Price Elasticity of Demand Based on Shelf Time and its Application for Fresh Agricultural Products

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Abstract: Fresh agricultural products, i.e., fruits and vegetables, originate in nature and therefore the value (price) of each product differs. For such non-uniform products, traditional price elasticity based on the sales amount does not indicate tendencies in demand. In this paper, we focus on shelf time defined as the period between shelf arrival and departure. We propose an elasticity of demand based on shelf time as an alternative indicator of demand. The elasticity is represented in terms of the relationship between price and shelf time, and is expected to be a positive value because shelf time increases as price increases. To clarify the relationship, we extend an information system for an existing farmers' market to record times of both arrival and sales. One-year practical operation at the market, we collect and analyze data on shelf time. We show the relationship between shelf time and price for several products and discuss the existence of the elasticity. Conditions needed to clarify the elasticity are also discussed in relation to farmers' markets.

Key words: demand curve, shelf time, fresh agricultural products, decision support system

1 INTRODUCTION

Fresh agricultural products such as fruits and vegetables originate in nature. Consequently, they have unique characteristics: size, weight, color, taste, state of surface and production area. No two products have identical characteristics. This property constitutes an important difference between fresh agricultural products and industrial products that are manufactured repeatedly according to certain specifications and plans. Therefore, the value and price of agricultural produce also differ, even for products of identical variety and weight. In fact, consumers select suitable fruits or vegetables for their own purposes according to the flavoring or style of cooking. The same is true even if the product is packaged or boxed.

The price elasticity of demand is obtained from the quantity demanded at every price. However, it is impossible to define the elasticity for fresh agricultural products because of the various properties mentioned above. Furthermore, similar properties may also be relevant in the case of industrial products. For example, so-called mass-customized products have their own custom parts and the combinations of parts are often rare. Products that are produced using returned or recycled parts collected via green logistics systems may differ in durability and performance.

In Hanzawa et al. [1] we proposed and implemented a sales and inventory management information system for fresh agricultural product at a farmers' market. In this system, e-mails were sent to farmers' cellular telephones, notifying them current sales tendencies of the need to replenish the stock presented for sale. Horikawa et al. [2][3] regarded this replenishment mechanism as Vender Management Inventory (VMI) and described analyses of this data. Kasai et al. [4] updated a database to identify 900 individual items and to record detailed information of sales and arrivals. Using the database, we can calculate the mean shelf time of the products from the period between arrival time and departure time for conditions of identical species, price and farmer. Ma et al. [5] analyzed sales records of the system and applied forecasting methodologies, such as the Box–Jenkins method, to the store.

The purpose of this research is to propose a new definition and utilization of elasticity of demand suitable for non-uniform products such as fresh agricultural products. This paper presents a definition of price elasticity of demand based on shelf time at

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the store, where shelf time of a product is defined as the period between shelf arrival and departure. The elasticity is represented in the relationship between price and shelf time rather than in terms of quantities. From one-year operational records of farmers’ markets, we present some examples of price elasticity based on shelf time. As a case study, we show the tendencies of the elasticity from practical sales data of certain farmers’ market, i.e. retailers. The tendencies can be seen in three out of five products.

A definition of alternative price elasticity of demand is presented in section 2. Farmers’ markets, location of the case study, and the business model are introduced in section 3. To collect data on elasticity, we use the information system utilized at the farmers’ market and present it in section 4. Case studies relating to elasticity are shown in section 5. Finally, we conclude the paper in section 6.

2 PRICE ELASTICITY OF DEMAND BASED ON SHELF TIME

2.1 Background

Generally, the price of fresh agricultural products is determined at wholesale markets established by the national or local governments in Japan. For that reason, farmers in Japan have less opportunity to make their own decisions about price. However, in case of farmers’ markets, farmers must determine the price and quantity of products to ship to the store by themselves. Stock shortages present a loss of opportunity. Alternatively, excess supply may occur according to farmers’ decisions. Despite this, most farmers have insufficient information, experience and knowledge to perform these tasks because their core competency is farming.

Furthermore, fresh agricultural products differ individually leading to price differences. Here, we focus on shelf time for measurement of sales demand. Product freshness is an important advantageous point of farmers’ markets. Some products are harvested within a couple of hours before their display in the store. To use that advantage, it is important to manage shelf time for the purpose of inventory control.

2.2 Definition

A suitable price is determined according to price elasticity to balance supply and demand (Soper [6]). However, every fresh agricultural product is different. It is therefore difficult to compare effects in prices of two products because they are not identical. Price elasticity cannot be applied to a product without some arrangements because elasticity is calculated according to the number of products sold. Here, we propose an alternative measurement of price elasticity of demand based on shelf time.

Suppose a product whose shelf arrival and departure time are \( A \) and \( D \), respectively. Shelf time \( T \) is defined as follows

$$ T = D - A. $$

(1)

Here, departure time \( D \) corresponds to the time of purchase. If a product is attractive to consumers owing to the price, shelf time \( T \) is expected to be a low value. As \( T \) is an ideal value, it is difficult to directly calculate it from practical data. In application, \( D \) can be substituted with cashing time at Point of Sale (POS) terminals. \( T \) can be calculated from the mean of certain product groups. Then, we have

$$ \text{Elasticity} = \frac{\text{Proportional change in shelf time}}{\text{Proportional change in price}} = \frac{\delta T}{\delta P}. $$

(2)

Here, \( P \) represents the price. Note that the elasticity is a positive value because shelf time is expected to be longer if price increases. Fig. 1 presents the concept of price elasticity of demand based on shelf time.

2.3 Application

We can calculate the shelf time at the store from point of arrival to the point of sales at a cashier. In applica-

![Price elasticity of demand based on shelf time](image-url)
tion of price elasticity in farmers' markets, the lead time for supply, i.e. agricultural production, takes a much longer time than consumption does. Consequently, it is difficult to adjust the current supply according to the price elasticity of supply.

In Fig. 1, horizontal and vertical axes show the sales price and shelf time at the store, respectively. The demand curve shows the relationship between the price and shelf time. At higher prices, the shelf time is longer because the consumer feels that the price is high. Conversely, at lower prices, the shelf time is shorter. The supply curve is also useful for farmers' decision-making especially for long-term decisions. However, it is difficult to adjust the amount of supply in the short term; the curve is regarded as a rather rigid line. The point at which the demand and the supply curves cross is theoretically the ideal price point.

3 FARMERS' MARKETS

Farmers' markets have become an important distribution channel in fresh agricultural products in Japan in the last 20 years. Farmers sell their products directly to consumers at a store. Since the person who made the product might be readily known or identifiable, the products satisfy consumers' demands in regard to food safety. In Japan, such stores are called Sancho, which means direct sales at production areas.

Farmers' markets require the participation of customers, farmers and a manager who is a representative of farmers and the shop. Shelves inside the shop are assigned to farmers. Farmers prepare and manage their products on these shelves. Customers come to the shop and select some products from these shelves. They make payments to a cashier, as in a supermarket, while farmers are able to work and spend time performing farming tasks. Occasionally, farmers visit the store to confirm the inventory. If the stock level dips below a certain level, farmers can replenish the products. After closing the store, the manager calculates the total sales for the day and informs each farmer of the total sales.

Farmers must determine their own production, shipment, sales and other operation parameters. However, the core competency of farmers is agricultural production, especially medium-scale and small-scale farmers. Therefore, they have insufficient knowledge and methods to manage their businesses in farmers' markets. A certain amount of support for their store business is necessary to manage and run the store. Utilization of an information system can be a smart solution.

3.1 Case Study of Akasawa Farmers' Market

As a case study, our theory and information system are evaluated at an existing farmers' market. The store is located in a suburb of Morioka city, a 30-min drive from the city center. The store is established and managed by a farmers' cooperative union and the chair of the union is the management leader. There are approximately 130 registered farmers, i.e., 130 families. Annual sales at the store are approximately 200M JPY, implying that the management scale of the store is middle-sized. Most farmers run small businesses as retired workers. The store staff members consist of homemakers employed on a part-time basis. Most work as cashiers.
Fig. 2 shows percentages of items in the 2008 annual sales. Main products are green vegetables, apples and grapes, where apples and grapes constitute over half of all sales. Fig. 3 presents percentages of each month in the annual sales. Over 70% of sales are made during September–December: the high season of grapes and apples. At the store, problems of stock shortages and excess supply are more severe than at other farmers’ markets. Solutions for this are anticipated.

4 SALES AND INVENTORY MANAGEMENT SYSTEM

We have developed and extended an information system for sales and inventory management at farmers’ markets [3][4]. The system is designed to realize and support farmers’ business through such activities as sending e-mail messages occasionally to let farmers know about current sales tendencies and releasing current inventory levels to consumers through a website. The system has the following modules: product arrival, sales and stocks, sales promotion, production planning and management analysis.

4.1 Modules

(1) Product arrival management

Before displaying agricultural products at the store, a price tag is issued for each product package. The item name, price, farmer name, issued dates, contact address, barcodes for cashier and other information are shown on the tag. This information is entered in the information system terminals in the office. It is then sent for use in sales management functions at the time of printing. The system identifies over 900 items. For consumer convenience, the shelf location module is implemented as an application of the product arrival management module. A kiosk terminal is installed inside the store and consumer can determine the location of certain farmers’ products.

(2) Sales and stock management

Sales records are retrieved from POS terminals at the cashier every 15 min. The are saved in a database and are then collated with arrival information collected from the product arrival management module to update inventory information. Products of deteriorated quality are taken off the shelves. Stock information is updated when such an adjustment occurs.

(3) Sales promotion management

Introductions of the store, each farmer and seasonal products are provided to consumers through website promotions. This function manages the website and sends e-mails to each farmer to notify them of current sales tendencies at a previously determined time. The time can be set to every 15 min. However, the system regularly sends e-mail four times a day as requested. Inventory information is retrieved from the sales and stocks management module.

For consumer support, according to the inventory information, products currently being sold can be confirmed via the website with maximum and the minimum prices. Since such stores are generally located in farming areas, there is a higher risk of stock shortages for consumers. Via the website, consumers can be kept well-informed of current stock levels before departure. The information is also used to decide the farmers’ sales strategies.

(4) Production planning (prototype)

Since production areas are limited to the store vicinity, the variety of products and harvest seasons are also limited: they are small and short, respectively. Therefore, the variety of species and high season are rather convergent. In light of this situation, consumers might encounter stock shortages and farmers may gain less profit because of lower prices through stiff competition. This is a fundamental and structural problem of farmers’ markets. To overcome it, we intend to implement a new function of sharing shipping plans among farmers and providing sales forecasts. Farmers can adjust shipping plans considering the sales forecasts and other farmers’ plans. Part of this function is implemented and analyzed [7].

(5) Management analysis (prototype)

Management information is analyzed in this function. The major role of this function is demand forecasting and consumer behavior analysis. Details are described in Ma et al. [5].

4.2 Implementation

Fig. 4 presents a practical implementation of the system at the Akasawa farmers’ market. Table 1 presents the setup of the information system. The system comprises four x86 servers, four computers, and three POS terminals. These machines comprise an Ethernet LAN. Three computers are used for the product arrival management
Fig. 4 Practical implementation of the system at the Akasawa farmers' market.

<table>
<thead>
<tr>
<th>Table 1 Setup of the developed system.</th>
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<tbody>
<tr>
<td><strong>Arrival management system</strong></td>
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<td>Arrival management system</td>
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<tr>
<td>Arrival management terminals</td>
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<tr>
<td>POS terminals</td>
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<tr>
<td>Sales &amp; inventory management server</td>
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<td>Sales promotion server</td>
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</table>

module. The other is used for sales and stocks management. The POS terminals were introduced before the system implementation. The production planning and management analysis are under development. A server for sales promotion management is set at the university and connected to the system through a public network.

5 CASE STUDIES

5.1 Preparation

As price elasticity of demand is an abstract idea, it is difficult to present the existence of the hypothesis directly. However, it is meaningful to measure actual consumers behaviors to estimate the adequacy of the hypothesis. We have updated the information system to calculate the shelf time. We collected POS data from September 2008 to August 2009. Here, we have selected five products out of about approximately 900 products sold in the farmers' market. Characteristics of the products are summarized in Table 2. Packaged tomatoes can be characterized by variation of packaged size; in other words, the contents of a package are different for each package and its variation is rather large. On the other hand, sales unit of Japanese
Table 2 Characteristics of products.

<table>
<thead>
<tr>
<th>Product (item)</th>
<th>Unit of sale</th>
<th>Variation of package size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese radish</td>
<td>A piece</td>
<td>Small</td>
</tr>
<tr>
<td>Chinese cabbage</td>
<td>Packaged in a plastic container</td>
<td>Middium</td>
</tr>
<tr>
<td>Prune</td>
<td>Bagged in a plastic bag</td>
<td>Large</td>
</tr>
</tbody>
</table>

radish and Chinese cabbage is by piece. Every piece of radish and cabbage differs according to natural variation. However, variation of contents such as in weight or size is expected to be smaller than that of the packaged tomatoes.

We collate sales records which have identical product name and identical price. Then, we calculate the mean shelf time for every price group, where the number of groups depends on variations in price decided by the farmer. These values are plotted on the graph. The points on the graph are not points of elasticity of demand, but they show the relationship between the price and shelf time.

5.2 Results

Here, we show the outcomes of five examples. Fig. 5 shows the relationship between the price of a package of prunes and the mean shelf time. In this case, there are seven points plotted in the graph where each point corresponds to the price groups of 200, 250, 315, 320, 380, 420 and 500. According to the graph, farmers can determine the price of their product at a suitable shelf time. If a farmer sets a higher price, then the stock level will be maintained at a higher level. However, the farmer can reduce the amount of stock in a short time if the price is set lower. For fresh agricultural products, the display time is a rather limited and fixed depending on each product to maintain quality. The farmers determine a price considering the conditions presented above.

Fig. 6 and Fig. 7 present examples of a piece of Japanese radish and Chinese cabbage respectively. The graphs show the same tendency as shown for prunes. However, variation in shelf time is rather milder resulting in gradual curves.

Fig. 5 Mean shelf time and the price of a package of prunes.

Fig. 6 Mean shelf time and the price of a package of Chinese cabbage.

Fig. 7 Mean shelf time and the price of a Japanese radish.
nese radish and Chinese cabbage. The result for packaged prunes is a remarkable outcome and distinguished from the case of Japanese radish and Chinese cabbage. On this basis, the existence of price elasticity of demand based on shelf time is not contradicted. However, the property cannot be observed in other cases. In fact, most products which are not presented in this paper show the same tendency as that of packaged Niagara grapes. Furthermore, the number of price groups also affects the outcome, especially the shape of the curve. To clarify the relationship between price and the mean shelf time, additional experiments with intentional price setting are necessary. From the viewpoint of management of farmers’ markets, variation of product and price are important characteristics to compete with other retailers such as supermarket.

6 CONCLUSION

In this paper, we presented a new definition of elasticity of demand derived from the relationship between price and shelf time instead of quantity. We showed the practical usefulness of the elasticity at the retailer of fresh agricultural products, such as farmers’ market, where farmers face decision-making problems in relation to product price. We updated and extended the information system of the market to measure shelf time and applied it to collect data for the elasticity. According to the analysis on some products with one-year sales records, tendencies of the elasticity can be recognized. However, the characteristics we found were weak, and further investigations are necessary.

Developing a decision-support system to determine a suitable price of agricultural products for farmers is the next step of our research project. The system will adopt human interfaces to support elderly users. To do this, further analysis on elasticity on different items and the effect on the observation period will be conducted. Presenting applications of the new elasticity in other product segments is another important objective.

REFERENCES


