

## Product Line Pricing Effect Modeling for Shipment Timing Support System for Stored Apple

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### Abstract

*The purpose of the study aims to develop comprehensive modeling alternatives for intra-product line pricing effect and compare the explanation power among them. The researchers want to include the highest explanation power model for Shipment Timing Support System for stored apple. Five intra-apple pricing models were developed and applied to the wholesale price data with four graded Fuji apple announced by SAMPC in Korea. Five intra-apple pricing model divided into three dichotomies: the first model for price level effect with proportional response, the second and third models for price gap effect with proportional response, and the fourth and fifth models for price gap effect with non-proportional response.*

*The result showed that the modeling of the price gap between excellent grade and three lower grade apples with proportional response showed the highest adjusted R<sup>2</sup> among five models. This result implies that the interdependency among apple grades has the proportional response to price difference instead of non-proportional response to price difference among apple grade.*

**Keywords:** *Product Line Pricing, Shipment Timing Support System, Gutenberg modeling*

### 1. Introduction

The Shipment Timing Decision-making Support System (STSS) for stored apple is to help the farmers and wholesalers to decide when the stored apples should be shipped from the warehouse to market [1]. The decision making should be based on the price level at wholesale market, because farmers want to ship the stored apple with higher price than ever before. The price level at wholesale market for stored apple at a given period depends on the various variables such as the price level at the previous period, the total shipment volume at the previous period, the price level of substitute or product line, the price expectation effect, the holiday effect, the day-of the week effect and so on. Therefore, STSS should faithfully incorporate the variables with comprehensive modeling [2]. However, among the variables, the price level of substitute effect or product line has been explored rare relative to the other variables in academic field.

If an increase in demand for A leads to higher demand for B, we deem A and B to be compliments. If the interrelation is negative, we refer to A and B as substitutes [3]. Seoul Agricultural & Marine Products Corporation (SAMPC) has reported 4-grade apples such as excellent, high, middle, and low grade, at daily base. We call apple's four grades the apple's

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product line. The farmers' four product line can be complements and substitutes, simultaneously. For example, if the price of the excellent grade apple is increasing, the demand of the excellent graded apple would decrease accordingly. This situation leads the increase of demand for lower grade apple. In this situation, we regard the interdependence of the excellent and lower grade apple as substitutes. However, the increase of demand for lower grade apple may stimulate the increase of price level for lower grade apple, which would decrease the demand of the lower grade apple. Customers may purchase other apple type or other type of fruits. This situation makes the relation between the excellent grade and lower grade compliments. In this regard, depending on the price difference between grade A and grade B, two products can be sold as complements or substitutes at stored apple. Therefore, the STSS should incorporate the interdependency in price and demand between the apple grades. We call it intra-apple pricing effect.

To explore the intra-apple pricing effect, so many manipulations can be existed for stored apple [3]. However, the empirical studies to explore the intra-apple pricing effect found rare in academic field.

The purpose of the study aims to develop comprehensive modeling for intra-apple pricing effect and compare the explanation power among alternative modeling. The researchers want to include the highest explanation power model for intra-apple pricing for STSS for stored apple.

## 2. Data and Modeling

### 2.1. Data Sets

The wholesale prices of apples used in this study were daily announcement sales data presented by the Seoul Agricultural & Marine Products Corporation (SAMPC) on on-line in Korea. Because prices of apples were depending on the type, grades, and package units of apple, Fuji 15kg apple with four grades were selected to be the subjects in the study. The data was collected from October 6 in 2012 to February 28 in 2013. The number of auction at a given period is 121 observations for four graded apple.

### 2.2. Modeling

Because the SAMPC reported the wholesale price for four grades, the researchers should limit the scope of apple grade for the study. First of all, we set the excellent grade apple as a reference point. The study investigates the intra-apple pricing effect twofold. We can infer that the price level of excellent grade might be affected by the price level of other grade apple. The other rival explanation is that the price level of excellent grade might be affected by the price level of only high grade apple, because the buyers for excellent grade apple are hardly searching middle and low grade apple.

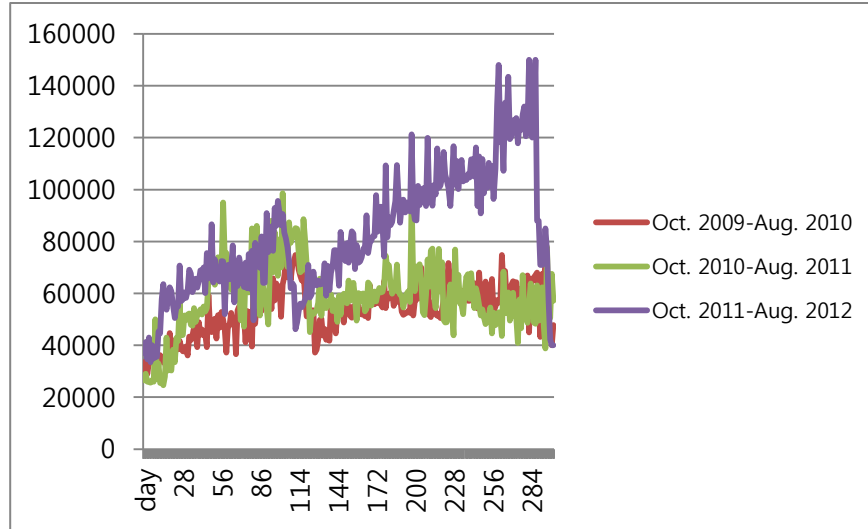
The researchers developed five intra-apple pricing effect modeling. Because price is subjectively recognized by buyer and seller, the intra-apple pricing modeling should focus on the psychological aspect of pricing [4, 5].

First, the researchers assume that the price level of the other grade apple at the previous period  $t-1$  would directly affect the price level of the excellent grade apple at the period  $t$ .

$$p_t = a_t - c_1 p'_{t-1} \quad (2-1)$$

where  $p_t$  = wholesale price at period  $t$  for excellent grade,

$p'_{t-1}$  = average wholesale price at period t-1 for high, middle, and low grade or high grade  
and  $a_t$ , and  $c_1$  = parameters to be estimated



**Figure 1. The Fluctuation of Wholesale Price from 2009 to 2011 of Excellent Grade Apple. The Day Elapsed from the First Auction for Apple, Day (Horizontal Axis) and the Price, KRW (Vertical Axis)**

The reason of developing formula 2-1 is to explore the price level effect. The retail and wholesale price have the unpredictable fluctuation at daily, weekly, and monthly. Furthermore, as shown Figure 1, each year has its own fluctuation pattern. In this regard, farmers and wholesalers always experienced subjective evaluation for the price level for everyday. For example, at the beginning of the season and the end of the season, the same price level gives the different psychological impact on wholesalers' cognition for the price level. So, their shipment volume will vary depending on the price level and the season [6, 7]. In this regard, the price level of the object will be affected by other product line.

Second, the difference in price level between excellent grade and other grade at the previous period t-1 would affect the price level of the excellent grade apple at the period t. The formula 2-2 is to ignore the price level effect. Regardless the price level, we assume that the price gap between the product and its substitutes or compliments will affect the price level of excellent grade. We got

$$p_t = a_t - c_1 (p_{t-1} - p'_{t-1}) \quad (2-2)$$

where,  $p_{t-1}$  = wholesale price at period t-1 for excellent grade.

The reason of developing formula 2-2 is to explore the price gap effect. Using the price gap modeling we can investigate several rival explanations for price gap effect on the dependent price level. If buyers choose more expensive apple, when the price gap is wider than ever, we can explain the phenomenon as price-quality effect. In this situation, buyers prefer the more expensive apple, because buyers have doubts to the cheap priced apple's

quality. The sign of the coefficient for formula 2-2 with this explanation will be appeared positive, vice versa.

Third, the ratio of the difference in price level between excellent grade and other grade at the previous period t-1 would affect the price level of the excellent grade apple at the period t. The formula 2-3 assumes that the reference price is the average price of three apple grades to evaluate the price level of excellent grade apple. We manipulated

$$p_t = a_t - c_1 (p_{t-1} - p'_{t-1}) / p'_{t-1} \quad (2-3)$$

The rational of developing formula 2-3 is to explore the price gap effect and price level effect simultaneously. According to the reference price level, the price gap between the excellent grade and other grade apple will be recognized differently at individual and segment level.

Fourth, in many cases, it seems that small price changes cause under-proportional responses and big price changes produce over-proportional responses. For example, price reduction of less than 10% has no significant effect on sales, while the sales increase strongly when price reductions are more than 15% [7]. The hypothesis of non-proportional response to price changes is similar to Gutenberg hypothesis for price differentials between competitive products [8]. Relatively, farmers who stored apple would not response to small wholes price in comparison to big price gaps. Figure 2 shows such a function with a non-proportional response to price change or gap.

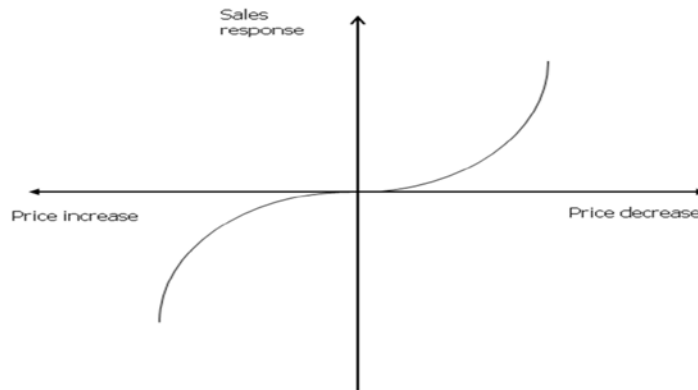
Formally Gutenberg asserted that a sinus-hyperbolic function can generate the shape of the curve and non-proportional response to price gap. If we choose the relative price gap as the independent variable, we manipulated the price gap as the absolute gap or relative gap as follows.

$$p_t = a_t - c_1 \sinh(c_2 (p_{t-1} - p'_{t-1})) \quad (2-4)$$

$$p_t = a_t - c_1 \sinh(c_2 (p_{t-1} - p'_{t-1}) / p'_{t-1}) \quad (2-5)$$

where,  $c_1$  = fixed constant by the researchers.

Formula 2-4 and formula 2-5 can explore the price gap effect, price level effect, and price gap effect between objects with non-proportional price response simultaneously. On the other hand, formula 2-2 and 2-3 can be characterized as proportional price response model.



**Figure 2. Non-proportional Response to Price Change or Gap**

### 3. Results and Discussion

#### 3.1. Explanation Power of the Average Price of Three Apple grade

To apply the five rival explanation modeling to observations, the researchers conduct regression analysis. Five models showed the significant F-value. So, the researchers regard the five modeling as comprehensive model for intra-apple pricing effect. The results are as follows.

First, five manipulated formulas showed statistically significant effect on the price level of excellent apple grade ( $p < 0.01$ ). That is, the coefficients of the intra-apple pricing effect are significant. So, researchers can compare the explanation power among them, through which researchers can find more comprehensive model to include the STSS.

**Table 1. Results of Regression Analysis from Five Models with Average Price for Three Apple Grades**

Independent variables	coefficient	Standardized coefficients	t	p-value	F	Adjusted R <sup>2</sup>
$P'_{t-1}$	0.580	0.246	2.740	0.007	7.51	0.052
$p_{t-1} - p'_{t-1}$	0.456	0.411	4.873	0.000	23.74	0.162
$(p_{t-1} - p'_{t-1}) / p'_{t-1}$	13994.3	0.334	3.834	0.000	14.697	0.104
$\sinh(c_2(p_{t-1} - p'_{t-1}))$	536.89	0.340	3.917	0.000	15.341	0.108
$\sinh(c_2(p_{t-1} - p'_{t-1}) / p'_{t-1})$	11242.05	0.324	3.710	0.000	13.76	0.098

Second, the direction of sign of coefficients is positive for five models. Formula 2-1 shows that the higher average price for three apple grade yields the higher price level for excellent price. The positive sign of the coefficients means that the relationship of the excellent grade and other grade is substitutes at the sample. The result of formula 2-2 to 2-5 appears that the price gap between the grades is increasing the price level of the excellent grade apple. This result implies that when the demand for the excellent grade apple is constant and the price level of lower grade apple is constant, if wholesalers want to increase the profit, they should set the excellent grade apple higher than before.

Third, the proportional response to gap in price level between excellent grade and average three grades at the previous period t-1 showed the higher effect on the price level of the excellent grade apple at the period t than in case of non-proportional response modeling. Adjusted R<sup>2</sup> of proportional modeling is 0.162. The non-proportional modeling's adjusted R<sup>2</sup> is 0.108. That is, the proportional response modeling produces more explanation power than non-proportional modeling. The researchers assumed that because the price data was collected daily base market, the price level for excellent grade apple did not easily response to the width of price gaps between price level at period t and period t-1.

#### 3.2. Explanation Power of the Price Level of High Grade Apple to Excellent Grade

When the researchers applied the formula 2-1 to 2-5 to excellent and high grade data set, the regression showed that the price level of the high grade affected the price level of the excellent grade significantly ( $p < 0.001$ ). We can summarize the results as follows. First, five manipulated formulas with high grade showed statistically significant effect on the price level of excellent apple grade.

Second, the direction of sign of coefficients is positive for five models at Table 2. Formula 2-1 result means that the higher average price for high graded apple yields the higher price level for excellent price. The positive sign of the coefficients means that the relationship of the excellent grade and other grade is substitutes at the sample.

**Table 2. Results of Regression Analysis from Five Models with High Graded Apple's Price**

Independent variables	coefficient	Standardized coefficients	t	p-value	F	Adjusted R <sup>2</sup>
$P'_{t-1}$	0.745	0.371	4.322	0.000	18.681	0.130
$p_{t-1} - p'_{t-1}$	0.511	0.384	4.505	0.000	20.291	0.141
$(p_{t-1} - p'_{t-1}) / p'_{t-1}$	23896.84	0.347	4.008	0.000	16.063	0.113
$\sinh(c_2(p_{t-1} - p'_{t-1}))$	1823.88	0.324	3.707	0.000	13.742	0.097
$\sinh(c_2(p_{t-1} - p'_{t-1}) / p'_{t-1})$	22824.46	0.344	3.966	0.000	15.728	0.111

Third, shown Table 1 as the relationship between the excellent grade and other grade apple, the absolute price level effect modeling as formula 2-1 showed the lowest explanation power as adjusted R<sup>2</sup> 0.052. However, in case of the relationship between the excellent grade and high grade, the absolute price level effect modeling showed 0.130 as adjusted R<sup>2</sup>.

Fourth, formula 2-2 to 2-5 appear that the gap between the excellent and high grade apple is increasing the price level of the excellent grade apple. This result implies that when the demand for the excellent grade apple is constant and the price level of high grade apple is constant, the wholesalers should set the higher price for excellent grade apple than the high grade apple for more profit. In addition, the price gap between two grade should be wider as possible.

Fifth, the proportional response modeling in price gap between excellent grade and high grade apple at the previous period t-1 showed significantly the highest adjusted R<sup>2</sup> among five models. That is, the proportional response modeling yields more explanation power than non-proportional modeling. Especially, the non-proportional response to price difference formulas, formula 2-4 and 2-5, showed the lower R<sup>2</sup> with 0.097 and 0.111 than proportional response, respectively. This result implies that the interdependency among apple grade has the proportional response to price gap.

#### 4. Conclusion

The purpose of the study aims to develop comprehensive modeling for intra-apple pricing effect and compare the explanation power among them. The researchers want to include the highest explanation power model for intra-apple pricing. Five intra-apple pricing models are developed and applied to the wholesales apple price data announced by SAMPC in Korea. Five intra-apple pricing model divided into three dichotomies: the first model for price level effect with proportional response, the second and third models for price gap effect with proportional response, and the fourth and fifth models for price gap effect with non-proportional response.

**Table 3. Intra-apple Pricing Effect Schemata and its Explanation Power**

	Price Level Effect model Independent Variable	Price Gap Model Independent Variable
Proportional Response in Price Difference	$p'_{t-1}$	$\frac{p_{t-1} - p'_{t-1}}{(p_{t-1} - p'_{t-1}) / p'_{t-1}}$
Non-Proportional Response in Price Difference		$\frac{\sinh(c_2(p_{t-1} - p'_{t-1}))}{\sinh(c_2(p_{t-1} - p'_{t-1}) / p'_{t-1})}$

The result showed that the proportional response modeling of the difference in price level between excellent grade and three lower grade apples at the previous period t-1 showed the highest adjusted  $R^2$  among five models. This result implies that the interdependency among apple grade has the proportional response to price difference instead of non-proportional response to price difference among apple grade. The researchers concluded that the price gap with proportional response model for intra-apple pricing should be incorporated into STSS to enhance the explanation power of whole dynamic pricing model [9].

The price gap models show that the gap between the excellent and other grade apple is increasing the price level of the excellent grade apple. Therefore, the researchers can find the profit opportunities. When the demand for the excellent grade apple is constant and the price level of the other grade apple is constant, the wholesalers should set the higher excellent grade apple than the other grade apple as possible as the wholesaler can, vice versa.

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