Effect of Size and Grade on Profitability of Marketing D'Anjou Pears

by

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Abstract

The objective of this study is to analyze the relative profitability of pears by pear size and grade, and to predict changes that would occur in overall industry profitability due to specific management strategies relating to altering the sales mix among various sizes and grades, as well as altering the distribution of pear supplies over the marketing year. The analysis is conducted by constructing a demand and hedonic-type model of the relationship between grades, sizes, and other factors affecting the demand for pears, and then simulating the model to assess the marginal economic impacts of the proposed strategies.

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1. Introduction

Traditionally, winter pears, of which D'Anjou is the leading domestic variety, have been harvested in a single pass through the orchard. Each tree is stripped of its fruit and all fruit are taken to a warehouse where the fruit are stored, graded, sorted, and packed. Some warehouses also sell the packed fruit, while others use sales agents to move the crop. Since cull fruit have very little value, the warehouse focus is entirely on the fresh market.

Legally, the warehouse works for the grower. Typically, a grower will contract annually with a warehouse for a set of services. The set of services varies from house to house, but will include those services identified above and may include others such as field service. Warehouses will assess the grower a handling charge based on the volume of fruit delivered and add a charge for each carton of fruit packed and sold. Generally, it is in the best interests of the warehouse to pack fruit as long as the FOB price equals or exceeds the cost of warehousing and packing.

Until recently, production of D'Anjou pears was sufficiently profitable that growers found it less troublesome to maintain the harvest tradition of stripping trees and letting the warehouse handle all grading and sizing. Unfortunately, the profitability of D'Anjou pears resulted in new plantings of D'Anjou trees. As these trees matured supplies of the fruit increased more rapidly than demand and prices began to fall. The problem of low prices has persisted for several years and the industry is searching for ways to mitigate the problem of low returns.

A preliminary review of annual price data by grade and size suggested that some size/grade combinations were seldom, if ever, able to generate a price sufficiently high to cover the cost of production and warehousing (Schotzko). Smaller fruit, in particular, especially in the lowest grade, were consistently unprofitable.

The principal objective of this study was to analyze the relative profitability of pears by pear size and grade, of which there are twelve sizes and three grades, and to predict the change in overall industry profitability resulting from altering the sales mix among various size and grade combinations as well as altering the distribution of pear supplies over the marketing year.

Because of the way the industry is organized profitability to the industry is a key concern. The elimination of some fruit from the fresh market may improve grower receipts, but could reduce the net returns to warehousing. The combined effect could be reduced industry returns.

To estimate the relationship between size, grade and price, a hedonic-type analysis was conducted that examined both the quantity and quality effects on price and profitability. D'Anjou quality is explicitly measured in the market place by size and the grade standards which include such physical characteristics as firmness, color and defects due to mechanical or other means. Other quality characteristics such as texture and flavor are not included in the standards and are not incorporated in the model.

In a traditional hedonic analysis the focus is on demand for product characteristics, where prices are regressed on quality attributes and other variables and shifters such as consumer characteristics. Estimated implicit prices associated with product characteristics are used to predict prices for heterogeneous commodities, differentiated by varying product characteristic content.

In contrast to a “pure” hedonic technique, this study follows a methodology similar to that used by Chen, Ethridge and Fletcher (1997) and mixes product characteristic information with information on other factors shifting the demand for pears to arrive at a final model of price determination. It is assumed here that wholesalers/retailers (W/Rs) who buy pears are a relatively homogeneous group with similar preferences, so including buyers’ characteristics in the demand equations is unnecessary. Therefore, it is hypothesized that pear prices are a function of fruit size and grade, as well as consumer demand for competing fruit, season, the crop year (since the distributions of the various fruit characteristics are affected by growing conditions each year), and the level of D’Anjou quantities supplied.

2. Institutional and Market Considerations

D’Anjou pears are fully harvested by late September. The fruit are warehoused by approximately 90 packers throughout the Pacific Northwest who receive the harvest in bulk. D’Anjous are then marketed throughout the marketing year, which spans September through July, with the bulk of the sales occurring in the months of December through February. After the packers have deducted their packing charges, the balance of the revenue is returned to the participating growers.

In attempting to model pear price determination on a monthly basis, seasonality in supply and demand over the crop year, as well as changes in quantity and quality of the harvest from one crop year to the next, become relevant considerations. The significance of demand seasonality and crop year quality effects were investigated explicitly in the analysis through the use of indicator variables that discriminated among the seven years of observed data, spanning from 1993 through 1999, with 1993 representing the base year; and among the months during which sales occur in a crop season, with September being the base month. These seasonal and yearly demand shifters may also proxy the seasonal and yearly quantity and quality variability of competing fruit.

Historically, D'Anjous compete in the early fall with Bartlett pears from California (CA Bartletts), and with imported pears (I. pears) from South America beginning in February or March. Bosc pears, along with apples, oranges and bananas compete with D'Anjous throughout the entire D'Anjou marketing year.

In the latter years of the study period imports of pears increased significantly and industry members were of the opinion that those were sufficient to impact prices. Quantity of imported pears was included in the model as an interaction with an indicator variable for those months during which imports were most significant.

Competition between CA Bartlett and winter pears from Washington and Oregon is keenest in those years where, due to a large crop, shipments of the Bartletts were extended in volume and timing well into the typical market season for winter pears. An interaction term was created by the multiplication of an indicator variable for the large Bartlett crop years with fresh shipments of Bartletts during that market season.

A primary objective of this analysis, as requested by industry participants, was to examine the impact on industry profitability of eliminating certain sizes and grades of D'Anjou pears. An auxiliary objective, suggested to the industry by postharvest physiologists specializing in winter pears, was to examine the economic impact of redistributing pear sales so that more pears were placed on the market earlier in the marketing year, and closer to the time when the pears were harvested.

Addressing these objectives requires measuring the rate of demand substitution and elasticities among D'Anjous of different grades and sizes. Ideally, the analysis should then specify the rate at which the price of a specific size and grade of pear is affected by each of the other pear quantities across sizes and grades, which would require the addition of over 40 quantity (by size and grade) variables as explanatory factors in the price prediction relationships. This approach was attempted, but was ultimately found to be infeasible because of the very intensive model parameterization that severely depleted the degrees of freedom and resulted in pervasive insignificance of parameter estimates.

The final specification was more parsimonious, and allowed the price of a specific size and grade of pear to be a function of its own quantity, the total quantity of all three grades of pears available on the market, as well as a host of other variables including prices and quantities of substitutes and seasonal indicator variables. The specification focuses the price analysis on an examination of the rate of own price substitution, the effect of size and grade, plus the impact of overall supply of pears on price, and is discussed in more detail in section 4 ahead.

3. Data

There are three principal grades of D'Anjous in use: Washington Extra Fancies (XFs); US#1s (comprising about 75% of the D'Anjou market); and US#2s, which do not appear to compete directly with XFs and US#1s, and these grades are in the order from highest to lowest in terms of quality, respectively. There is a fourth grade of pears, but the volume of sales for this grade is very small, and this grade was excluded from the analysis.

All of the data in the model relating to D'Anjou transactions were provided by the Pear Bureau. The original data comprised daily observations on D'Anjou pear transactions at shipping point (F.O.B) for the years 1993-1999, and included information on size, grade, quantity sold, destination (whether domestic or export), and month sold. The exact day on which a given sale occurred was unobservable, but the month in which the sale occurred could be identified with accuracy. Therefore, all prices were aggregated up to a monthly level and expressed in terms of weighted average prices by month, size and grade. Weights used in forming the weighted averages were based on quantity shares.

Regarding substitutes for D'Anjou pears, the final model included apples, oranges, bananas, Bosc pears, California Bartlett pears and imported pears. Price data on apples were expressed in U.S. Dollars (USD) per pound per month received by growers for Red Delicious. Prices for oranges were in USD per box in monthly equivalent-on-tree returns received by growers for California Navel, and both the apple and orange price data were obtained from the U.S. Department of Agriculture's publication, *Fruit and Tree Nuts*. Quantities imported of bananas and pears were obtained from the U.S. Department of Agriculture's *World Horticulture Trade and U.S. Export Opportunities*. These volumes are reported in metric tons at port of entry. Data on quantity sold per month of Bosc pears were received from the Pear Bureau.

California pear shipping data are reported in the USDA's *Fresh Fruit and Vegetable Shipments*, where it was assumed that all Northern Californian shipments are Bartletts. These quantity data are reported in 1000 cwt units. There is some limited volume of winter pear production in California, but it is less than 1% of the California shipments.

4. Model Specification and Results

The final model uses a mixed functional form. The dependent variable is in log form, and is explained by a mixture of variables, all of which are in linear form except for pear substitute quantities, which appear in log form. The principal and pragmatic reason for choosing this functional form is that it leads to a well fitting model with statistically significant coefficients. In specifying a model and trying to establish a regression curve through a hyperplane of three or more independent variables (there are twenty-seven for this model) it may be the case that some variables have to be nonlinearly transformed to establish this regression curve. For this model, the best statistical fit, as well as the most rationally interpretable model, was established by taking the natural logarithm of substitute pear quantities for Bosc, CA Bartletts and I. Pears.

The model, where the natural logarithm of D'Anjou price is to be explained, is:

$$\begin{aligned}\ln P_{S,G,m} = {} & \beta_{0G} + \beta_{1G} Qty_{S,G,m} + \beta_{2G} Qty_{All,m} + \beta_{3G} Price_{Apples,m} + \beta_{4G} Price_{Oranges,m} \\ & + \beta_{5G} Price_{Bananas,m} + \beta_{6G} Qty_{Bosc,m} + \beta_{7G} Qty_{I\,Pears,m} + \beta_{8G} Qty_{CABartletts,m} \\ & + \sum_i \beta_{iG} Z_i + \delta_{1G} S_{S,G,m} + \delta_{2G} S^2_{S,G,m} + \delta_{3G} S^3_{S,G,m}\end{aligned} \quad (1)$$

where Z is used to generically denote all of the indicator variables in the model. Upon applying an exponential transformation to both sides of the equation, pear price is scaled by functions of size and quantity. That is, the model is multiplicative in functions of size and quantity and takes the basic form:

$$\begin{aligned}& P_{S,G,m} = \\ & h_g(Z, Qty_{S,G,m}, Qty_{All,m}, Price_{Apples,m}, Price_{Oranges,m}, Price_{Bananas,m}, Qty_{Bosc,m}, \\ & Qty_{I\,Pears,m}, Qty_{CABartletts,m}) \times f_g(Size_{S,G,m}, Size^2_{S,G,m}, Size^3_{S,G,m})\end{aligned} \quad (2)$$

where the f_G and h_G functions are defined as

$$f_G = (S_{S,G,m}, S^2_{S,G,m}, S^3_{S,G,m}) \equiv \exp[\delta_{1G} S_{S,G,m} + \delta_{2G} S^2_{S,G,m} + \delta_{3G} S^3_{S,G,m}] \quad (3)$$

and

$$\begin{aligned}h_g = {} & \exp[\beta_{0G} + \beta_{1G} Qty_{S,G,m} + \beta_{2G} Qty_{All,m} + \beta_{3G} Price_{Apples,m} + \beta_{4G} Price_{Oranges,m} \\ & + \beta_{5G} Price_{Bananas,m} + \beta_{6G} Qty_{Bosc,m} + \beta_{7G} Qty_{I\,Pears,m} + \beta_{8G} Qty_{CABartletts,m} + \sum_i \beta_{iG} Z_i]\end{aligned} \quad (4)$$

where *exp[x]* = $e^x = (2.7182818....)^x$, and

$P_{S, G, m}$ = Average D'Anjou pear price per box for size S, grade G[1], and month m. This is the dependent variable (variable to be explained), expressed in natural logarithmic form and measured in $/box.

Intercept, I_{Year}, $I_{Seasonal}$ = There are six yearly indicator variables, ten monthly indicator variables, and an intercept.

$Qty_{S, G, m}$ = Numbers of boxes shipped of size S, Grade G, and month m;

$Qty_{ALL, m}$ = Total number of boxes of ALL D'Anjou domestic pears (XF's, US#1s, US#2s) shipped in month m;

$S_{S, G, m}$ = Size corresponding to price $P_{S, G, m}$ of pears;

$S^2_{S, G, m}$ = Same as above squared;

$S^3_{S, G, m}$ = Same as above cubed;

$P_{Apples,m}$ = Average Price/pound of domestic apples in month m, in $/pound;

$P_{Oranges,m}$ = Average Price/pound of domestic oranges in month m, in $/box;

$P_{Bananas,m}$ = Average Price/pound of imported Bananas in month m; in $/kg;

$Qty_{Boscs,,m}$ = Total number of boxes shipped domestically of Bosc Pears in month m, expressed in natural logarithmic form.

$Qty_{I\ Pears,\ m}$ = 1000s of metric tons of imported pears in month m, expressed in natural logarithmic form, and multiplied by a yearly indicator variable where I_{year} = 1 for 1998 and 1999, and 0 otherwise.

[1] Grades are G = Extra Fancies, US#1s, or US#2s, and sizes are S = 50, 60, 70, 80, 90, 100, 110, 120, 135, 150, 165, or 180.

$Qty_{CA\ Bartletts,\ m}$ = 1000's of cwts shipped from Northern California in month m, expressed in natural logarithmic form, and multiplied by a year indicator variable where I_{year} = 1 for 1994, 1996 and 1999, and 0 otherwise.

The function of size, f_G, acts as a scaling factor in determining pear prices within the context of the mixed logarithmic model. Thus, for example, as quantity decreases or increases the price is scaled up or down proportional to the function of size. A different function of size is used for every grade of pear, thereby allowing for potentially different effects that size has on pear price as the grade of pear changes. Note that the cubic polynomial form of the size relationship was chosen to allow substantial flexibility[2] in the way size is allowed to affect pear price. In analyzing the regression models, it was found that a quartic polynomial was ineffective in adding additional flexibility to the size-price relationship, and a quadratic polynomial was not sufficiently flexible.

We note here several clarifying comments regarding the form of explanatory variables used relating to substitute fruits. We utilized *prices* of apples, oranges and bananas but *quantities* of Boscs, CA Bartletts and I. Pears. In undertaking this empirical work we have deviated from the typical specification derived from textbook classical economic theory, which states that quantity is a function of price (and other quality variables), and therefore, inversely, price is a function of quantity. Here we have adopted a so-called "mixed" demand specification (as distinct from "direct" or "inverse") in which price and quantity appear on both sides of the equation. This was done for two

[2] By saying that the cubic function of size is highly flexible, we mean that the cubic function allows price to be explained by size in a potentially wide variety of different curvilinear shapes, depending on the signs and magnitude of the estimated coefficients.

principle reasons. The first and most pragmatic reason is that this is the empirical form that led to interpretable and useful models for predicting pear prices with a reasonable degree of accuracy. A second reason has to do with the usefulness of the model for management purposes. The pear industry has considerable control over its own quantities shipped of D'Anjous and Boscs. Additionally, it is likely that the industry can better predict shipments of competing pears, rather than prices of these competing pears.

CA Bartletts and I. Pears have been multiplied by indicator variables. For I. Pears the year indicator, I_{year} , is equal to 1 for crop years 1998 and 1999 and zero otherwise, and for CA Bartletts, the year indicator, I_{year} , is equal to 1 for crop years 1994, 1996 and 1999 and zero otherwise. This is done to allow the effect on D'Anjou prices from imported pears, for example, to be expressed explicitly only for the last two crop years, the assumption being that imported pears did not have a statistically significant explicit impact on D'Anjou prices in the previous five years. An analogous argument was made for CA Bartletts; there is no perceptible statistical impact on D'Anjou prices from CA Bartletts for crop years 1993, 1995, 1997 and 1998, over and above the seasonal effect expressed by the year and seasonal indicator variables. The years for which the indicator variables are equal to one correspond to those years when it appears that shipments of these substitute pears have been unusually high, compared to other years, and it was for these years that a statistically significant impact could be measured.

A further note should be made about choosing the years for which the indicator variables are equal to one. There is only a slight difference in magnitude between imports for 1997 and 1999 and the statistical fit is at least adequate when I_{year} = 1 for all three crop years, 1997, 1998 and 1999. However the statistical fit is superior and the coefficients more precisely estimated when I_{year} = 1 for 1998 and 1999 alone. With respect to the indicator variable choice for CA Bartletts, only the one combination led to an adequate statistical fit, and that is the one being reported.

There were three equations of the form (1) estimated, one for each grade. To allow for the possibility that size might have either a concave or convex relationship with price, a cubic function of size was chosen to provide sufficient flexibility to accommodate such a relationship. *Prices* of apples, oranges and bananas and *quantities* of Boscs are used in the specification of this model, which is a deviation from the usual empirical inverse demand function specification in which only own price and quantity are reversed as dependent and explanatory variables. For this study, the mixed demand specification was used for two principal reasons. The first and pragmatic reason was that this specification led to interpretable and useful models for predicting pear prices with a reasonable degree of accuracy. A second reason related to the usefulness of the model for management purposes. The pear industry has considerable control over its own quantities shipped both for D'Anjou and Bosc pears (controlled atmosphere storage being a primary reason for this flexibility), and little or no control over quantities of substitute fruit. It was thus important, for the purposes of testing various marketing scenarios relating to different shipment strategies, that Bosc and D’Anjou quantities be explicit explanatory factors in the model.

The results of estimating equation (1) are displayed in Table 1. All of the estimated coefficients associated with economic variables have the expected signs and the R^2's indicate that a fairly substantial proportion of variability in the prices is explained by the explanatory variables. An interesting feature of the log-linear function used in the price prediction model is that pear prices can be interpreted as being *proportional* to a function of pear size. In effect, this implies that prices for different sized pears are all linked to some base level of pear prices, with the marginal value of size differences then being determined as percentage markups from the base price level.

The model specification was analyzed for heteroskedasticity, and a Breusch-Pagan-Godfrey test (Mittelhammer, et. al, p.537) suggested that the residual variance might be functionally related to pear size in some form and to some degree. However the estimated parameters from equation (1), without any form of heteroskedasticity correction, were precisely estimated and had defensible economic interpretations. Moreover, it was thought, after various correction attempts led to models that were less defensible economically, that attempting to correct for some unknown or highly tentative functional form of heteroskedasticity would not necessarily lead to more useful estimation results, and in fact had the potential to bias the parameter estimates by imposing an incorrect heteroskedastic structure[3]. Instead, White's heteroskedasticity-robust estimate of the covariance matrix was used to ensure that T-tests and other inferences accommodated whatever heteroskedastic structure existed for the disturbance terms of the model. Testing for various orders of autocorrelation provided no evidence that autocorrelation existed in the models.

[3] See Mittelhammer, Judge and Miller (2000), Chapter 19 for a discussion of the difficulties involved in correcting for heteroskedasticity in the absence of strong a priori knowledge regarding its functional structure.

Size was found to be a very important determinant of price, and the relationship between D'Anjou prices and pear size was quite stable across pear grades. Estimated coefficients indicate that optimal pear size, when all other variables are held constant, is in the 80 to 90 range, which are pears that are medium-large in physical size. The estimated relative value of various sized pears, holding all other variables constant, can be defined by first isolating that portion of equation (1) related to the size effect (in equation 3).

The values for all pear sizes, relative to size 50 which is the *largest* pear in physical size (sizes range from 50 to 180), can then be calculated as in equation (5),

$$f_S^*(S) = \frac{f_S^{(S)}}{f_S^{(50)}} \tag{5}$$

where $f^*_s(S)$ is a function depicting the value of size S pear *relative* to size 50. For XFs the optimal size pear, holding all other factors constant, is approximately 80, which is a medium- to- large size. The optimal size for US#1s and US#2s is also approximately 80. Figures 1 and 2 summarize graphically the price level of pears of various grades, expressed relative to pears of size 50, for the XF and US#1 grades. The figure for US#2s follows a similar pattern.

Table 1. Statistical Results for Domestic Pear Price Models

Variables	Coefficients for Extra Fancies	Coefficients for US#1s	Coefficients for US#2s
Size S	0.08485672	0.04661962	0.03928470
Size S^2	-0.00078848	-0.00041781	-0.00033668
Size S^3	0.00000217	0.00000104	0.00000082
$Qty_{S,G}$	-0.00000957	-0.00000131	-0.00000353
$Quantity_{All}$	-0.00000026	-0.00000040	-0.00000036
$Price_{Apples}$[1]	2.25036810	2.36755160	2.80281910
$Price_{Oranges}$	0.02910555	0.03373817	0.03224593
$Price_{Bananas}$	1.53805370	1.50253210	1.60564090
$Ln(Qty_{Bosc})$	-0.00836514*	-0.01337349	-0.02318695
$Ln(Qty_{CA\ Bartkett})$	-0.010837636*	-0.014503156	-0.023233694
$Ln(Qty_{I\ Pears})$	-0.035792462	-0.023377151	-0.018315126*
Intercept	-1.0958977	0.069555979**	-0.039913723**
Crop Year I_{94}	0.20439879	0.27652315	0.28628038
Crop Year I_{95}	0.059804206	0.11535481	0.11659854
Crop Year I_{96}	0.31717669	0.32034214	0.30729502
Crop Year I_{97}	-0.027836148**	0.040311167*	0.059027991*
Crop Year I_{98}	0.44933665	0.37131306	0.37473978
Crop Year I_{99}	0.36457867	0.29910751	0.2647362
Month I_{OCT}	0.13647365	0.14997146	0.21700462
Month I_{NOV}	0.13866248	0.19559075	0.23370693
Month I_{DEC}	0.1962214	0.3209207	0.32043999
Month I_{JAN}	0.22692715	0.36429748	0.36772465
Month I_{FEB}	0.26657336	0.42282848	0.41165647
Month I_{MAR}	0.25967018	0.39441082	0.37500461
Month I_{APR}	0.22349965	0.33484033	0.33285178
Month I_{MAY}	0.23761103	0.31828426	0.30890465
Month I_{JUN}	0.26377975	0.24708849	0.26374695
Month I_{JUL}	0.16897016	0.13975663	0.12788539
R-Squared	0.7918	0.7275	0.6526

** Indicates p-value greater than .25. * Indicates p-values between .02 and .10. All other coefficients significant at the .01 level or better.

[1]Apple prices are measured in $/lb. Oranges prices are in $/box. Banana prices are in $/kg.

Figure 1. Relative Effects of Size on Prices for Extra Fancy D'Anjous

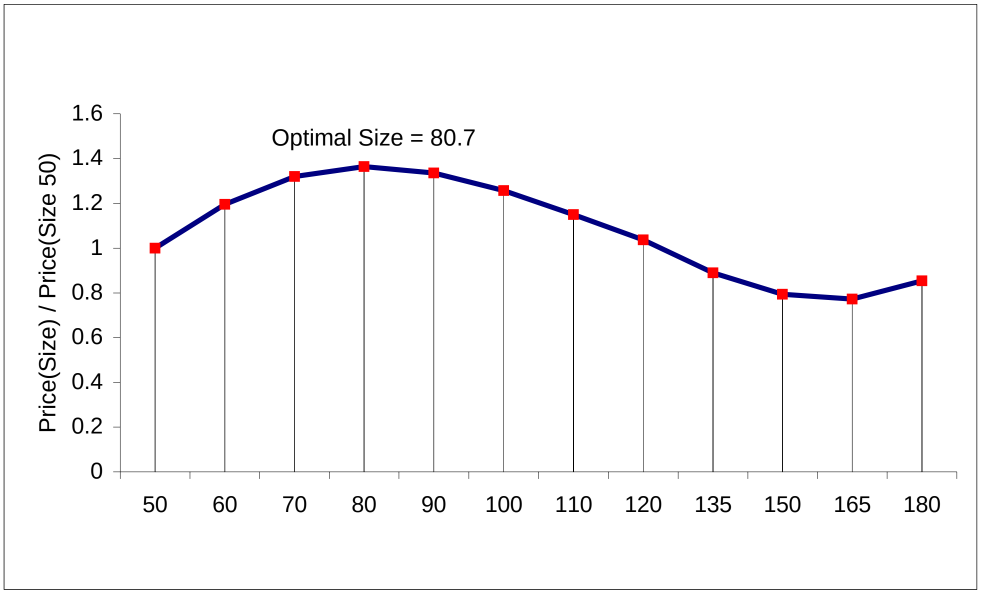
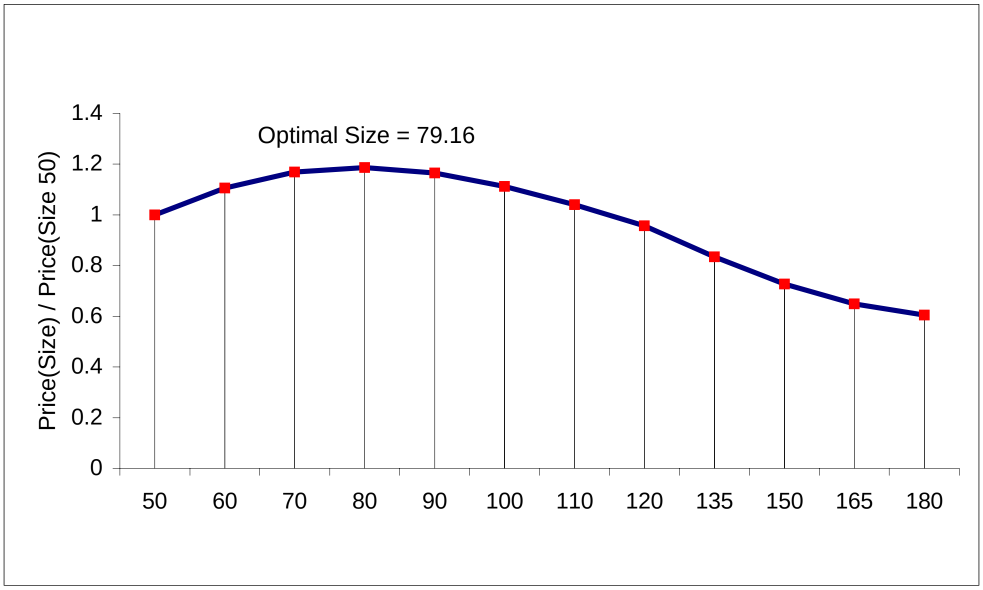


Figure 2. Relative Effects of Size on Prices for US#1 D'Anjous



When *predicted* prices (as opposed to relative prices) are graphed based on equation (1), the curves retain the general shape depicted in Figures 1 and 2 but are attenuated in terms of degree of curvature due to the effect of price changes induced by changes in other market factors besides pear size. Figures 3 and 4 depict average predicted prices for US#1s and Extra Fancies across all months as a function of pear sizes for crop year 1999. The straight line indicates approximate average growing and packing cost per box and the figures illustrate a general point that can be made upon observing results across all three grades and years: pears of size 135 and above (corresponding to *small* sizes) are priced below average cost, and only sizes 50 through 120 appear to be profitable for the industry, on average. The dotted lines in the graphs contain 95% confidence intervals for prices, where variance is calculated based on a log-normal distribution for the residual terms. In comparing Figures 3 and 4, note that it is evident that expected prices for XFs are higher than for US#1s, as would be anticipated a priori.

Figure 3. Estimated Domestic Prices vs. Costs for Extra Fancy D'Anjou Pears '99 Crop Year

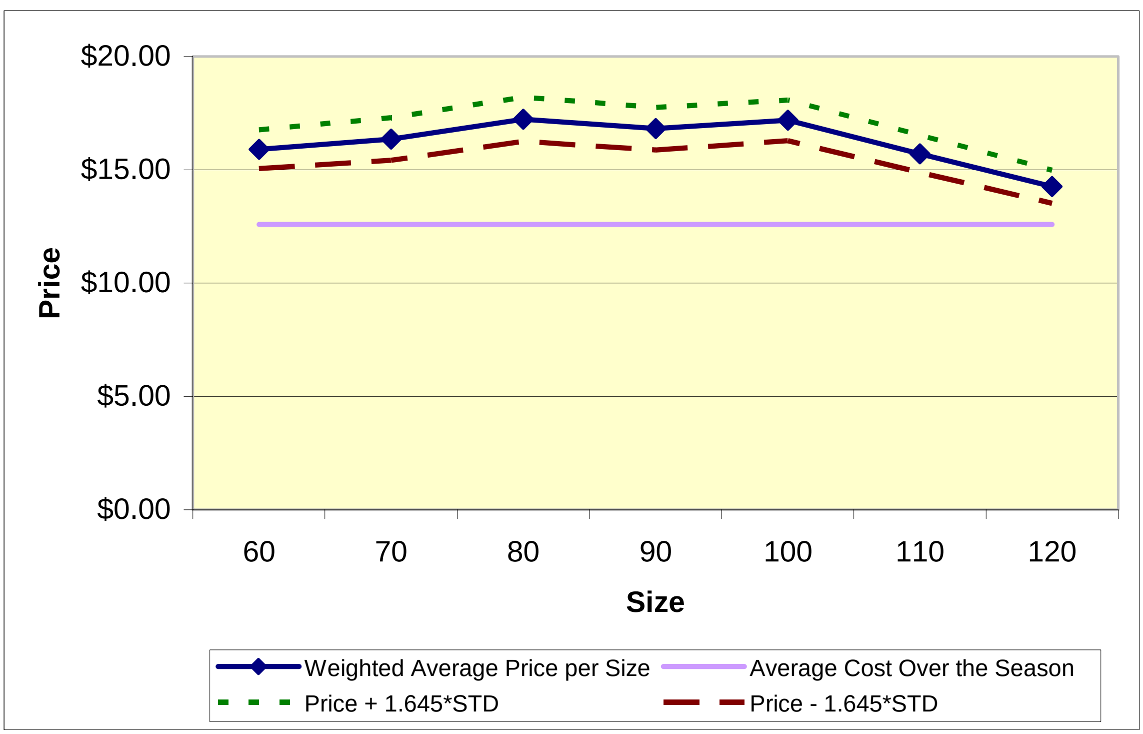
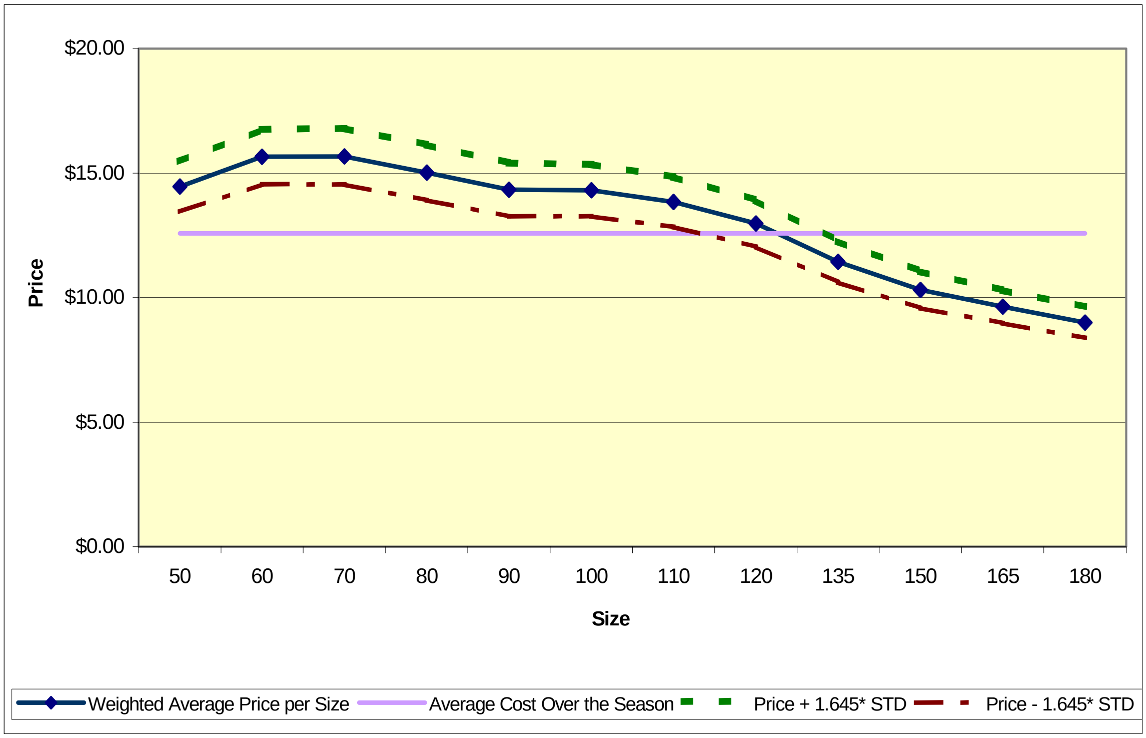


Figure 4. Estimated Domestic Prices vs. Costs for US#1 D'Anjou Pears '99 Crop Year



Price Flexibilities

The price flexibility with respect to own quantity is calculated by dividing the percentage change in price by the percentage change in the quantity, which, in the current model, can be represented by

$$\frac{\%\Delta P_{S,G,m}}{\%\Delta Q_{S,G,m}} \approx \frac{Q_{S,G,m}\partial P_{S,G,m}}{P_{S,G,m}\partial Q_{S,G,m}} \equiv (\beta_{1G} + \beta_{2G}) * Qty_{S,G,m} \equiv Flexibility. \tag{6}$$

As $Qty_{S,G,m}$ increases or decreases the price flexibility increases or decreases. This means that the price flexibility is larger when a larger quantity of a certain size and grade is shipped in a month than when a smaller quantity is shipped, which makes sense since a one percent change in a larger shipment is a larger nominal change in quantity than a one percent change in a smaller shipment.

In contrast to the own price flexibility, the price flexibilities for substitute pears (Boscs, CA Bartletts or imported pears) are constants. For example, a 1% increase in boxes of Bosc would lead to a constant .0134% decrease in D'Anjou US #1 prices, all else held constant (see Table 5.1). The formula for the price flexibilities with respect to each of these competing pear quantities is of the general form:

$$\frac{\%\Delta P_{S,G,m}}{\%\Delta Q_{jG}} \approx \frac{Q_{jG}\,\partial P_{S,G,m}}{P_{S,G,m}\,\partial Q_{jG}} = \beta_{jG} = Flexibility,\ for\ \ j = Bosc, IPears, CABartletts. \quad (7)$$

Table 2 Price Effects for Given Changes in Explanatory Variables

	Price of Extra Fancy	Price of US#1	Price of US#2
Price $_{Apple}$	↑ in \$.01/lb ⇒ ↑2.25%[1,2] in price per box	↑ in \$.01/lb ⇒ ↑ 2.39% in price per box	↑ in \$.01/lb ⇒ ↑ 2.8% in price per box
Price $_{Orange}$	↑ in \$1/box ⇒ ↑ 2.91% in price per box	↑ in \$1/box ⇒ ↑ 3.37% in price per box	↑ in \$1/box ⇒ ↑ 3.23% in price per box
Price $_{Banana}$	↑ in \$.01/kg ⇒↑ 1.54% in price per box	↑ in \$.01/kg ⇒ ↑ 1.50% in price per box	↑ in \$.01/kg ⇒ ↑ 1.61% in price per box
Qty $_{All\ D'Anjou}$	↑ 10,000 boxes ⇒ ↓ 0.257%[3] in price per box	↑ 10,000 boxes ⇒ ↓ 0.4% in price per box	↑ 10,000 boxes ⇒ ↓ 0.36% in price per box
Qty $_{G,S}$	↑ 10,000 boxes ⇒ ↓ 9.83% in price per box	↑ 10,000 boxes ⇒ ↓ 1.71% in price per box	↑ 10,000 boxes ⇒ ↓ 3.89% in price per box
Qty $_{Bosc}$	↑ 1% in boxes ⇒ ↓ 0.008% in price per box	↑ 1% in boxes ⇒ ↓ 0.013% in price per box	↑ 1% in boxes ⇒ ↓ 0.023% in price per box
Qty $_{Imp\ Pears}$	↑ 1% in boxes ⇒ ↓ 0.036% in price per box	↑ 1% in boxes ⇒ ↓ 0.023% in price per box	↑ 1% in boxes ⇒ ↓ 0.018% in price per box

[1]Apple prices are measured in \$/lb. Oranges prices are in \$/box. Banana prices are in \$/kg.

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[1]

[2] To calculate this: (.01 x 2.250) x 100 = 2.25%

[3] To calculate this: (10,000 × -.000000257) x 100 = .257%

5. Simulation of Culling and Market Timing Strategies

Given the result that fruit smaller than size 120 are estimated to be unprofitable for the industry, a simulation was run to examine the impact on profitability, for the 1993 through 1999 crop years, of eliminating these sizes from the market for all three grade categories. A scenario was examined in which the historical shipping levels, seasonal patterns, and all other market factors were maintained as they were in each of those years, except that all size 135-180 shipments were deleted from the marketing mix. In doing this, between 275,000 and 575,000 cartons of fruit, depending on the crop year, were effectively eliminated from the market place each year. On average, 7.8% of the D'Anjou volume was diverted.

Recalling the results in Table 1, it is clear that the impact on per unit prices of removing size 135-180 shipments will be positive because the quantity effect on price is negative. For example, each 10,000-box decrease in output would increase domestic US#1 prices by about .26%. Therefore, eliminating 275,000 to 575,000 boxes would be projected to increase average prices for US#1s by 7% to 15%. In addition to the supply impact on price and profitability, there is a positive quality impact on prices as well. Recall that smaller pears are generally priced below average costs, it is evident that eliminating the small sized fruit also eliminates pears which are not likely to earn prices equal to or above the cost of production and warehousing. Aggregating across all three grades and over the seven-year period, the scenario ultimately results in an estimated increase in annual average profits of approximately 9%.

A second scenario was examined, based on recommendations by Chen and Varga (1999), that closely approximates the physiological storage capabilities of

D'Anjous. In this scenario, 40% of total annual production in each of the seven years was reallocated equally among the first four months of the market season, September through December, while holding to the original pear size distribution available from each year's harvest. Another 30% of total annual production was redistributed between January and February, and 7.5% was redistributed to each month from March through June. Unlike the previous scenario, the total annual relative pear size distributions were not altered for this experiment. This marketing strategy represents a significant change towards increasing pear shipments early in the marketing year and shortening the shipping season compared to historical shipping patterns. The results of this experiment resulted in an estimated average annual improvement in profitability of about 4% per year.

A final simulation was performed to evaluate the combined effect of altering the shipping season and eliminating small fruit from the domestic market. The combined results suggest that significant synergies may exist when pursuing both changes at once. The combined effects indicate that net revenues to growers would increase by almost 25%, nearly doubling the individual effects of the two alternatives. Table 2 shows the annual net revenues for each of the scenarios tested.

Table 3. Projected Net Returns to D'Anjou Industry

	Historical	Small Fruit Eliminated	Adjusted Shipping Pattern	Both
	$	$	$	$
1993	-5383958	-9099927	-5926743	-2444351
1994	10515215	12432181	10262532	12080860
1995	11755207	13559417	12207406	13964390
1996	24383770	25501858	26320131	27323658
1997	7312078	8615905	7081054	8357452
1998	5526210	7021931	637462	7812908
1999	5381982	6790818	5753542	7214790
Average Improvement over History		8.9%	4.3%	24.9%

6. Summary and Conclusions

An economic analysis was performed to examine the effects of size and grade on expected D'Anjou prices. Optimal sizes across all three grades, when all other variables are held constant, are approximately size 80, a finding that provides statistical confirmation of expectations held by many industry's participants. When prices are predicted allowing all explanatory factors to change as opposed to being held constant, the curvature of the size/price relationship is attenuated, and moreover it was found that sizes 50 through 120 are not unprofitable for the industry. Using a market simulator based on the estimated price prediction equations, a marketing scenario was tested to examine the impact on profitability of culling all sizes smaller than 120. Under this scenario, profitability would have increased by about 9% for the industry and this increase in profitability was due to two factors: the positive impact on price from constricting supply, and the positive impact on profitability from eliminating pears for which prices are below the average growing and handling costs, as predicted by the size/price relationship. An alternative non-culling strategy of marketing more pears much earlier in the marketing year was predicted to increase industry profitability by 4%. Combining the elimination of small fruit and a shorter shipping season increased net revenues by some 25%.

One key implication seems to emerge from these results. The industry has been reasonably successful in achieving optimum size and shipping patterns vis-à-vis market preferences. Future gains in the market are more likely to come from the optimization of multiple objectives. Only limited benefits may be gained from pursuing single goal optimization.

This study utilized a combination of demand and hedonic-type analyses to provide industry participants with a management tool that can be used to attain valuable insight into the marketing dynamics of a horticultural crop. The marketing simulations performed with this tool, and reported here, suggest to the industry that there may be significant profit opportunities available from altering size, quantity, and timing of pear sales in the domestic U.S. market.

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