

OPTIMAL PRICING USING A GAME THEORY APPROACH

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Abstract. Micro, small and medium enterprises (MSMEs) play an important role in supporting economic growth in developing countries, including Indonesia. However, MSMEs face various challenges such as limited institutional capacity and human resources, slow adoption of technology, and difficulties in marketing. This study focuses on the traditional food and beverage market in Mojokerto, where there is a significant profit gap between suppliers and retailers. This condition indicates inefficiency and suboptimal profit distribution, which requires a pricing mechanism that is able to consider changes in strategy from other market players. This research combines Monte Carlo simulation and Game Theory approaches. Monte Carlo simulation is intended to accommodate demand uncertainty and simulate the system in the future while Game Theory is used to analyze and optimize the strategy of each player to obtain an equilibrium point. From this research, results are obtained for two game schemes: non-cooperative and cooperative. In the non-cooperative game, the optimal strategy for each player is that both use the high strategy which results in a total profit of Rp. 103,972,500 for the supplier and Rp. 77,735,250 for the retailer. For cooperative games, the optimal strategy for suppliers is a high strategy and a low strategy for retailers, resulting in an accumulated profit of Rp. 189,354,000.

Keywords: Micro, small and medium enterprises (MSMEs), Price, Monte Carlo, Game Theory

I. INTRODUCTION

Small and medium enterprises (SMEs) play an important role in supporting economic growth in developing countries, including Indonesia (Hizam et al., 2024). Their large number contributes significantly to job creation. According to the Coordinating Ministry for Economic Affairs of the Republic of Indonesia (Press Release HM.4.6/27/SET.M.EKON.3/01/2025), SMEs contribute more than 60% to the national Gross Domestic Product (GDP) and absorb 97% of the workforce, with around 64 million business units currently operating in Indonesia.

Despite their crucial role, SMEs face various challenges both internally and externally. Internal barriers include limited institutional and human resource capacity, slow adoption of technology, and difficulties in marketing. Externally, SMEs face high production and distribution costs and inefficient bureaucratic processes (Budhi et al., 2020). These limitations often lead to strategic mistakes, especially in determining the right selling price. Limited resources and a lack of understanding of competitive strategies make pricing decisions tend to be conventional and less effective.

Pricing strategy has long been recognized as a key determinant of firm performance. Avlonitis and Andounas (2005) emphasize that price directly affects revenue, while Farm (2020)

explains that both individual prices and market prices can change depending on pricing methods and cost fluctuations. Sarjono (2014) also states that retailers should consider customer satisfaction in setting prices to remain competitive. Therefore, the selection of the right pricing strategy becomes very important for SMEs to improve competitiveness and achieve long-term sustainability (Abidin et al., 2023). While previous studies have addressed SMEs' pricing strategies or issues separately, there is limited research that integrates demand uncertainty, pricing decisions, and strategic interactions between suppliers and retailers.

This research focuses on the traditional food and beverage market in Mojokerto, where there is a significant profit gap between suppliers and retailers, as shown in Figure 1. This gap occurs because suppliers apply higher profit margins to compensate for the risks they bear, especially the risk of loss due to unsold products at the retailer level. However, the current pricing interactions between suppliers and retailers suggest inefficiencies and a suboptimal distribution of potential profits, which calls for a pricing mechanism that takes into account changes in other players' strategies.



Figure 1. MSMEs' Profit

Based on historical data, Monte Carlo simulation was used to predict future demand under various strategy scenarios. The total profit generated from each cross-strategy combination is then analyzed using game theory to determine the equilibrium pricing strategy for each player. The uncertainty of demand in traditional food markets makes static pricing less effective; therefore, the combination of simulation-based forecasting and game theory-based optimization offers a more realistic decision-making framework. This research contributes a pricing model that considers demand uncertainty and strategic dependencies, and offers a practical decision-making tool for MSMEs.

II. LITERATURE REVIEW

A. Pricing Strategy

Price is an important element in business that aims to determine value for the company while generating revenue (Taylor et al., 2019). Price can also be defined as the amount of costs that must be incurred by customers to obtain a product offering (Al Badi, 2018). Price has a significant influence because it is directly related to consumer responses in making purchases. Avlonitis and Indounas (2005) explain that pricing approaches can generally be classified into three main groups, namely:

1. Cost-based approach, which is pricing by adding a markup to production costs. This approach includes techniques such as target return pricing, break-even analysis, contribution analysis, and marginal pricing.
2. Competition-based approach, which is pricing with reference to competitors' price levels, either by matching market prices, setting prices above or below competitors, or following market leader prices.
3. Demand-based approach, which focuses on the customer side, where prices are set based on perceived value, overall value offered, or specific customer needs.

In pricing at both the supplier and retailer level, pricing decisions refer to Equations (1) and (2). For a given product, the supplier purchases the product at a production cost of c and sells it to the retailer at the wholesale price w . Next, the retailer sets the selling price to consumers at p , where D represents market demand. The symbols π_s and π_r represent the profit earned by the supplier and retailer, respectively (Zhong et al., 2020).

$$\begin{aligned}\pi_s(w) &= (w - c)D(p) \\ \pi_r(w, p) &= (p - w)D(p)\end{aligned}$$

B. Game Theory

Game theory is a branch of mathematics developed to build mathematical models. This theory is used as a decision-making tool in situations involving two or more decision makers (players) to determine the optimal strategy (Shirazi, 2019). Zhang et al., as cited in Shirazi (2019), also stated that game theory is a very useful approach to analyze interactions between many decision makers. The main challenge in its application is how to achieve real-time data-driven optimization at the operational level to obtain the desired energy efficiency and production performance.

The central concept in game theory is Nash equilibrium. In recent years, game theory models have been increasingly combined with other theories to analyze problems related to regional equilibrium stability (Xia et al., 2021).

In game theory, there are two general game schemes: cooperative and non-cooperative. Cooperative games are arguably best understood as strategic games in which players can sign binding agreements at no cost to form coalitions aimed at maximizing their collective outcomes. Non-cooperative games, most simply represented by normal-form games, consist of a set of players, each having a number of strategies and an outcome function, where the outcome is determined by the strategy chosen by each player (Chan, 2025). In cooperative game models, the development of solutions is based on the maximization of total profit (Hamidi et al., 2016).

C. Monte Carlo Simulation

Before discussing Monte Carlo simulation, it is important to first understand the concept of simulation itself. Simulation is widely recognized as an invaluable method in management science for analyzing complex systems (Winston, 2003). However, since real-world systems often involve high complexity, stochastic relationships, and various practical limitations, not all phenomena can be adequately represented through traditional mathematical models. Therefore, simulation becomes an important alternative approach in modeling and analyzing such systems.

Monte Carlo simulation is a mathematical technique used to estimate the probability of an outcome based on a set of randomly generated data (Talwariya et al., 2019). This method is

considered superior to many other mathematical modeling approaches because it is able to provide an overview of the future performance of the system (Ross et al., 2022). Through Monte Carlo simulation, the behavior of systems that face limitations of experiments or interventions in the real world can be represented more accurately.

III. RESEARCH METHODOLOGY

A. Stages of Monte Carlo Simulation

This study aims to determine the optimal price between retailers and suppliers in the traditional food and beverage market in Mojokerto. This research uses a game theory approach through a cross combination of strategies from both players. The output generated from each strategy combination is the profit value, which is obtained through simulation of each strategy condition based on changes in demand due to price changes. Monte Carlo simulation is used to estimate demand based on historical data. The simulation results will later be adjusted related to strategy changes. Based on existing conditions, both retailers and suppliers set pricing strategies as shown in Table 1.

Table 1. Current Price Condition

Supplier		Retailer	
Cost (c)	IDR 1300	Product price at retailer (P_r)	IDR 2500
Product price at supplier (P_s)	Rp. 2300	Product price at supplier (P_s)	Rp. 2300
Fix cost/day (f)	IDR 150000	Retailer's profit/product (π_{rs})	IDR 200
Supplier's profit/product (π_s)	IDR 1000		

Based on the data in Table 1, the profit functions for suppliers and retailers are formulated as follows:

$$\begin{aligned}\pi_s &= P_s Q_{rs} - c Q_s - f \\ \pi_s &= (P_r - P_s) Q_{rs}\end{aligned}$$

Where π_s is the supplier's profit and π_{rs} is the retailer's profit related to the supplier-retailer relationship. The variables $P_{(s)}$ (price at the supplier) is greater than c (production cost), and $Q_{(rs)}$ (quantity of product sold in the supplier-retailer relationship) is less than or equal to $Q_{(s)}$ (quantity supplied by the supplier), which is the supplier's profit constraint. Meanwhile, for the retailer, the condition $P_{(r)}$ (retailer selling price) is greater than $P_{(s)}$ (supplier buying price). In the context of this research, Monte Carlo simulation is used to simulate the amount of supply and sales over a certain period. The Monte Carlo method is used as a tool to generate new data sets based on historical data obtained from real systems. The simulated data is then used to analyze various research scenarios, particularly focusing on price changes at the supplier, distributor, and retailer levels.

The product sales data that has been collected is then used in the Monte Carlo simulation procedure. The simulation process begins with determining the frequency of data and the probability of occurrence of each data. This simulation aims to illustrate product sales at the retailer level in the supplier-retailer relationship.

Based on the data, the cumulative probability distribution for each data group is calculated. This probability distribution is then used as a reference to determine the simulation results

based on historical sales data at each unit of time. This simulation process is shown in Figure 2.

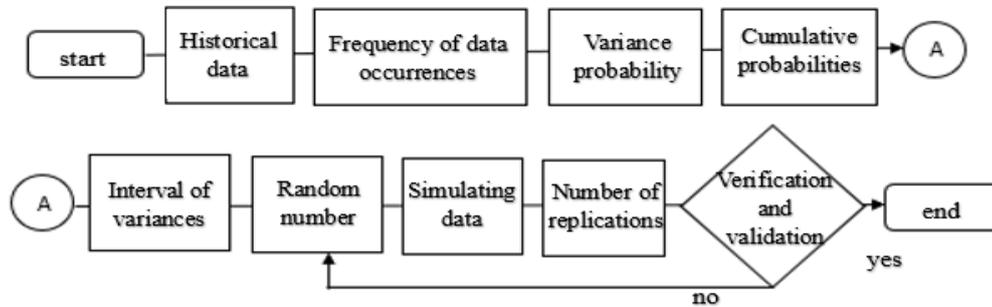


Figure 2. Stages of Monte Carlo Simulation

B. Determination of the Number of Replications, Simulation Scenario, and Payoff Matrix

The determination of the minimum number of replications of the simulation model is obtained from the half-width calculation. The simulation model is then validated using a paired sample t-test on the number of products supplied and sold between the existing conditions and the simulation results. Several scenarios are simulated by changing certain parameters and compiled into a payoff matrix as a combination of cross strategies from each player. In the existing situation, it is assumed that suppliers use the mid strategy and retailers use the low strategy, which is in accordance with the results of data collection in table 1. Regarding changes in demand due to changes in strategy, it is assumed that changes in quality (k) and price (b) factors are assumed to have a 5% and 10% change in demand at the retailer level (Q'_{rs}), respectively. The list of strategies and parameter changes in the payoff matrix is presented in Table 2.

Table 2. Supplier and Retailer Price Strategy Matrix

Player	Retailer	
	Low	High
Supplier	Low	High
	Mid	High
	High	High

C. Monte Carlo Simulation for Supply and Demand Data Generation

In the Monte Carlo simulation process, it is necessary to generate random numbers. The random numbers are used as the basis for determining simulation data based on historical data. The generated random values are then matched with probability intervals that have been calculated cumulatively. Random number generation is used to determine the amount of

supply and demand for the simulated state. Tables 3 and 4 show the probability of frequency of occurrence of data and generated data for simulation, respectively.

Table 3. Cumulative Probability of Occurrence of Supply Data

Variant Quantity (Supply)	Frequency	Frequency Probability	Cumulative Frequency	Interval From	Interval To
0	5	0.054	0.054	0	0.054
400	2	0.022	0.076	0.054	0.076
500	1	0.011	0.087	0.076	0.087
600	62	0.674	0.761	0.087	0.761
650	4	0.043	0.804	0.761	0.804
675	2	0.022	0.826	0.804	0.826
700	8	0.087	0.913	0.826	0.913
750	3	0.033	0.946	0.913	0.946
770	1	0.011	0.957	0.946	0.957
800	3	0.033	0.989	0.957	0.989
875	1	0.011	1.000	0.989	1.000

Table 4. Generate New Supply and Demand Data

Jan-26						
Date	Random Generator	Supply	Sold	Validation (Q<A)	Supplier Revenue	Retailer Revenue
1 - Jan	0.353492	600	557	TRUE	351100	111400
2	0.63934	600	578	TRUE	399400	115600
3	0.668839	600	586	TRUE	417800	117200
4	0.391706	600	562	TRUE	362600	112400
5	0.358824	600	558	TRUE	353400	111600
6	0.229119	600	541	TRUE	314300	108200
...						
...						
...						
31- Dec	0.22131	600	541	TRUE	314300	108200

D. Evaluation of the Number of Simulation Replications with the Half-Width Method

To determine the adequate number of replications in a simulation, half width, expected half width, and n' values for each simulation parameter were calculated. The initial number of replications was set at 5 replications. Based on Table 5, it is known that the parameters used to determine the number of simulation replications show that the 5 replications performed are sufficient and representative to simulate the existing situation. This is shown in the condition of $hw' > hw$ and $n > n'$.

Table 5. Calculation of Halfwidth and N'

Parameter	St. deviation	hw	hw'	hw<hw'	n	n'	n' < n	Description
Supplier profit	1827765.17	2269470	6050350	TRUE	5	1	TRUE	Enough replication
Retailer profit	553837.9077	687680.6	1895322	TRUE	5	1	TRUE	Enough replication
Total Supply	3037.526955	3771.588	10225.38	TRUE	5	1	TRUE	Enough replication
Number sold	2769.189538	3438.403	9476.61	TRUE	5	1	TRUE	Enough replication

E. Simulation Model Validation with Black Box Approach

Model validation is carried out with a Black Box approach, which compares simulation output with real system data (Siswanto et al., 2018). In this study, validation was carried out by comparing the number of products supplied by suppliers and distributors, as well as the number of products sold at the retailer level in the period January to March, with actual data. The validation process uses the Paired Sample Test to determine whether there is a significant difference between the real system and the simulation results at each replication.

F. Paired Sample Test and Model Validation Results

The validation test is based on the following criteria:

H0 : $\mu_e = \mu_{\text{simulation}}$

$\alpha = 0.05$

H1: $\mu_e \neq \mu_{\text{simulation}}$

t-table = 3.1824463

H0 is accepted when the t-count value is within the range between the upper and lower t-values. From the table, it can be seen that there is no significant difference between the real system and the results obtained from the simulation.

Table 6. Validation of

Parameter Validation	F-count	F-table	Description
Supply Quantity	0.491482455	2.23052503	H0, accepted
Sold Amount	0.47304328	2.23052503	H0, accepted

IV. RESULT AND DISCUSSION

Based on historical data, a Monte Carlo simulation is carried out to generate demand and supply data for the next one-year period. The simulation results are then validated which is intended to test whether the simulated data and existing data are significantly different or not using the paired sample t test. The results of the simulation of existing conditions (suppliers and retailers, each using the mid and low strategies) that have been validated can be seen in Table 7.

Table 7. Existing State Simulation Results

Month	Profit		Number of Products sold at Retailer	
	Supplier	Retailer	Supply	Sold
January	IDR 11,105,200.00	IDR3,508,800.00	18920	17544
February	Rp9,668,300.00	Rp3,089,200.00	16775	15446
March	Rp10,855,600.00	Rp3,373,400.00	18145	16867
April	IDR10,504,900.00	IDR3,331,600.00	18045	16658
May	Rp11,699,600.00	Rp3,594,400.00	19220	17972
June	Rp9,781,700.00	Rp3,040,800.00	16375	15204
July	Rp11,347,200.00	Rp3,490,800.00	18690	17454
August	Rp11,004,300.00	Rp3,428,200.00	18400	17141
September	Rp11,058,100.00	Rp3,433,400.00	18520	17167
October	Rp10,618,800.00	Rp3,386,200.00	18325	16931
November	Rp11,145,800.00	Rp3,464,200.00	18725	17321
December	Rp11,108,700.00	Rp3,467,800.00	18670	17339
Total	Rp129,898,200.00	Rp40,608,800.00	218810	203044

The existing condition simulation results become the base model for strategy changes made by each player. Changes in profits based on changes in demand, the results of accumulated profits for each strategy are presented in Table 8.

Table 8. Profit Calculation Results for each Strategy

No	Supplier Strategy	Retailer Strategy	Payoff P1	Payoff P2
1	Low	Low	Rp107,201,900.00	Rp42,440,600.00
2	Mld	Low	Rp129,898,200.00	Rp40,608,800.00
3	High	Low	IDR150,738,400.00	Rp38,615,600.00
4	Low	High	Rp63,214,400.00	Rp86,885,100.00
5	Mld	High	Rp83,601,500.00	Rp82,311,750.00
6	High	High	Rp103,972,500.00	Rp77,735,250.00

In this study, the determination of the optimum strategy of each player uses the help of Gambit software to determine the nash equilibrium. The optimum strategy is determined using non-cooperative and cooperative games. Non-cooperative and cooperative games will be conducted.

Determination of the first optimum strategy using non-cooperative game. The results of calculations using non-cooperative games using Gambit assistance on the supplier-retailer game scheme can be seen in Figure 3. From the figure it is found that the dominant strategy is when the supplier uses the high strategy and the retailer uses the high strategy. This strategy is also a strategy that shows an equilibrium condition which is shown in the probability of suppliers and retailers each choosing a high strategy is 1 (100%) as in Figure 4. As for the non-cooperative game, the pay-off profits obtained by suppliers and retailers are Rp. 103,972,500.00 and Rp. 77,735,250.00, respectively.

 Supplier Payoff: 103972500.0000  Retailer Payoff: 77735250.0000		Low		High	
	Low	107284500	4744800	63244000	86885100
	Mid	129898200	40888800	83884500	82311750
	High	150738400	38845800	103972500	77735250

Figure 3. Data Processing using Gambit

#	1: Low	1: Mid	1: High	2: Low	2: High
1	0.0000	0.0000	1.0000	0.0000	1.0000

Figure 4. Probability of Strategies Chosen by each Player

When using cooperative games, the pay-off value obtained is based on the accumulated profits of suppliers and retailers. The pay-off value of the cooperative game can be seen in Table 9. Based on the cooperative game, the optimal pay-off value (the largest accumulated profit) occurs if the supplier chooses a high strategy while the retailer chooses a low strategy which results in an accumulated profit of Rp. 189,354,000.

Table 9 cooperative game results

Player and Strategy		Retailer	
		Low	High
Supplier	Low	Rp149,642,500.00	Rp150,099,500.00
	Mid	Rp170,507,000.00	Rp165,913,250.00
	High	Rp189,354,000.00	Rp181,707,750.00

From the two game schemes, non-cooperative and cooperative, it is known that there are different strategies to be chosen. For suppliers, the high strategy can be done for both cooperative and non-cooperative game schemes. As for retailers, they still need to adjust to the game scheme where when the scheme is non-cooperative, the optimal strategy is to use a high strategy while for a cooperative scheme, the optimal strategy is a low strategy.

Non-cooperative games occur when players focus on their respective pay-off values. This happens because players aim to get the most profitable strategy for each of them. In contrast to non-cooperative games, cooperative games focus on the total accumulated profit obtained by both, where one of the players must accept the highest accumulated profit result even though one of them has a non-optimal pay-off profit.

V. CONCLUSION

This study aimed to determine the equilibrium price for retailer-supplier in Traditional Food MSMEs in Mojokerto. The equilibrium pricing in this study is based on two game schemes: non-cooperative and cooperative. In the cooperative game, the optimal strategy for each player is that both use the high strategy. The production cost per product at the supplier is Rp. 1,100 which when sold to retailers costs Rp. 2,300, so the profit earned by the supplier is Rp. 1,200 per product. For retailers, the cost of buying products from suppliers is Rp. 2,300 which when sold to customers costs Rp. 2,750, so the profit earned by retailers is Rp. 450 per product.

This game will generate a total profit in one year of Rp. 103,972,500 for suppliers and Rp. 77,735,250 for retailers.

For the cooperative game scheme, the optimal strategy for the supplier is the high strategy. Meanwhile, the optimal strategy for the retailer is the low strategy. Retailers buy products from suppliers at a price of Rp. 2,300 and sell them at a price of Rp. 2,500, so the profit per product is Rp. 200. From this combination of strategies, the highest accumulated profit when compared to other strategies is Rp. 189,354,000.

Suppliers, both in cooperative and non-cooperative schemes, get optimal profits when using the high strategy. For retailers, when the non-cooperative scheme applies, the optimal profit is obtained when using the high strategy. Meanwhile, when the cooperative scheme applies, the optimal strategy for retailers is the low strategy.

This research discusses the pricing point of view by considering the pricing strategies of other players. However, this study only involves two players. For further research, it can include several players in one supply chain system, which is more representative of the real system situation.

ACKNOWLEDGEMENT

The author would like to express gratitude to all the people who have helped in the completion of this study.

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