EFFECT OF THE PRIVATE BRAND ON THE GAME MODEL OF FOOD SUPPLY CHAIN

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ABSTRACT

The reduction of food loss and decision regarding whether to adopt private brand (PB) are critical issues for food supply chain (SC) management. In this study, the effect of PB introduction to the food SC was examined. Initially, the stakeholders' decision-making in the food SC was modeled as a game with manufacturers and supermarkets considered as game players. The Japanese milk SC was considered as a case study. Next, using the proposed method, the equilibrium states of the game were efficiently searched and compared for cases with and without PB introduction. In our experiments, the total profit of the food SC increased, total amount of waste decreased, and consumer utility increased by introducing PB.

1   INTRODUCTION

Food loss and waste is a global issue mentioned in the Sustainable Development Goals. Managing food loss and waste generated in the food SC is important for sustainability. Additionally, more manufacturers and retailers in the food SC have started to adopt PB. The decision regarding whether to adopt PB and how to manage PB is also a critical issue for SC management. PB management has been studied by theoretical and empirical approaches and is of immense significance (Wu et al. 2021).

One method to evaluate a rule imposed on a social system, such as the PB contract between companies, is to model the target system as a game model and derive the equilibrium of the game under the rules. For this purpose, applying existing methods is often difficult in terms of the calculation time as payoff calculations require simulations. In this study, the equilibrium states with and without PB introduction were derived from our previously proposed effective equilibrium search method (Morita et al. 2022), and effects on the stakeholders' profit and amount of waste in the food SC were examined.

2   GAME MODEL OF FOOD SUPPLY CHAIN

We modified the Japanese milk supply chain management game (Sato et al. 2018) into a simulation model

and defined a game on the model. In the simulation model, dairy farmers produce raw milk, manufacturers process raw milk and package it into milk cartons, and supermarkets sell milk cartons to several consumers. The transaction of raw milk between farmers and manufacturers and that of milk cartons between manufacturers and supermarkets are modeled as double auctions. The purchasing behavior of consumers is expressed by a logit choice model based on consumer utility. The utility increases when the selling price is low or the carton is fresh. The manufacturers and supermarkets have to discard cartons according to the delivery and sales deadlines, respectively.

In the game model without PB introduction, the game players are three manufacturers and three supermarkets. The manufacturers' decisions in the game are the target stock amount of cartons and bid price for cartons. The supermarkets' decisions are the extra stock amount of cartons (buffer), bid price for cartons, and selling price offered to consumers. For the game model with PB introduction, we build three PB players by creating one-to-one pairs of manufactures and supermarkets, thereby eliminating the auction of cartons. The manufacturers in the PB contract ship all the cartons they stock to the paired supermarkets. The PB players' decisions are the extra stock amount of cartons and selling price offered to consumers.

For both models with and without PB introduction, the set of decisions is a pure strategy of the player. The payoff is the player's money after playing 30 days using the fixed strategy. The actions of farmers and consumers are given, although they vary slightly on a daily basis depending on the random number.

3   RESULT AND DISCUSSION

Figure 1 shows the average results of 100 games for the models with and without PB introduction. In each game, the strategies of all players were sampled from the probability distribution in the obtained equilibrium. For the model without PB introduction, the total profit and total amount of waste of players are shown. As can be observed from Figure 1(a) and 1(b), the PB players had higher profit and less waste amount than the total profit and waste amount in the model without PB introduction. It is assumed that the PB players could suppress the waste amount as they make decisions based on the sold amount to consumers, whereas the manufacturers make decisions based on their target stock amount of cartons. Moreover, the PB player selected the strategy that lowers the selling price, and thus, the consumer utility was higher with PB introduction as shown in Figure 1(c). As a result of the higher utility, a higher amount was sold to consumers. The high sales and low wastage resulted in PB players′ high profit despite the low selling price.

For practical use, we need a utility model reflecting consumers' realistic preferences and a case study where part of players in the food SC make PB contracts.
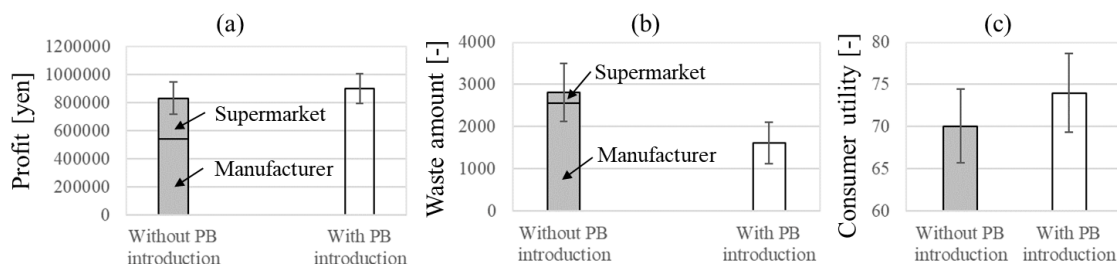

Figure 1: The average profit, waste amount, and consumer utility.

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