressing the location-allocation problem to stabilize prices because the commodities cannot be stored for more than 3 months. Thus, the warehouse receipts system cannot be applied to support stabilization. Meanwhile, A Game Theory Model of Salt Price Stabilization can be used to support a decision of the times in warehouses to increase selling prices by utilizing the WRS mechanism.

4. Conclusion

Game theory is able to describe the interaction between Farmer and Warehouse in the application of the warehouse receipt system in maintaining stability and increasing the selling price of salt commodities. The average price of salt when the WRS is not applied is IDR 884.95 during the dry season and IDR 886.73 during the wet season. Meanwhile, when the WRS is implemented, it gives a higher price of

IDR 1,085.60 during the dry season and IDR 1,298.27 during the wet season. The result of the game shows two nash equilibria (NE) namely the WRS application of controlled wholesaler distribution scheme without capital loans (interaction a_{21}) and WRS application of monopolistic distribution scheme (interaction a_{32}). The single solution is obtained by expanding the game using extensive form games which shows that WRS application of monopolistic distribution scheme (interaction a_{32}) provides greater profit for Farmer by profit value of IDR 58,090,962,000 and Warehouse of IDR 11,122,735,000. The result shows that the proposed model can be applied to solve the distribution problem and can give a more promising outcome than its counterpart. Based on numerical examples, it can be concluded that monopolistic distribution of WRS scheme gives more benefit with the bigger payoff for both farmer and warehouse comparing with a controlled wholesaler.

In the real system of salt distribution, there is much uncertainty such as deterioration of the salt during storage, number of salt imported by National, probability of weather, and some others. Those limitations have not been discussed in this model and could be an interesting topic to discuss in future research. The optimization concept can be used to analyze the optimal decision, for instance, the optimal number of salt that must be kept by farmers in WRS in order to maximize their benefit. Due to this research using hypothetical data, it would be better for future research to use more empirical data and less assumption. Furthermore, adding other entities is suggested for future research in order to obtain a broader picture of the system.

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References

1) Z. Salim, and E. Munadi, “Info Komoditi Garam,” 2016.
2) Y.A. Hidayat, and N. Suroija, “Analisis Pengendalian Persediaan Industri Penglahan Garam,” in: Pros. SENTRINOV, 2015: pp. 483–502.
3) Suryati, W. Sutopo, and M. Hisjam, “Optimization Model Supply Chain Network Design Determine Location-Alocation The Terminal Cathode Factory,” in: Proc. Int. Conf. Eng. Inf. Technol. Sustain. Ind., 2020: p. (1-6).
4) D.A. Susanto, "Implementation of Standards in International Trade: Benefit or Barrier? A Case Study from Indonesia," *Evergreen*, **09** (03) 619-628 (2022) doi:10.5109/4842518.
5) E. Jubaedah, and A.H. Budiman, “Kajian roadmap pengembangan energy storage untuk smart grid system,” *Pus. Teknol. Konversi Dan Konserv. Energi BPPT*, (2013).
6) S.I. Park, S. Okada, and J.I. Yamaki, "Symmetric Cell with LiMn_2O_4 for Aqueous Lithium-ion Battery," *Evergreen*, **3** 27–31 (2011).
7) Suryati, W. Sutopo, and M. Hisjam, “Technopreneurship & Innovation System : Comparative Analysis of Technology Development of Salt Derivative Products in Indonesia,” in: Proc. Int. Conf. Eng. Inf. Technol. Sustain. Ind., 2020: p. (1-6).
8) A. Habibie, M. Hisjam, W. Sutopo, and M. Nizam "Sustainability evaluation of internal combustion engine motorcycle to electric motorcycle conversion," *Evergreen*, **08** (02) 469-476 (2021) doi:10.5109/4480731
9) Gheidan, A. A., Wahid, M. B. A., Chukwunonso, O. A., & Yasin, M. F. (2022). Impact of Internal Combustion Engine on Energy Supplyand its Emission Reduction via Sustainable Fuel Source," *Evergreen*, **09** (03) 830-844 (2022) doi: 10.5109/4843114.
10) M.K. Barai and B.B. Saha, "Energy Security and Sustainability in Japan", Evergreen (02) 49-56 (2015) doi: 10.5109/1500427.
11) T. Sato, "How is a Sustainable Society Established? A Case Study of Cities in Japan and Germany", Evergreen 03(02) 25-35 (2016) doi:10.5109/1800869.
12) T. Tsubota, A. Kitajou, and S. Okada, “O3-type na(fe1/3mn1/3co1/3)o2 as a cathode material with high rate and good charge-discharge cycle performance for sodium-ion batteries,” *Evergreen*, **6** (*4*) 275–279 (2019). doi:10.5109/2547348.
13) B. Xie, A. Kitajou, S. Okada, W. Kobayashi, M. Okada, and T. Takahara, “Cathode properties of na3mpo4co3 (m = co/ni) prepared by a hydrothermal method for na-ion batteries,” *Evergreen*, **6** (*4*) 262–266 (2019). doi:10.5109/2547345.
14) K. Chihara, M. Ito, A. Kitajou, and S. Okada, “Cathode property of na _ 2c _ x0 _ x [x = 4 , 5 , and 6] and k _ 2c _ 60 _ 6 for sodium-ion batteries,” *Evergreen*, **4** (*1*) 1–5 (2017).
15) Suryati, “Integrasi Model Supply Chain Network Design dan Opsi Simpan Resi Gudang Komoditas Garam Untuk Evaluasi Kelayakan Pendirian Pabrik Bahan Katoda,” Universitas Sebalas Maret, 2021.
16) Fauziyah, and Ihsannudin, “Pengembangan kelembagaan pemasaran garam rakyat (studi kasus di desa lembung, kecamatan galis, kabupaten pamekasan),” *J. Sos. Ekon. Pertan.*, **7** (*1*) 52–59 (2014).
17) N. Ashari, “Potensi dan kendala sistem resi gudang (srg) untuk mendukung pembiayaan usaha pertanian di indonesia,” *Forum Penelit. Agro Ekon.*, **29** (*2*) 129–143 (2011). doi:10.21082/fae.v29n2.2011.129-143.

18) E. Gunawan, J.K.M. Kuwornu, A. Datta, and L.T. Nguyen, “Factors influencing farmers’ use of the warehouse receipt system in indonesia,” *Agric. Financ. Rev.*, **79** (*4*) 537–563 (2019). doi:10.1108/AFR-11-2018-0099.
19) W. Sutopo, S. Nur Bahagia, A. Cakravista, and T. Arisamadhi, “A Buffer Stocks Model for Stabilizing Price of Commodity under Limited Time of Supply and Continuous Consumption,” in: Proc. 9th Asia Pasific Ind. Eng. Manag. Syst. Conf., 2008: pp. 321–329.
20) G. Athanasiou, I. Karafyllis, and S. Kotsios, “Price stabilization using buffer stocks,” *J. Econ. Dyn. Control*, **32** (*4*) 1212–1235 (2008). doi:10.1016/j.jedc.2007.05.004.
21) P.A. Dorosh, S. Dradri, and S. Haggblade, “Regional trade, government policy and food security: recent evidence from zambia,” *Food Policy*, **34** (*4*) 350–366 (2009). doi:10.1016/j.foodpol.2009.02.001.
22) S. Jha, and P. V. Srinivasan, “Food inventory policies under liberalized trade,” *Int. J. Prod. Econ.*, **71** (*1–3*) 21–29 (2001). doi:10.1016/S0925-5273(00)00104-3.
23) K. Ayenagbo, J.N. Kimatu, Z. Jing, S. Nountenin, and W. Rongcheng, “Analysis of the importance of general agreement on tariffs and trade (gatt) and its contribution to international trade,” *J. Econ. Int. Financ.*, **3** (*1*) 13–28 (2011).
24) W. Sutopo, S.N. Bahagia, A. Cakravastia, and T.M.A. Arisamadhi, “A buffer stock model to ensure price stabilization and availability of seasonal staple food by empowering producer using warehouse receipt system,” *Proc. IEEE IEEM*, (*2*) 298–302 (2011). doi:10.5614/itbj.eng.sci.2012.44.2.3.
25) W. Sutopo, S.N. Bahagia, A. Cakravastia, and T.M.A. Arisamadhi, “A buffer stock model to ensure price stabilization and availability of seasonal staple food under free trade considerations,” *ITB J. Eng. Sci.*, **44 B** (*2*) 128–147 (2012). doi:10.5614/itbj.eng.sci.2012.44.2.3.
26) W. Sutopo, S.N. Bahagia, A. Cakravastia, and T.M.A.A. Samadhi, “An indirect market intervention instrument to control price and availability of seasonal staple food using buffer stock and warehouse receipt,” *Int. J. Eng. Technol.*, **12** (*05*) 75–82 (2012).
27) M. Widiyani, “Analisis Program Sistem Resi Gudang di Kabupaten Indramayu,” Institut Pertanian Bogor, 2014.
28) A. Septiani, “Model Persediaan Penyangga Komoditi Gula Pasir dengan Menggunakan Instrumen Resi Gudang yang Mempertimbangkan Deteriorasi Produk,” Institut Teknologi Bandung, 2011.
29) R. Widiyanti, “Pengembangan Model Perhitungan Manfaat Finansial Sistem Resi Gudang Untuk Komoditas Bawang Merah,” Institut Teknologi Bandung, 2013.
30) M. Jenar, W. Sutopo, and Yuniaristanto, “Pengembangan model game theory pada skema persediaan penyangga untuk menjamin ketersediaan dan kestabilan harga komoditas gula pasir,” *J. Tek. Ind.*, **X** (*2*) 97–102 (2015).
31) D.E.P. Wicaksana, M. Hisjam, Yuniaristanto, and W. Sutopo, “Model of price stabilization in staple food distribution using game theory: comparative study,” *Lect. Notes Eng. Comput. Sci.*, **2** (*October 2016*) 824–828 (2015).
32) A. Wardayanti, A.S. Aviv, W. Sutopo, and M. Hisjam, “A game theory model for stabilizing price of chili: a case study,” *AIP Conf. Proc.*, **1902** (2017). doi:10.1063/1.5010635.
33) B.Z. Orbay, and L. Sevgi, “Game theory and engineering applications,” *IEEE Antennas Propag. Mag.*, **56** (*3*) 255–267 (2014). doi:10.1109/MAP.2014.6867726.
34) M.D.A. Habib, K.M.A. Kabir, and J. Tanimoto, “‘Do humans play according to the game theory when facing the social dilemma situation?’ a survey study,” *Evergreen*, **7** (*1*) 7–14 (2020). doi:10.5109/2740936.
35) S.M. LaValle, “Planning Algorithms,” 2006. doi:10.1017/CBO9780511546877.