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# A Study of Price Response Function for Asymmetric and Non-Proportional Demand Response to Price Change

Youngsik Kwak[1], Yoonjung Nam[2], Yoonsik Kwak[3], Pil Hwa Yoo[4]

[1] Gyeongnam National University of Science and Technology, yskwak@gntech.ac.kr
[2]Instructor, Woosong University, jean@hanyang.ac.kr (Corresponding author)
[3]Korea National University of Transportation, yskwak@ut.ac.kr
[4]SKK Graduate School of Business at Sungkyunkwan University, phyoo362@daum.net

**Abstract.** The purpose of this study is to propose asymmetric and non-proportional response function tracks demand response to price changes and to apply it to STSS(Shipment Timing Decision-making Support System) for conducting empirical analysis with one of four iconic Korean fruit products, apple.

**Keywords:** none- proportional price response, asymmetric price response, price response function, wholesale price of apple, segment analysis

## 1 Introduction

Price elasticity of demand (PED) gives the percentage change in quantity demanded in response to a one percent change in price, ceteris paribus. However, there is a controversy on it with its limitations in some points of view in real market environment (Kim, 2005; Hwang, 2009; Nam and Kwak, 2010; Bae, 2012). First, it doesn't consider asymmetric demand response to price change. Second, it doesn't consider the difference of price change effect in different scopes, non-proportional response of demand. To measure the non-proportional response, Gutenberg Price Response Function was proposed in Germany (Simon, 1987; Yoo, 1991; Kim, 2002). However, it is based on the assumption of proportional price change. There are a few price response function studies that cover asymmetric and non-proportional price change effect.

Third, it doesn't consider price level effect, the possibility of different PED in various price levels (Dolan and Simon, 1997; Kim, 2007). Fourth, it has a controversy on measuring unit of price elasticity (Yoo et al., 2012) because there is a possibility of tidal elasticity (Nagle, 1995). Therefore it is necessary to measure PED by segment unit. Kwak (2015) proposed a price response function that tracks asymmetric response by segment. However, it has a limitation that it can't measure non-proportional response.

The purpose of this study is to propose a price response function that tracks non-proportional response of demand in securing directionality of price change (table 1).

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**Table 1.** Positioning of the study

| | | Response of demand | | | |
|---|---|---|---|---|---|
| | | Proportional response | | Non-proportional response | |
| | | Whole market | segments | Whole market | segments |
| Price increasing / decreasing | NO (proportional response expected) | Point-price elasticity, Arc elasticity | | Gutenberg Price Response Function | |
| | YES (symmetric response expected) | | Kwak (2015) | | This study |

## 2 Literature Review

### 2.1 Proportional volatility of demand without directionality of price change

The relationship between alternative prices and the resulting sales quantity is called the price response function (Simon, 1987). A static price response function can be represented by a mathematical equation.

$$q_t = a_t - bp_t . \quad (1)$$

Formula (1) measures only volatility of demand (b) regardless of directionality of price change and volatility of price, which makes a gap between reality in the market.

### 2.2 Non-proportional volatility of demand without directionality of price change

Yoo et al. (2012) proposed another price response function with average price as a denominator, given product level of as a numerator. In the formula (2), price response coefficient, b is price elasticity. Therefore lower the price, bigger the effect of decreasing price and vise versa. This formula measures non-proportional demand, however it has a limitation that it is unable to discriminate between increase and decrease of price.

$$q_i = a(p_i/\overline{p})^b \quad (2)$$

It has been acclaimed that Gutenberg Price Response Function is appears most valid in an economic sense (Yoo, 1991).

$$q = a - bp - c_1 \sinh[c_2(p_i - \overline{p})] \quad (3)$$

With q denoting the quantity sold at price p, the average price of competing brands is marked by $\overline{p}$. This formulation does not either incorporate any reference price or other multi-period effects, or measure symmetric demand response regardless of directionality of price change.

### 2.3 Proportional volatility of demand with directionality of price change

Price change effect explains how the change in price of a product changes the demand of the product (Simon, 1987; Hwang, 2011). Formula (4) and (5) are for the price change effect, while formula (4) is for response of demand toward an absolute range of price change, and formula (5) is for response of demand toward relative range of price change against price level in previous period.

$$q_t = a_t - b(p_t - p_{t-1}) \quad (4)$$

$$q_t = a_t - b(p_t - p_{t-1})/p_{t-1} \quad (5)$$

$$q_t = a_t - c(p_t - p_{t-1})^+ - d(p_t - p_{t-1})^- - ep_t \quad (6)$$

$$q_{t+1} = a_t - c(p_t - p_{t-1})^+ - d(p_t - p_{t-1})^- - ep_t \quad (7)$$

In formula (6) and (7) c indicates price increasing effect, while d indicates price decreasing effect and e indicates price level effect. With formula (6), it is assumed that directionality of price volatility in given period against previous period affects demand in given period. With formula (7), it is assumed that directionality of price volatility and price level in given period affects directly demand in next period. Therefore, researchers propose formula (7) as a suitable model for the purpose of the study.

### 2.4 Non-proportional volatility of demand with directionality of price change

The primary purpose of this study is to propose a model tracks demand change with a directionality of price change (increase or decrease). In other words, it has to be with

 

directionality of price change effect and to track proportional demand change against price change. It is needed to apply formula (3) on formula (7) to measure non-proportional price change effect. And researchers propose formula (8) as a suitable model for the purpose of the study.

$$q_{t+1} = a_t - bp_t - c_1 \sinh[c_2(p_i - p_{t-1})]^+ - c_3 \sinh[c_4(p_i - p_{t-1})]^- \quad (8)$$

## 3 Research Methodology

### 3.1 Data set

Data used in this study are the wholesale price data of Fuji 15kg apples and sales volume data announced by Seoul Agricultural & Marine Products Corporation (SAMPC). Price data of apple has enabled researchers to trace change of the prices in its product life cycle (PLC). The data used in this study is from October 15th in 2009 to July 26th in 2014. The number of days of transaction is 1,311, thus the number of days for analysis is 1,310.

### 3.2 Operational Definition

Demand volume, dependent variable of formula (8) is daily wholesale price and is equal to the product's delivery amount. Price, independent variable of formula (7) is measured by price differentials between average price of given day and that of previous day.

## 4 Empirical analysis and Contribution

As there are a few studies on pricing of Korean agricultural products (Seo and Woo, 2007), researchers expect that this empirical study can contribute to the criteria of Korean agricultural product studies. Results of the empirical study will be presented at the conference.

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