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Market Windows and Hedonic Price Analyses: An Application to the Apple Industry

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Marketing concepts associated with quality, location, and time are integrated into a complete model, revealing the linkages between market window approaches and hedonic analysis. An integrated hedonic price model for the U.S. apple industry was estimated. Results suggest that size, storage method, grade, and seasonality are the most important influences on the price of apples. Area of apple origin and variety were the least important influences on apple prices, with the exception of the Granny Smith variety.

Key words: Alar, market value, quality characteristics, seasonality.

Introduction

In addition to aggregate supply and demand forces, commodity prices vary according to quality characteristics, timeliness of product sale, and spatial factors. The market window approach originally was developed to help small farmers in Florida identify when they could most profitably produce and market highly perishable fruit and vegetable crops (Colette and Wall). Hedonic price analysis has been utilized by many studies to determine the market value attributed to quality characteristics for agricultural goods (e.g., Ethridge and Neeper; Brorsen, Grant, and Rister; Veeman). No studies have linked the market window approach with hedonic price analysis to simultaneously sort out the market values associated with seasonal, spatial, and quality factors. In part, this is because most hedonic price analyses of agricultural products have considered goods that are easily stored, transported cheaply, or blended together so that their origin is not differentiated.

This article provides a marriage between the market window and hedonic price approaches, and shows the potential problems that can arise when the approaches are not integrated. The difficulty occurs because seasonal factors not only influence aggregate output, but also the supply of quality characteristics. The latter effect is especially important for perishable commodities and for commodities that vary in their degree of storability. For example, one size of apple may deteriorate more rapidly with storage than another size. The larger cell structure associated with large apples is believed to cause them to deteriorate more rapidly under storage than small apples (Kilby). Therefore, quality and seasonal factors need to be analyzed simultaneously or research results will be biased.

A hedonic price model for the U.S. apple industry was estimated to determine the implicit value of spatial, seasonal, and quality characteristics. Such information is central to benefit–cost analyses of almost all potential changes in production or marketing decisions. Growers from most states advertise their apples as superior to other states. Spatial price information on apple origin thus has useful implications for cooperative advertising campaign efforts. Seasonal price patterns determine market windows; in the apple market, such results give insights into the returns to investment in storage facilities and the potential

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returns to new producing regions. The premia associated with quality factors also are needed to determine the net benefits of changes in technologies that alter quality.

Models of price characteristics are presented in the following section. Data sources and estimation procedures are outlined in the third section, followed by a discussion of empirical results. The last section discusses implications for apple growers and future research needs.

Theoretical and Empirical Considerations

Quality characteristics are at the heart of hedonic price analysis. Perhaps the first analysis to consider the influence of quality on prices was the work in 1928 of Frederick Waugh on vegetables. In 1951, both Houthakker and Theil formalized independently many of the theoretical issues of consumer demand for quality. Gorman's 1956 paper on quality differentials in the egg market links consumer demand with measurable product characteristics. Lancaster further developed the notion that consumer utility is derived from the characteristics of the good rather than the goods themselves. The empirical application of characteristics demand is represented by a hedonic price function, where commodity price is a function of the good and its quality characteristics.

Timing is the central concern of market window analysis. The market window approach comprises a search for time intervals when expected prices are relatively high and production through delivery of product is feasible. Such studies have proliferated as fresh produce markets have expanded and sources of supply have diversified. Real prices have declined steadily in the last two decades (Barichello), prompting producers to look even more closely at seasonal price behavior. Seasonal price patterns can be considered analogous to variations in quality characteristics since time of sale generates a premium or discount in price. Market windows thus can be treated as "quality characteristics"; failing to incorporate them in a hedonic price model can yield biased results, as later demonstrated.

Hedonic price functions are of the form (Lucas):

$$P_i = f(C_{i1}, \ldots, C_{ij}; u_i), \tag{1}$$

where P_i is the observed price of commodity i; C_{ij}, $j = 1, \ldots, J$ measures the amount of some intrinsic "quality characteristic" for each unit of commodity i; and u_i is a disturbance term.

Characteristics incorporated in the apple model are crop year, region, variety, size, grade, seasonality, storage method, and a variable intended to measure the effect of the Alar scare on Red Delicious apple prices. The model was estimated with seven years of data, beginning in 1982 and ending with the 1988 crop year. Yearly dummy variables were included to account for the effects of annual supply variation. The 1986 crop year was selected as the base year so that all results for crop year are in reference to 1986 price levels. October was selected as the reference month since virtually all varieties are sold during October. Four regions of production were selected for this analysis: (*a*) Hudson Valley, New York; (*b*) Western and Central New York; (*c*) Washington State; and (*d*) Michigan. These regions account for about two-thirds of the nation's total commercial apple production. Washington was selected as the base region because it is the largest producer.

Seven varieties were considered: Red Delicious, Golden Delicious, McIntosh, Idared, Empire, Red Rome, and Granny Smith. These varieties account for over two-thirds of the apples grown in the U.S. (Bultitude). Other varieties, such as Winesap, Jonathan, Gala, and Fuji, would have been interesting to consider but lack of price quotes for these varieties in several regions posed potential multicollinearity problems. Red Delicious was selected as the base variety since it is the most widely marketed.

The fifth variable is size, measured as the number of apples that will fit into one standard box (weighing between 40 and 42 pounds). Four size groups were classified: 72 and below is large, 72 to 120 is medium, 125 and above is small, and bag prices are considered as extra small. Medium was chosen as the base size since this size is by far the most widely sold. The premium associated with size is hypothesized to vary throughout the marketing year since larger apples are expected to deteriorate more rapidly under storage than smaller apples. Dummy variables for size multiplied by month were utilized to determine how the premium for size varied throughout the marketing year.

Grades considered were Extra Fancy, Fancy, and a combination grade consisting of Fancy and Extra Fancy. U.S. One was omitted since it was only reported in one region and this grade is considered only slightly better than apples sold for processing. Extra Fancy was chosen as the standard grade.[1] Because the sale of cold storage overlaps the period of apples sold from controlled atmosphere (CA) storage, a dummy variable was constructed for the months where overlap occurs. CA stored apples endure better than cold stored apples, so they are expected to receive a premium during the months of January and February. All price quotes from March through August are for CA stored apples.

The final variable measures the impact of Alar on the apple industry. Since Red Delicious apples received the media attention during the "Alar scare," only these apple prices were considered, even though other varieties were treated with Alar, too. The Alar variable represents Red Delicious apple sales between February 1989 and July 1989 for all regions. For example, the Alar variable for Michigan would take on a value of 1 for all Red Delicious apples sold from Michigan during this time period and 0 otherwise. Because Washington is the region best known for the Red Delicious apple, this region was expected to show the most substantial price effect. The Western and Central New York region was selected as the base region for Alar.

Data Sources and Estimation Procedures

Weekly price data were obtained from the Market News Branch of the Agricultural Marketing Service, U.S. Department of Agriculture (USDA). Prices reported represent f.o.b. quotes for 40-pound boxes. Monthly averages were used to reduce the size of the model and avoid problems associated with sparse data for some locations during off-season time periods. Prices were deflated by the Consumer Price Index for all goods. Because the crop year is different from the marketing year, price quotes begin in September 1982 and progress through August 1989. Availability of price quotes in a season vary depending on the crop size and variety. Red Delicious are typically the first to be harvested and Granny Smith the last. In total, 1,771 observations were utilized in the analysis.

For time-series hedonic estimations of marginal implicit prices of quality characteristics, Rosen showed that supply response functions also should be determined. In this study, the supply of each product characteristic is assumed to be perfectly inelastic within each crop year; none of the variables considered are inputs into the production process and annual supply variation is accounted for by yearly dummy variables. This treatment also eliminates the problem of identification posed by McConnell and Phipps.

The hedonic price function of apples used in this analysis was expressed as follows:

$$(2) \qquad P_t = \alpha + \sum_{b=1}^{6} \beta_b Y_{bt} + \sum_{x=1}^{11} \Lambda_x M_{xt} + \sum_{d=1}^{3} \delta_d R_{dt} + \sum_{f=1}^{6} \phi_f V_{ft} + \sum_{g=1}^{3} \Gamma_g S_{gt} + \sum_{x=1}^{11} \sum_{g=1}^{3} \gamma_{xg} M_{xt} \cdot S_{gt} + \sum_{v=1}^{2} \upsilon_v G_{vt} + \sum_{c=1}^{2} \Pi_c C_{ct} + \sum_{a=1}^{3} \Theta_a A_{at} + \epsilon_t,$$

where P_t is the real f.o.b. price of apples in period t (\$/40 lb. box), α is a constant, Y equals crop year, M signifies month, R equals region, V is variety, S equals size, $M \cdot S$ measures how quality varies with storage for different sized apples, G stands for grade, C

denotes CA storage for the months of January and February where overlap with cold storage occurs, A (Alar) is a variable representing a 1988 Red Delicious price quote (between February and July 1989), and ϵ is the disturbance term. All independent variables are expressed as dummy variables because the quality factors considered are quantifiable only in discrete form, as are most quality factors (Petzel and Monke).

An initial OLS regression of equation (2) revealed the presence of autocorrelation. To correct for this problem, the Cochrane–Orcutt procedure for autocorrelation was followed. First and second degree autocorrelation were considered, but only first degree autocorrelation was found. Although an error components model may have yielded more efficient parameter estimates, the lack of data for many varieties in different regions and time periods made this approach impractical. Furthermore, even if the parameter estimates reported here are not fully efficient, they are unbiased. Equation (2) also was estimated in log-linear form (i.e., natural log of price regressed on the independent variables). Results from this regression were very similar to those presented and therefore are not reported here. We prefer the linear form due to the ease with which the empirical results can be interpreted.

Empirical Results

Estimated results of equation (2), using the Cochrane–Orcutt procedure for first order autocorrelation, are presented in table 1. Quality and seasonal factors identified in equation (2) explain 86% of the variation in apple prices between 1982 and 1988, as indicated by the adjusted coefficient of determination. F-statistics indicate how significant each class of variables is in determining apple prices, whereas the t-statistics indicate individual variable significance. F-statistics reveal that size, storage method, variety, and month are the most influential factors in explaining apple prices. For variety, t-statistics indicate that Granny Smith is the only variety that has much statistical significance in explaining apple prices. The group F-statistic for variety when Granny Smith is excluded is 1.055 [$F(5, 1721)$], which is not significant for even a 60% confidence interval.

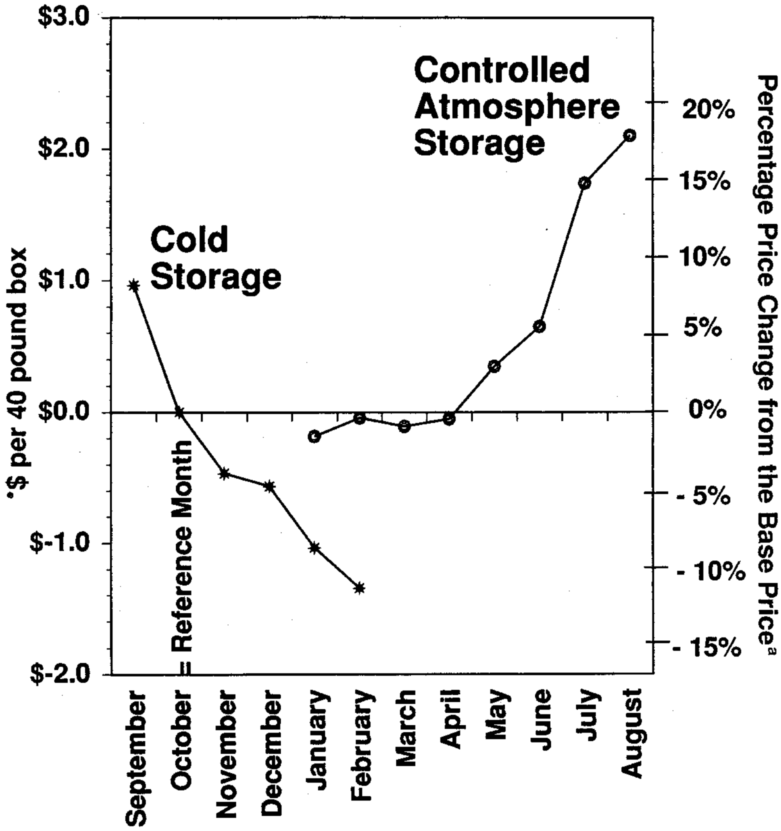
The constant term measures the value of the bundle of base characteristics—an Extra Fancy, Red Delicious, cold stored, medium-sized box of apples grown in Washington and appearing on the market in October of 1986. Coefficients associated with the crop year variable indicate that, as suspected, all years received a discounted price relative to the base year of 1986. Demand growth outpaced supply growth in 1986, causing prices to surge. In 1987, the U.S. apple crop was the largest on record, a 33% increase from 1986. Estimated results show that prices in the 1987 crop year were discounted almost twice as much as any other year.

As shown in figure 1, monthly dummy variables indicate distinct seasonal patterns, with the summer months offering the highest price premiums. August prices were $1.15/box more than September prices (when the new harvest starts) and $2.10/box more or 18% higher than October prices. Cold stored apple prices continue a modest decline through December and then drop off sharply through February. The price decline from October through December is attributed mainly to supply since all varieties are available from every region and in competition with one another. Deterioration in apple quality, competition from CA stored apples, and a relatively weak demand for fruit during the winter months are believed to cause the dramatic price drop from December through February for cold stored apples.

CA storage brought a significant and substantial premium to cold storage. This premium reflects a higher cost of storage, but it also reflects the higher quality associated with CA stored apples. The demand for CA stored apples was relatively weak in the winter and early spring months with price levels almost equal to October prices. But between April and June, prices climbed about 3% every month, almost attaining September's price level. July prices increased a hefty 9% from June's price level, and another 3% price increase occurred in August. This substantial summer price increase reflects a strong consumer demand for fruit during the warmer summer months and limited supplies.

Table 1. Estimated Results of Factors Affecting the Real Price of Apples

Variable	Coeffi-cient	*t*-Statistic	*F*-Statistic for Group
Constant	11.844	36.849	
Year (Base Year = 1986):			*F*(6, 1721) = 12.737
1988	−1.287	−3.759	
1987	−2.543	−7.881	
1985	−.506	−1.610	
1984	−.472	−1.392	
1983	−.596	−1.724	
1982	−1.478	−4.368	
Month (Base Month = October):			*F*(11, 1721) = 34.229
January	−1.036	−8.723	
Feburary	−1.343	−9.217	
March	−.108	−.802	
April	−.052	−.408	
May	.350	2.494	
June	.650	3.104	
July	1.738	6.290	
August	2.103	6.839	
September	.964	8.102	
November	−.363	−3.807	
December	−.564	−4.962	
Region (Base Region = Washington State):			*F*(3, 1721) = 2.958
Hudson Valley, NY	.432	1.070	
Western/Central NY	.932	2.522	
Michigan	.444	1.132	
Variety (Base Variety = Red Delicious):			*F*(6, 1721) = 36.228
Golden Delicious	−.066	−.351	
McIntosh	.205	1.428	
Idared	.116	.489	
Granny Smith	4.579	14.031	
Empire	.436	1.657	
Rome	.037	.170	
Size and Monthly Effect for Large:			*F*(14, 1721) = 31.553
Size (Base Size = Medium):			*F*(3, 1721) = 61.223
Extra Small	−3.358	−8.346	
Small	−1.362	−9.365	
Large	.971	2.691	
Monthly Effect (Base Month = October):			*F*(11, 1721) = 3.745
Large—January	1.158	2.977	
Large—February	1.166	2.742	
Large—March	.974	2.078	
Large—April	.822	1.734	
Large—May	.345	.708	
Large—June	.553	.946	
Large—July	.403	.600	
Large—August	−1.729	−2.363	
Large—September	.927	2.503	
Large—November	.632	2.011	
Large—December	1.396	3.719	
Grade (Base Grade = Extra Fancy):			*F*(2, 1721) = 12.493
Combo	−1.239	−4.377	
Fancy	−1.053	−3.126	
Storage Method (Base Storage = Cold Storage):			*F*(2, 1721) = 56.243
Controlled Atmosphere January	.852	6.629	
Controlled Atmosphere February	1.299	9.869	
Alar Variable (Base Alar = West/Central NY, Only Red Delicious Variety):			*F*(3, 1721) = 12.688
Washington	−2.243	−5.923	
Hudson Valley, NY	−.846	−1.307	
Michigan	−.715	−1.344	
Rho (first order autocorrelation):	.723	44.048	
Adjusted Coefficient of Determination:	.861		
Durbin–Watson Statistic:	1.830		

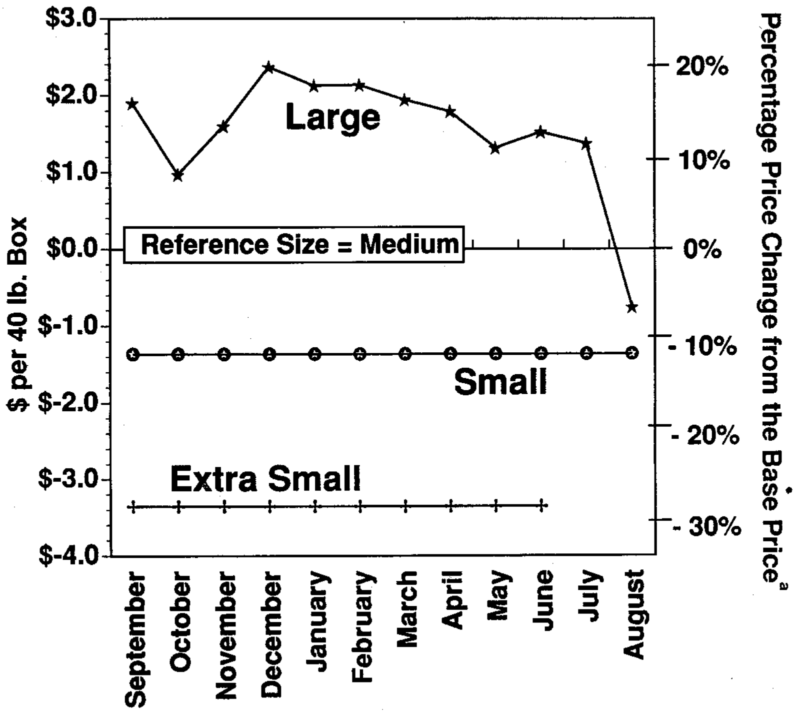


[a] The "Base Price" is an Extra Fancy, Cold Stored, Medium sized Red Delicious Apple that was grown in Washington State and sold in October, 1986.

Figure 1. Seasonal price premium for apples with October's price as the reference price

Returns to advertising that associate apple quality with place of origin appear limited.[2] Regional results suggest that the leader in U.S. production, Washington, does not receive any price premium from marketing its apples as "Washington." It might be thought that Washington apples receive a discounted price compared to other regions, since they are not as centrally located to the overall U.S. market. However, in 1988, the cities of Los Angeles and San Francisco received 87% of the total fresh apple shipments that the six cities of Baltimore, Boston, New York, Philadelphia, Atlanta, and Chicago received (USDA, *Agricultural Statistics*). Also, Washington State has a locational advantage for shipping to the growing Pacific Rim markets.

Early adopters of new varieties generally enjoy a substantial price premium, but our results indicate that variety is not a big factor for the consumer. The exception is Granny Smith, which received a price premium of over $4 per box more than any of the other varieties considered. This result suggests that consumers prefer the tart-crisp taste of the Granny Smith that is usually grown in the western states. However, growers should take caution in assuming that this high a price premium will always exist for Granny Smith. The variety was relatively new for the period analyzed and a large increase in Granny Smith acreage is now ready to start full production. On average, the price premium for Granny Smith has eroded at $.52 per box annually, among each of the three-year sample periods of 1982–84, 1983–85, 1984–86, 1985–87, and 1986–88. For newer varieties (not included here because of limited data), scattered evidence suggests substantial price differences relative to the more traditional varieties (Barichello). Nonetheless, these price



[a] The "Base Price" is an Extra Fancy, Cold Stored, Medium sized Red Delicious Apple that was grown in Washington State and sold in October, 1986.

Figure 2. Estimated monthly premium of extra small, small, and large apples relative to medium sized apples

differentials undoubtedly will diminish as producers adjust varietal mixes and thus eliminate price differences through arbitrage.

Quality characteristics associated with size were highly significant in affecting apple prices. Figure 2 shows the estimated monthly premium for apple size. As expected, larger sizes are preferred to smaller sizes. F-statistics for size multiplied by month (i.e., the variable $M \cdot S$) indicate that only the large size had any significant premium variation relative to medium sized apples. In general, large apples received about a $1.60/box premium over medium sized apples.

The monthly variation in premium for both small and extra small apples was insignificant for an 80% confidence interval,[3] suggesting that the consumer does not differentiate between the storable properities of apples that are medium sized and smaller. Therefore, the monthly variation in premium for small and extra small apples was eliminated from the model specification. Small and extra small apples were discounted $1.36 and $3.36 per box, respectively, compared to the base size of medium. The price spread between large and extra small was often over $5 per box, a price swing that commonly amounts to over 40% of the f.o.b. price received for medium sized apples.

In contrast, the seasonal premium for large apples fluctuated over the marketing year, reaching a peak in December ($2.37/box) and then declining $.14/box every month until July. During August the price premium for large apples dipped over $2 a box to −$.76/box. This pattern reflects the poorer storage properties of large apples. With the arrival of the new crop in September, the premium for large apples jumped up to $1.90/box and then dropped to $.97/box in October (when harvest and packing are in full swing). Between October and December the premium for large apples climbed to $2.37/box. Prices did not fall to the October premium level of $.97/box until May.

The Extra Fancy grade is preferred to other grades. Results indicate that Fancy apples were discounted \$1.05 per box from the Extra Fancy price. Interestingly, Combo apples appear to have received a higher discount than Fancy apples with a \$1.24 discount, even though the average grade mix is higher for a Combo than Fancy grade. This result suggests that uniformity has value. But the evidence is not conclusive since the null hypothesis that the coefficient for Fancy and Combo are equal has a t-statistic of −.243, insignificant for an 80% confidence interval.[4]

As suspected, coefficients on the Alar variables indicate that Washington was the region most impacted by the Alar scare. Because Washington State was the major supplier of CA stored apples when the scare initially hit in February of 1989, they were the focus of the "health risk" and appear to have suffered the greatest loss. Other regions suffered much smaller price discounts and the levels of statistical significance for these regions suggest that they may not have been damaged at all.

The importance of "quality" versus "timeliness" was explored by testing the joint statistical significance of (*a*) region, variety, size, grade, and storage method versus (*b*) year, month, large size by month, and Alar variables, respectively. An F-statistic value of $F(16, 1721) = 64.137$ was realized for all "quality" variables, and an F-statistic value of $F(31, 1721) = 18.221$ was obtained for all "time" variables. The high degree of statistical significance for both quality and timeliness indicates that biased results are a virtual certainty if one isolates just quality factors as in a traditional hedonic price approach or timeliness as in a typical market window approach.

Concluding Comments

Utilizing a hedonic pricing model, this analysis explored the impact that crop year, month, region, variety, size, grade, storage method, and the Alar scare had on the U.S. apple market. Our results suggest that apple size and grade, seasonal marketing considerations, and storage method are the most influential factors on apple prices. Returns to cooperative advertising that associate apple quality with place of origin appear small. Similar results also were found for the varieties represented in our sample. Supply response arbitrage of varietal mixes essentially has eliminated any premia that may have been present. Producers should be reluctant to jump from one variety to another unless they are confident that they can be one of the first to enter the market.

Size, grade, and storage method linked with seasonal marketing considerations are the areas that offer the most promise for enhanced returns. Opportunities for storing large apples in October appear favorable, provided that these apples are moved before December (for cold storage) or March (for CA storage). Higher seasonal apple prices associated with late summer marketings suggest that producers could receive a good return from investing in CA storage facilities. Because most regions have very little CA storage, this is an area which needs further research.

Finally, the results indicate that researchers may obtain biased results if quality factors and timeliness are modeled separately rather than integrated in a complete model. This result is especially likely for perishable and semi-storable commodities like apples that often are analyzed in either a market window or purist hedonic price approach.

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Notes

[1] Seasonal variation in quality for different grades and varieties also was explored but found to be statistically insignificant. Seasonal variation in quality by grade was questionable by horticultural specialists. Sparse data for some varieties during spring and winter months may have been a contributing factor for not detecting any significant seasonal variation in quality by variety.

[2] It is unclear whether consumers truly differentiate between apples from Hudson Valley, New York and

Western/Central New York since the nonnested *JA* test proposed by Fisher and McAleer was inconclusive regarding treating the two regions as a single variable instead of two separate regions. Because production from the two regions is segregated and both regions have different grower associations (Anderson), the two regions were not combined. Irrespective, results were very robust between these two different model specifications.

[3] F-statistic values of $F(11, 1710) = 1.186$ and $F(9, 1712) = 1.001$ were realized for the small and extra small, respectively. No extra small apple sales ever occurred in July or August.

[4] The nonnested *JA* test of Fisher and McAleer was inconclusive in picking between individual variables or a combined variable for Fancy and Combo grades. Because the two grades are packed and labeled differently, they were left in the model specification as two separate grades. Nonetheless, results were very robust between these two different model specifications.

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