Staff Paper

Optimal Supply Rules in the Tart Cherry Industry

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Executive Summary

This report examines optimum supply formula (OSF) in the tart cherry industry. The OSF is a tool for stabilizing market prices as authorized by a federal market order (FMO). The current OSF sets the optimum supply volume (OSV), or free sales of tart cherries in a given harvest year equal to the average sales of the three prior years plus 10 percent. This report evaluates the current OSF relative to several alternative formulations. The analysis reviews data to identify sources of market stability, analyzes the demands for tart cherries and compares the current OSF to the alternatives.

Historical data indicates that the primary sources of market and price instability are year-to-year changes in grower yields. Supply-side instability is primarily weather-related. Crop shortfalls appear to be caused largely by adverse weather in the early spring. In contrast to supply, demand for tart cherries appears relatively stable from year to year. Despite its stability, tart cherry demand is inelastic — a small reduction in quantities available results in a larger increase in what buyers are willing to pay for tart cherries. As a result, demand tends to accentuate market price changes resulting from changes in the quantity supplied.

The analysis used data from past years to estimate the demand relationship between average tart cherry prices and available quantities of tart cherries during a crop year. The analysis indicates that a change in quantity supplied brings about a demand price change that is about twice the size of the change in quantity and opposite in sign. This means that a 5 percent increase in marketed yield results in a 10 percent reduction in market price. A 5 percent reduction in marketed yield results in a 10 percent increase in market price. The net result is that the inelasticity of demand magnifies by about two times the market price changes that result from weather-induced variations in yield.

Alternative specifications of the OSF have a potential for reducing the negative effect of an extreme harvest shortfall on future supplies.

i. The simplest alternative rule is simply to delete the extreme shortfall year from the OSF and replace it with sales from a prior year. A deletion rule increases the average free percentage by about 2 percent and reduces the buildup of reserves by an average of 13 percent per year.
ii. A second alternative is to reduce the effect of an extreme production shortfall year on the OSF. The simulation implemented this second alternative by setting the OSF to an average of the three-year average OSV with and without the extreme shortfall. The effects of this second OSF lie midway between those of the current OSF and a simple deletion rule. It results in sales, prices and other metrics between those of the current OSF and the prior experiment.
iii. The simulation also indicates that a market price stabilization rule may be beneficial. The price stabilization rule is based on the supply requirements that stabilize prices from one year to the next. In the simulation, the price objective was set to the average tart cherry price for growers during the period 1997-2009. The price stabilization OSF reduced average annual contributions to reserves and increased average total sales by almost 5 percent.

It is possible to combine the alternative OSFs to take advantage of their different characteristics. A combination can take advantage of the benefits of two or more rules and soften their less beneficial features. For instance, increasing the number of years in the current moving average OSF from three to four would increase market stability. However, the same change in the number of years also lengthens the numbers of years affected by an extreme shortfall in production. To get the benefits of stability without the increased impact from extreme shortfalls, the moving average rule change may be combined with a rule that deletes an extreme shortfall. With the combined rule, stability is enhanced, market trends are preserved and the negative impacts of extreme shortfalls are avoided.

A significant benefit of the FMO is the extent to which it allows growers, processors and industry stakeholders to share market information. The FMO sets up collaborative institutions for the development of the OSV, collection and distribution of market statistics, and discussion of industry issues and opportunities. The CIAB compiles and publishes market statistics that give stakeholders an opportunity to study and understand larger market trends and influences. These FMO institutions and activities enable growers and processors to obtain better information about sales and investment prospects than would likely be the case without the FMO.

The analysis finds that the tart cherry industry has potential opportunities for improving its OSF and for developing market strategies that better reflect the sales and growth opportunities of various product lines and consumer demand categories. Better data is needed to take advantage of these opportunities. Better data is needed that affords matching precise measures of grower prices and processor selling prices by product line with grower output and product movement. A thorough analysis that

To evaluate how product line prices respond to changes in marketed quantities and whether OSV for specific product lines would improve sales, net returns and industry growth. Existing data reveals too little information about price, quantity and quality relationships to support the high reliability needed for designing OSF specific to the major product lines. To develop better data, the industry needs to give careful consideration to how data that is now proprietary to individual firms may be shared and analyzed at the industry level.

Optimal Supply Rules in the Tart Cherry Industry

The tart cherry Marketing Order and Agreement No. 930 (FMO) seeks to stabilize tart cherry prices in the United States by controlling tart cherry sales volumes (Federal Register, 2011, p. 10474). The FMO applies to production areas in seven states: Michigan, New York, Pennsylvania, Oregon, Utah, Washington and Wisconsin. The FMO establishes procedures to determine an annual optimal supply volume (OSV) for domestic tart cherry sales. The current OSV is set equal to the average of the three preceding years' sales, with adjustments for carry-in from previous years and other factors. The purpose of this study is to evaluate the properties of the current three-year average optimal supply formula (OSF) relative to alternative formulations. Alternatives include shortening or lengthening the number of years in the average, discounting or removing years affected by extremely low production, and building in demand-based factors.

The analysis examines whether the current OSF may be modified to better address factors that lead to price instability in the domestic tart cherry market. Three factors contribute to price instability.

First, tart cherry production can vary greatly from year to year because of transitory weather conditions. In 2002, for instance, a late spring freeze reduced U.S. production to only 20 percent of the 2001 production level. The current OSF attempts to dampen the market price of production variability by setting free sales, or OSV, to the average of the three prior years' sales. When one of the three prior years' sales is reduced because of extremely low production, that low production level becomes a permanent damper on future free sales, regardless of growth in either supply or demand in those future years.

The second factor is inelastic supply. Inelastic supply means that production makes only small adjustments in response to large price changes. Tart cherry orchards take years to establish, so productive acreages and production do not increase rapidly in response to higher prices. Once established, productive acreages yield tart cherries for many years and at a relatively low variable cost. Hence, sharply lower prices do not result in sharp reductions in production.

The third factor is inelastic demand. Tart cherry demand and sales at the grower and processor levels are derived from products at the consumer level. Tart cherries are an ingredient of consumer products such as pies, baked goods, snacks and juices. A change in tart cherry prices affects the prices of consumer products by less than the percentage change in tart cherry prices. Consumer demands for food products tend to be price-inelastic and derived demands are more elastic than demands at the retail level. Together, the three factors — weather-induced production uncertainty, inelastic supply and inelastic demand — create a market situation well-recognized for price instability and its financial implications.

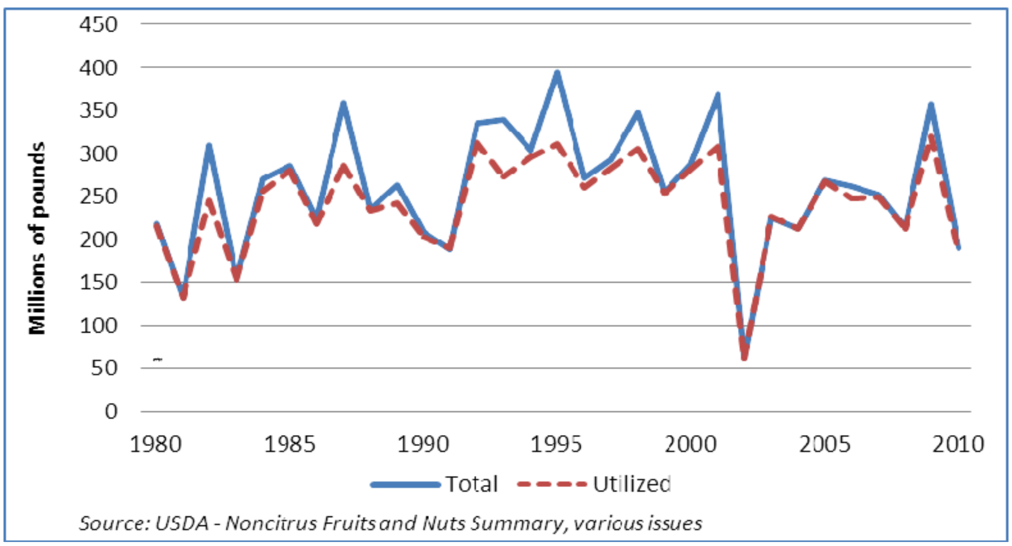
Alternative OSFs are developed with the objective of reducing price variability while enabling the industry to adapt to changing consumer demands and product innovations. A central focus of the alternative OSFs is whether and how to incorporate weather-related extreme shortfalls in production. Two alternatives change the number of years of sales that enter into a moving average OSF. The first alternative reduces the number of years in the average to two; the second alternative increases the number of years in the average to four. A third alternative OSF simply eliminates extreme production shortfalls from the three-year moving average. The fourth discounts the effect of an extreme shortfall on a three-year moving average OSF. The fifth alternative addresses inelastic demand directly by incorporating the price responsiveness of demand into the allowable supply volume. The current and alternative OSFs are compared within a dynamic model that simulates year-to-year market conditions on the basis of actual market conditions in the past several decades. The OSFs are compared with respect to their effects on total sales, prices, surplus cherries, and free and restricted percentages.

The report is organized in three sections. The first section analyzes trends and instabilities in the domestic tart cherry market. The analysis substantiates the roles of both supply and demand in market price instability. Weather-induced variations in production appear to be the primary source of instability, but the absence of elasticity in tart cherry demand accentuates the price effects of supply variation. Inelastic demand magnifies the percentage change price by an amount greater than the percentage change in quantity. Thus, a 20 percent reduction in sales is likely to result in a greater than 20 percent change in price. The degree of magnification depends on the price responsiveness of demand.

The second section analyzes demands for tart cherries. A key issue here is to evaluate the price responsiveness of demand so that this may be built into the fifth alternative OSF. The section also gives careful consideration to whether there are distinct demands for various tart cherry product lines. The analysis suggests that demands are indeed different, but deficiencies in the data prevent a precise determination of the differences in product line demands. Building product line differences into an alternative OSF requires better and more precise data on product line quantities, sales and prices than are publicly available.

The final section compares the current and alternative OSFs on the basis of the historical simulations.

Figure 1. Total Cherry Production and Utilization, 1980-2010.



1. Trends and Instabilities in the Domestic Tart Cherry Market

This section examines trends and instabilities in the domestic tart cherry market. The analysis focuses on production by growers, quantities sold by processors and prices at the grower level. An important feature of the market is that tart cherries are a tree crop. The overall acreage of tart cherry orchards varies little from year to year. Tart cherry production, however, can vary dramatically with transient weather conditions during the spring when the trees begin to blossom. Warm conditions in late spring followed by a late frost can result in significant losses of yield and production. The market and price effects are then magnified by the relatively inelastic demand for tart cherries.

Figure 1 plots annual tart cherry production in millions of pounds by year from 1980 to 2010. Tart cherry production reached a peak of 396 million pounds in 1995. In the following year, production dropped by one-third to 272 million pounds. From 1997 to 2000, production varied between 256 million and 348 million pounds. In 2001, production was 369 million pounds, but it fell in 2002 to an extreme low of 62 million pounds. In annual crops, such variations in production, when they occur at all, are often due to changes in the number of acres planted.

Figure 2. Trends in Total Tart Cherry Fruit-Bearing Acres, 1992-2010.

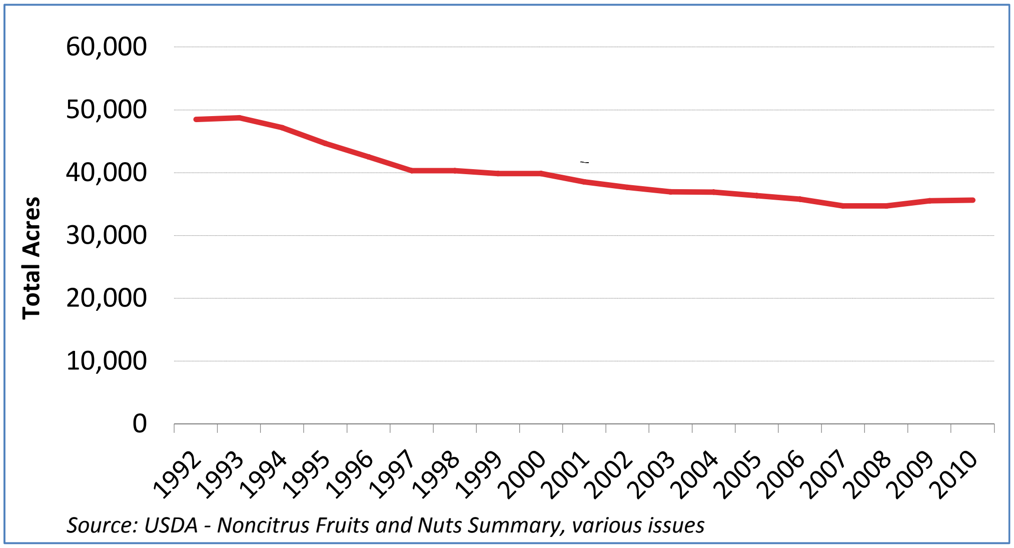


Figure 2 underscores the fact that acres of tart cherry orchards vary little from year to year. Bearing acres declined steadily from 1992 to 2007, but there is no noticeable random variation from year to year.

Figure 3. Trends in Average Tart Cherry Yields, 1992-2010.

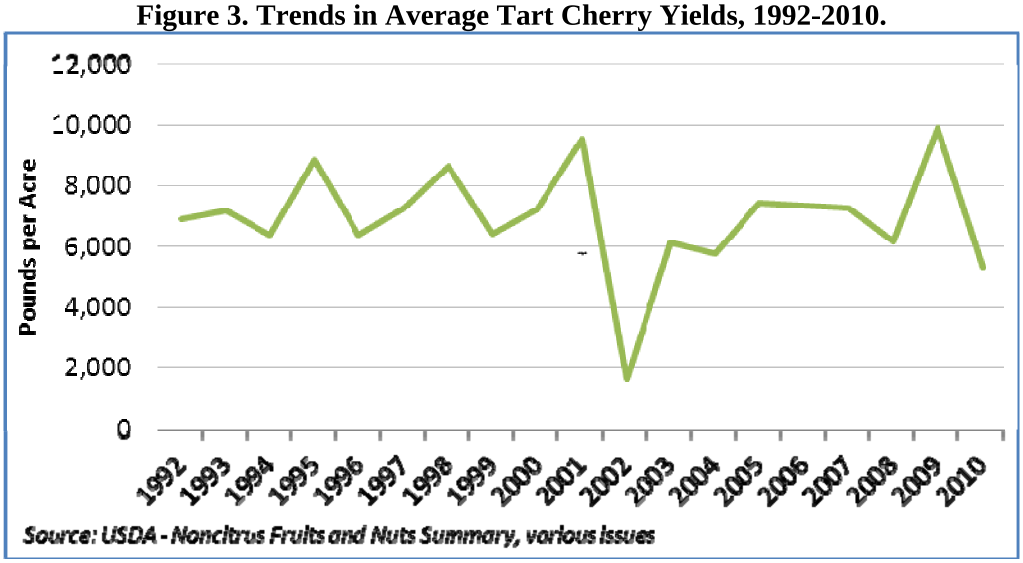


Figure 3 plots tart cherry yield per acre from 1992 to 2010. Tart cherry production is yield per acre multiplied by the number of bearing acres. Bearing acres show only a slight and steady decline over time, so the sharp weather-related variations in yields shown in Figure 3 are the dominant driver in the variation in annual production. Such variation is likely to differ by regions.

Figure 4. Tart Cherry Production by State, 1999-2010.

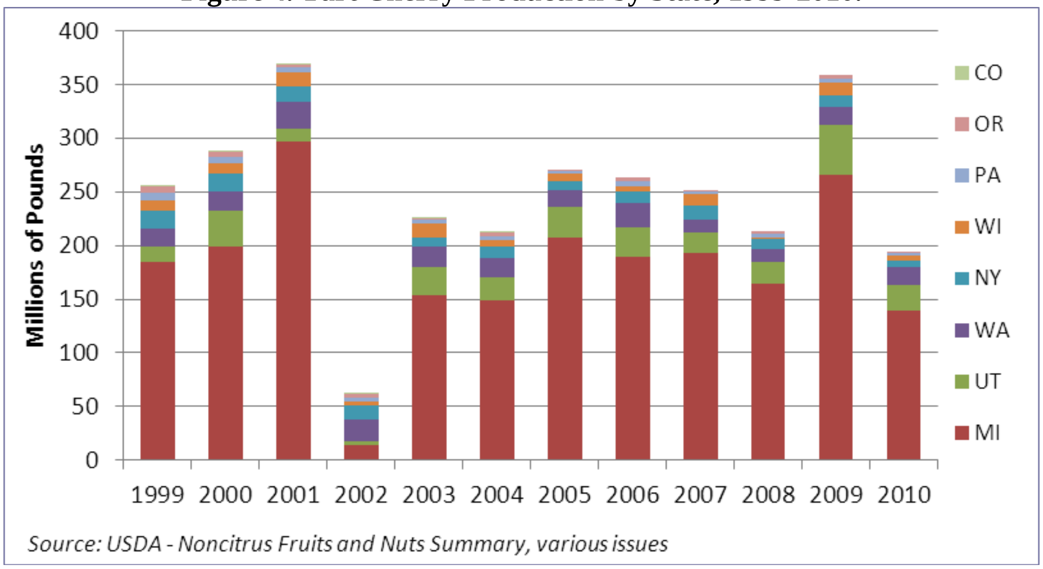


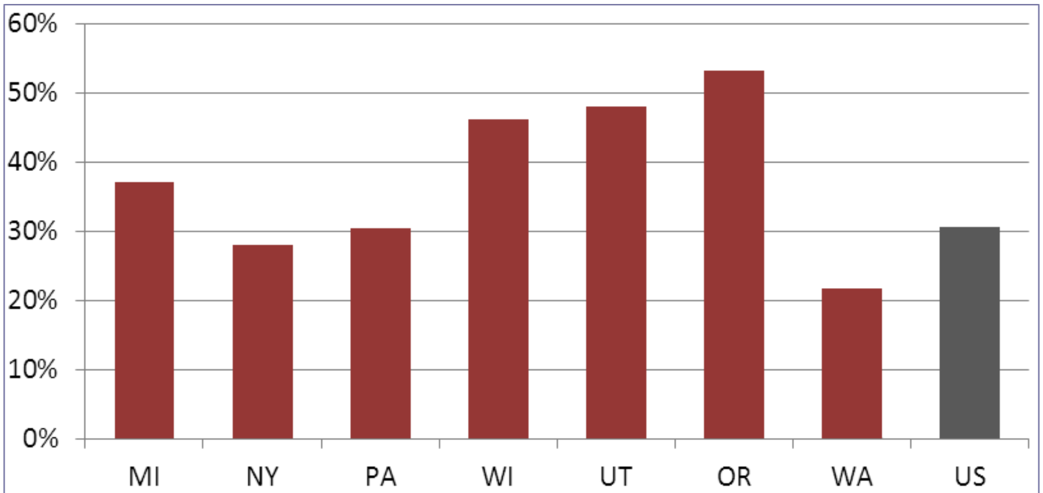
Figure 4 shows the contribution of the eight producing states to U.S. production from 1999 to 2010. Michigan production averaged 184 million pounds per year and was the largest of the seven states, accounting for about 70 percent of U.S. production. Utah was the second largest producer, with production averaging about 23 million pounds or about 9 percent of U.S. production.

Figure 4 shows that each of the eight states experiences substantial variation in annual production. Supply conditions in the United States are especially sensitive to growing conditions and production in Michigan, however. For example, in 2002, a late-spring freeze damaged the blossoming orchards in Michigan. As a result, the 2002 harvest in Michigan was only 5 percent of the 2001 harvest so that total production in the eight states subject to the FMO fell to about 20 percent of the 2002 harvest. Sensitivity of market supplies to Michigan growing conditions, especially an event as transient as a late-spring freeze, is a major factor in supply instability of the tart cherry market.

Figure 5 graphs standard deviations in production between 1999 and 2010. Standard deviation is a statistic that measures the average annual deviation from mean production. As percentages of mean production, the measures graphed in Figure 5 show average annual deviations relative to average production levels.

Figure 5 shows that the average annual deviations are substantial. Production levels in Oregon, Utah and Wisconsin show the largest deviations relative to average production. In Washington, Utah and Michigan, the average annual deviation in production ranges from 46 to 52 percent of average production. Washington exhibits the lowest annual variation — just over 21 percent of average production. The average annual production deviations in the two largest producing states, Michigan and Utah, are both larger than the average annual production deviation for the United States as a whole.

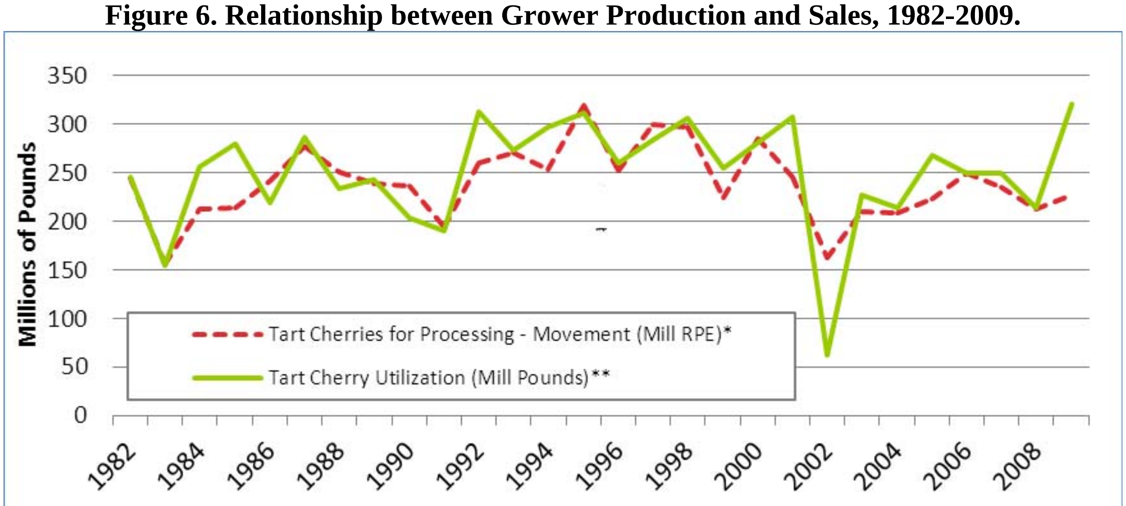
Figure 5. Standard Deviation of Regional Production Divided by Regional Mean Yield, 1999-2010.



Source: Calculations from U.S.D.A. Non Citrus Fruits and Nuts Summaries, 2000-2011.

The relatively low average annual deviation for U.S. production relative to the average of the individual state deviations indicates that variations in state-level production are not positively correlated and may be negatively correlated. That is, in a year when production is lower than average in one state, production in another state is likely to be higher than average.

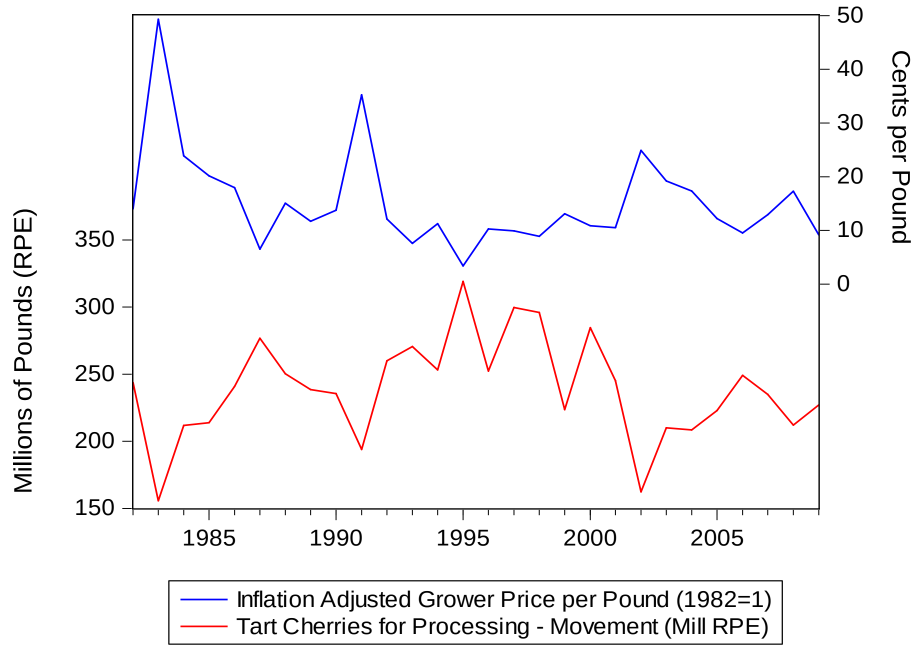
Figure 6. Relationship between Grower Production and Sales, 1982-2009.



** Source: Calculations from U.S.D.A. Non Citrus Fruits and Nuts Summaries, 2000-2011*
*** Source: Cherry Marketing Institute, Inc., Red and Tart,and Sweet Cherry Crop Statistics and Market Analysis: 2010*

Figure 6 plots the relationship between tart cherry production and tart cherry sales. Tart cherry production is measured by utilization, also measured in millions of pounds. Tart cherry sales are measured by the quantity of tart cherries used in processing, so-called movement in millions of pounds.[1] Figure 6 shows that there is a close relationship between annual production and annual sales. The difference between sales and production is composed of shrinkage and entries into and withdrawals from reserves. In most years, shrinkage and changes in reserves are relatively small so that sales and production are highly correlated. Large deviations between sales and production appear limited to extreme production shortfalls as in 2002 and production surpluses as in 2009.

Figure 7. Relationship between Grower Price and Production Utilization, 1982-2009.



Source: Cherry Marketing Institute, Inc., Red and Tart, and Sweet Cherry Crop Statistics and Market Analysis: 2010

Figure 7 shows the inverse relationship between tart cherry sales and inflation-adjusted, tart cherry prices that arises from demand. The economic concept of demand is not just a quantity demanded but an inverse relationship between quantity demanded and price. When production is low and quantities available for sale are in short supply, buyers tend to bid up prices and prices are relatively high. When production is high and larger quantities available for sale, suppliers may work to entice additional sales by offering terms of sale and prices that are advantageous to buyers. Figure 7 shows a distinct inverse relationship between quantities and prices — prices are high when supplies are low, and prices are low when supplies are high.

The inverse relationship between processed cherry sales and processed price was estimated statistically using a regression procedure. The regression used a double-logarithmic form with CIAB total processed sales as the dependent variable and USDA aggregate processed prices as an independent variable. Personal income, the aggregate prices of substitutes and a time trend were included as additional independent variables.

[1] Product movement and sales are used interchangeably throughout this report unless stated otherwise.

The estimates indicate that the change in tart cherry prices is about twice the size and opposite in sign from a change in sales. For example, a 20 percent increase in tart cherry sales results in a 40 percent reduction in tart cherry price. Conversely, a 20 percent reduction in tart cherry sales results in a 40 percent increase in tart cherry price. The magnified effect of quantity on price is due to an inelastic demand. Tart cherry demand responds inelastically to a change in quantity, so the change in price is greater in magnitude than the change in quantity.

The analysis indicates that both the supply and demand sides of the tart cherry market contribute to the instability of tart cherry prices. Year-to-year production variations originate with transitory weather conditions in the eight producing states. These transitory weather events have significant impacts on state-level production, but in most cases, the impact on U.S. supply is small because most states produce less than 10 percent of the U.S. harvest. Michigan, however, averages more than 70 percent of U.S. production. An occasional weather event in Michigan can devastate both Michigan and U.S. production, resulting in substantial effects, positive and negative, on U.S. tart cherry sales. Changes in sales are magnified by inelastic tart cherry demand. The result is price instability of roughly twice the magnitude of the changes in sales.

2. Tart Cherry Demand Estimates

This section reports estimates of the demands for tart cherries. The key relationship of interest is how the price that buyers are willing to pay varies with the quantity of cherries sold. It is this price-quantity relationship that magnifies year-to-year changes in supply-side production and sales. An estimate of this demand-side magnification effect can be built into an alternative OSF. The objective of this latter type of alternative OSF would be to mathematically offset the magnification effect and achieve greater price stability.

The demand analysis estimates demand relationships at two levels. The first is the product line level. Tart cherries are processed and sold in distinct market segments. These segments are supplied with five product lines: individually quick frozen tart cherries (IQF), canned, 5+1, pie-fill and other forms, including small quantities of fresh tart cherries. The purpose of the product line analysis is to determine whether product line demands may be different enough to warrant product line segmentation of an OSF. It turns out that product line demands do appear to be quite distinct — product line prices respond differently to quantities supplied, prices of alternative commodities such as apples and sweet cherries, consumer income and time trends. Unfortunately, though the publicly available data are sufficient to indicate demand differences across product lines, such data are not adequate for precise estimation of the demand coefficients. Hence, the product line coefficients are not reliable enough to build them into an OSF that distinguishes demand by market segment.

The second level of analysis examines aggregate tart cherry demand. Aggregate demand is the relationship between tart cherry price and the overall quantity of tart cherries supplied. This aggregate demand relationship is used to develop and evaluate an alternative OSF as described in the next section.

2.a. Product Line Demands

Product line demands were estimated as a mathematical relationship between the quantity of product line sales in a given year and the average annual price for a specific product line. Quantity of sales within a specific product line is the dependent variable in the relationship, and price is an independent variable determining the quantity demanded.

Product line demands also included other factors that shift and modify the basic relationship between tart cherry quantities and tart cherry prices. These other factors include the prices of apples and sweet cherries, which serve as product substitutes when tart cherries are scarce and prices are high. Consumer income was also included because previous analyses indicate that tree fruit demands are influenced by the income of those who purchase the final consumer products that contain or are composed of tart cherry ingredients. The final factor was a time trend variable. The time trend was included to account for factors such as nutritional knowledge and eating habits that change slowly over time but are difficult to quantify in a precise manner.

The mathematical relationship between the product line sales quantities and the independent variables was specified as a log-linear form. With a log-linear form, each of the variables is entered as the natural logarithm of the actual value of a specific variable. The log-linear relationship is useful because the estimated coefficients are elasticities. That is, an estimated coefficient describes the percentage change in sales quantity for a 1 percent change in tart cherry price or a 1 percent change in apple or sweet cherry price. Elasticities are also scalable by multiplication, so if the change in tart cherry price is 10 percent, one need only multiply the estimated coefficient by 10 to determine the change in product line sales.

The time trend variable is the one exception to the log-linear form. The time trend is simply a sequence of integers beginning with 1 in the first year of the data set and incrementing by one unit for each additional year. Because the dependent variable is the logarithm of sales quantities, the estimated time trend coefficients measure the annual rate of change in sales for a one-unit change — one year change — in time.

Data for the product line demand estimates came from several sources. Product line sales data were obtained from the Cherry Marketing Institute. Price data were obtained from USDA/NASS Quick Stats 2.0. Prices for apples and sweet cherries were taken from the USDA publication Noncitrus Fruits and Nuts Summary (NASS, various years-c). Consumer income came from U.S. Department of Commerce publications on real personal income per capita (U.S. Department of Commerce, 2011). The final data set included covered the sales and prices for 1997 to 2009 so that each equation was based on 12 observations. Table 1 lists the means, standard deviations, minimum value and maximum value for the variables in the data set.

Table 1. Summary Statistics of Product Line Demand Variables.

	Mean	Standard deviation	Minimum	Maximum
IQF sales	41.86	12.55	13.02	65.30
Canned sales	19.23	11.72	8.25	45.90
5+1 sales	90.20	21.86	48.62	122.86
Pie-fill sales	45.43	8.03	29.18	58.10
Other sales	39.82	14.56	18.14	66.99
Total processed sales	236.53	39.46	162.20	296.00
Frozen tart cherry price ($/lb.)	0.22	0.11	0.05	0.49
Canned tart cherry price ($/lb.)	0.23	0.12	0.06	0.50
Processed tart cherry price ($/lb.)	0.22	0.10	0.06	0.44
Apple price (Cents/lb.)	15.04	4.75	8.60	28.80
Sweet cherry price ($/ton)	1,150	445	554	2,390
Personal income ($Billions)	28,943	3,106	24,044	32,946

Table 2. Estimated Demand Coefficients by Product Line.

IQF (R-sq=0.84)	**Estimated coefficients**	**Standard errors**	**z**	**P>|z|**
Own price	-0.87	0.19	-4.66	0.000
Apple price	0.09	0.43	0.21	0.836
Sweet cherry price	-0.92	0.66	-1.39	0.165
Consumer income	-12.41	7.75	-1.60	0.109
Time trend	0.34	0.19	1.77	0.077
Constant	-540.20	299.28	-1.80	0.071

Canned (R-sq=0.87)	**Estimated coefficients**	**Standard errors**	**z**	**P>|z|**
Own price	-0.59	0.19	-3.14	0.002
Apple price	-0.06	0.53	-0.12	0.903
Sweet cherry price	-0.16	0.84	-0.19	0.849
Consumer income	-4.70	9.06	-0.52	0.604
Time trend	0.01	0.23	0.05	0.957
Constant	27.20	359.81	0.08	0.940

5+1 (R-sq=0.91)	**Estimated coefficients**	**Standard errors**	**z**	**P>|z|**
Own price	-0.49	0.07	-7.25	0.000
Apple price	0.38	0.16	2.35	0.019
Sweet cherry price	0.69	0.25	2.77	0.006
Consumer income	17.02	2.89	5.88	0.000
Time trend	-0.41	0.07	-5.73	0.000
Constant	643.50	111.96	5.75	0.000

Pie-fill (R-sq=0.70)	**Estimated coefficients**	**Standard errors**	**z**	**P>|z|**
Own price	0.12	0.09	1.22	0.223
Apple price	-0.73	0.27	-2.73	0.006
Sweet cherry price	-1.45	0.43	-3.39	0.001
Consumer income	-18.72	4.60	-4.07	0.000
Time trend	0.45	0.12	3.90	0.000
Constant	-698.32	182.81	-3.82	0.000

Other (R-sq=0.76)	**Estimated coefficients**	**Standard errors**	**z**	**P>|z|**
Own price	-0.53	0.22	-2.42	0.016
Apple price	0.20	0.47	0.43	0.666
Sweet cherry price	-0.33	0.72	-0.46	0.644
Consumer income	-11.39	8.27	-1.38	0.168
Time trend	0.33	0.20	1.63	0.103
Constant	-544.38	319.11	-1.71	0.088

A deficiency in the data is the inexact match between product lines sales quantities and prices. Sales quantities are available for each of the five standard product lines: IQF, canned, 5+1, pie-fill and other. Price data, however, are not available for the standard product lines. Rather, the USDA publishes price data for frozen, canned and processed tart cherries. The analysis uses the USDA frozen price in the demand analyses of IQF and 5+1 because IQF and 5+1 are frozen products. The USDA canned price is used in the analyses of canned and pie-fill because both of these products are canned. The demand analysis of the "other" category uses the USDA price for processed tart cherries.

Demand coefficients for each product line were estimated using seemingly unrelated regression (SUR). R-squared statistics for the SUR[2] equations ranged from a low of 0.69 for pie-fill to a high of 0.91 for 5+1 sales. R-squared statistics for IQF, canned and "other" were 0.84, 0.87 and 0.76, respectively. Large R-squared statistics suggest a close fit between the estimated equations and the data, but this is typically the case for time series analyses that include a time trend variable. Chi-squared statistics were calculated and indicated that the estimated coefficients were, as a group, statistically different from zero at the 1 percent level for all equations.

Table 2 lists the estimated demand coefficient for each product line beginning with the IQF coefficients in the first panel and ending with the "other" coefficients in the last panel. Rows within a panel list the estimated coefficients and statistical properties for each of the five independent variables and constant.

The rows labeled "own price" list the estimated price coefficients for each product line. These estimates vary quite substantially across the five product lines. The price elasticity for IQF is -0.87. This means that a 1 percent change in IQF price reduces quantity demanded by 0.87 percent. Hence, the percentage change in IQF price brings about a reduction in quantity demand that is about equal to but opposite in sign to the percentage change in price. In contrast, the price elasticity of pie-fill is very small and is not statistically different from zero – i.e., a change in price for pie-fill results in a negligible change in quantity demanded.

Price elasticity estimates for canned, 5+1 and "other" are within a narrow range of -0.49 to -0.59. Essentially, these price estimates are approximately equal to -0.5, so a price change of 10 percent brings about a change in quantity demanded of about 5 percent.

The effect of alternative product prices, consumer income and time trend have very different effects on product line demand. The coefficient estimates for apple price, sweet cherry price, consumer income and time trend are not statistically different from zero for IQF, canned and "other." This means that changes in apple price, sweet cherry price, consumer income and time have no statistically significant effect on quantities demanded for IQF, canned and "other." Demand for the latter three product lines is relatively stable over time and appears to be affected only by changes in their own prices, not the prices of alternative products and consumer income.

Unlike the demands for IQF, canned and "other," demands for 5+1 and pie-fill are sensitive to each of the four factors other than own price. The 5+1 coefficient estimates for apples and cherries are positive, indicating that 5+1 is a substitute for apples and sweet cherries. In contrast, the pie-fill coefficients for apples and sweet cherries are negative. This means that pie-fill sales

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[2] See Appendix A for an accessible description of SUR estimates.

complement apple and sweet cherry sales — a reduction in apple or sweet cherry prices tends to increase sales of pie-fill.

Overall, the estimates in Table 2 indicate the demand relationships are quite different across the standard product lines. IQF quantities demanded show almost a one-to-one responsiveness to changes in IQF price — a 1 percent reduction in price brings about a 0.87 percent increase in quantity demanded. In contrast, pie-fill demand is inelastic, showing almost no responsiveness to changes in price. The price elasticities for canned, 5+1 and "other" are approximately -0.5. In addition, canned and pie-fill demands are sensitive to the prices of apples and sweet cherries, consumer income and time trends. IQF, canned and "other" are unresponsive to all of the factors except their own prices.

The demand differences across product lines suggest that price stabilization may be improved by an OSF that accounts for such differences. The deficiencies in the data, however, suggest a degree of caution. A key data deficiency is the mismatch between product lines and the USDA price categories. In addition, there may be substitution and complementary relationships across product lines that cannot be detected with the relatively coarse annual data. Though the analysis suggests the potential for beneficial market segmentation of the OSF, an actionable analysis requires more precise and detailed data that accurately matches sales and prices.

2.b. Aggregate Demand

Aggregate demand coefficients were estimated in the log-linear form using two-stage least squares. The dependent variable was the natural logarithm of annual tart cherry sales from areas covered by the FMO. Aggregate sales and average annual prices were obtained from USDA/NASS Quick Stats 2.0. Prices for apples and sweet cherries were taken from the USDA publications on Noncitrus Fruits and Nuts Summary (NASS, various years-c). Consumer income came from U.S. Department of Commerce publications on real personal income per capita (U.S. Department of Commerce, 2011).[3]

Table 3 lists the estimated coefficients. The estimated price elasticity is -0.52, very close to the estimated price elasticities for canned, 5+1 and "other" product lines and essentially halfway between the price elasticities for IQF and pie-fill. That the aggregate price elasticity is in the middle of the range of product line elasticities is not unexpected, given the mathematics of the estimation process. Aggregate quantity demanded is the sum of the product line quantities, so the price responsiveness of the aggregate should reflect an averaging of the price responsiveness of the product lines.

The price elasticity of aggregate demand means that a 10 percent change in price results in a 4.9 percent change in quantity demanded. For price stabilization purposes, the relationship between price and quantity can be inverted to describe the price effect of a change in tart cherry sales. The algebraic inverse of -0.49 is -2.04, suggesting that a 1 percent reduction in quantity results in more than a 2 percent increase in price. A 10 percent change in sales results in about a 20 percent change in price. This inverse elasticity relationship between quantity and price is used in the next section to develop an alternative OSF.

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[3] Estimates take into consideration the joint relationships between supply and demand. See Appendix A for a discussion.

Table 3. Estimated Aggregate Demand Coefficients.

Other (R-sq=0.91)	**Estimated coefficients**	**Standard errors**	**z**	**P>|z|**
Own price	-0.49	0.10	-5.12	0.00
Apple price	0.18	0.20	0.89	0.41
Sweet cherry price	-0.02	0.31	-0.08	0.94
Consumer income	0.51	3.56	0.14	0.89
Time trend	-0.01	0.09	-0.12	0.91
Constant	19.83	137.19	0.14	0.89

3. Evaluation of Current and Alternative OSFs

The current OSF addresses instability in the tart cherry market by reducing variation in the quantity of tart cherries supplied to the market and maintaining a reserve capacity to fill supply gaps. The reserve stores surpluses arising in good harvest years for use during future short harvest years. The resulting OSV is based on a three-year average of past sales.

We drew on discussions with stakeholders and economic theory to identify four key issues associated with the current OSF. The first is whether a shorter or longer past average rule will change industry stability. The second is whether extreme events cause long-term impacts on the OSF. The third is whether the current OSF is responsive enough to current market conditions to stabilize the industry. The fourth is whether building demand projections into the OSF will lead to preferable outcomes. To address these issues, we created five alternative OSFs and observed the expected market outcomes through computer simulations.

i. ***2y-OSV*** reduces the number of years in the OSF moving average to two years. The two-year average makes the OSF more responsive to short-term changes in sales trends but also may create greater variation in annual free percentages.

ii. ***4y-OSV*** extends the length of the past-year period from three years to four. The four-year average reduces the susceptibility of sales to year-to-year shocks in sales but is also likely to make the OSV less sensitive to changes in sales trends.

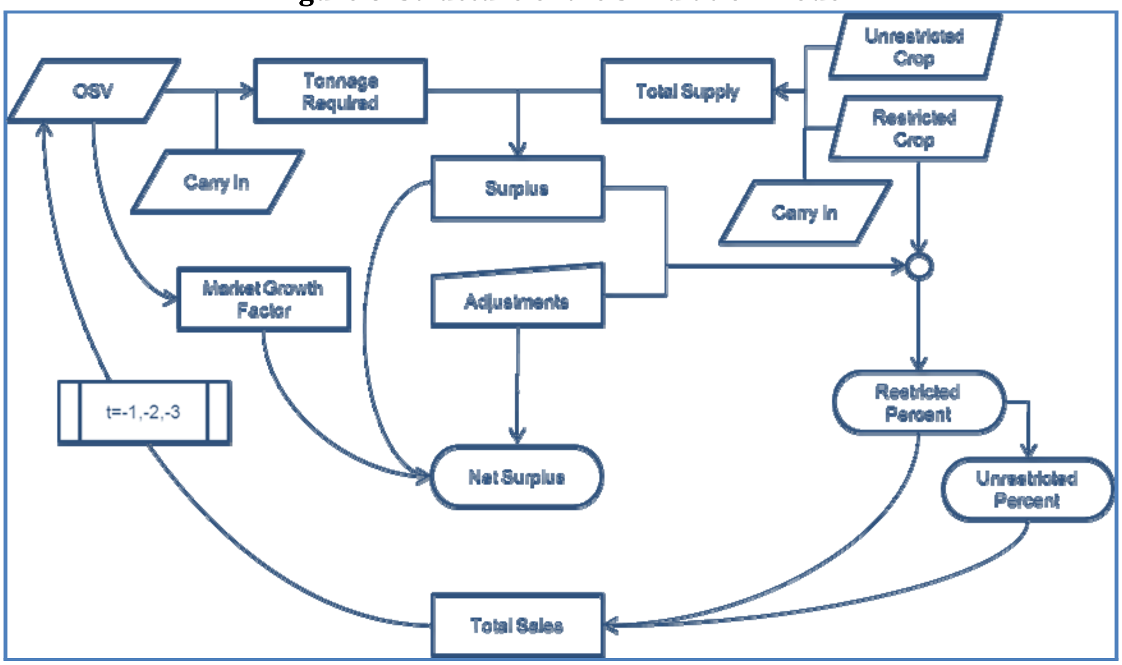
iii. ***DXS*** is the same rule as the three-year average OSF except in years with extreme shortfalls in production. *DXS* deletes extreme shortfalls from the calculation of the OSV. Historical production data from 1982 to 2010 (NASS, various years-c) indicates that such extreme events occur approximately once every 10 years.

iv. ***AdjX*** adjusts the three-year moving average OSF by 50 percent of the difference between the OSF and trend sales after an extreme production shortfall. When an extreme production shortfall occurs, market share unavoidably shrinks because sales cannot be maintained at OSV levels even with the addition of withdrawals from reserves. The loss of market share in an extreme shortfall year may make it difficult to bring sales up to the level implied by *DXS* — some of the buyers lost because of the shortfall may not return to buy tart cherries in subsequent years when product supply approaches normal levels. With a multiyear loss of buyers, *DXS* may result in sales levels too large to maintain stable prices. *AdjX* addresses this multiyear loss of buyers by adding to the OSV 50 percent of the difference between long-term trend sales and the three-year moving average OSF.

v. ***VSP*** aims at setting a sales volume that stabilizes tart cherry market prices. The rule incorporates the responsiveness of aggregate demand price to changes in the sales quantity. Responsiveness is measured by the inverse of the price elasticity of estimated aggregate demand as described in Section 2.b, above. The inverse of the price elasticity approximates the percentage change in prices that accompanies a 1 percent change in sales.

The current and five alternative OSFs were evaluated using a computer simulation model. The model uses historical data on prices to simulate 13-year sequences. Each year in the sequence is a random draw from the historical pattern of production. Each simulation averages results over 1000 sequences of 13 years of random draws. Results are characterized in terms of average annual OSV, total sales, grower price, net surplus, restricted percent and free percent.

Figure 8. Structure of the Simulation Model.



3.a. The Structure of the Simulation Model

The simulations are repeated experiments using a computer spreadsheet that tracks the tart cherry market outcomes over simulated crop years. "Simulated" means that crop years are not actual production levels from specific years but, rather, production levels that are representative of grower production experienced between 1997 and 2009.

The spreadsheet is set up to follow the rules of the tart cherry marketing order as outlined in the U.S. Federal Register (Agricultural Marketing Service, 2010). The software program @Risk (Palisade Corporation, 2011) is used to random draw production levels for each year and to average the results over the 1000 sequences of 13 years for both the current and alternative OSFs.

Figure 8 depicts the relationships underlying the simulation model. The model replicates the underlying structure of the calculations necessary to calculate the current OSF. The simulation starts with total grower supply of tart cherries. Grower supply is the sum of production from restricted and unrestricted regions and total carry-in. The current OSF is calculated as the average of the past three years' total sales.

The optimum supply less carry-in determines the total tonnage required to meet expected market demand. Surplus is the difference between total supply and tonnage required to meet expected demand. Net surplus is surplus less adjustments and a market growth factor. Surplus plus adjustments divided by the total grower production from restricted regions determines the gross restricted percentage.

The free restricted percentage is calculated as one minus the restricted percentage. Free and restricted percentages affect the supply for processed cherries that interacts with demand in determining total sales, and past total sales determine future optimum supply calculations, thus completing the cycle.

The current and alternative OSFs are computed for each of the 1000 thirteen-year production sequences. Keeping the production sequences unchanged for calculating each OSV and its consequences eliminates the possibility that differences in production create differences in outcomes when comparing to the alternatives to the baseline solutions. The idea is to compare OSFs for the same production history to avoid attributing differences in production to differences in the OSFs.

3.b. The Two-year and Four-year Moving Average OSVs

Simulations were carried out to evaluate the performance of the two-year moving average OSF, *2y-OSV*, and the four-year moving average OSV, *4y-OSV*, relative to the current three-year OSF. Table 4 lists the resulting outcomes for the three OSFs. Outcomes measured are average total sales, optimum supply values under each of the rules, prices, net surpluses, restricted percentages and free percentages. The outcomes for the current OSF are given in levels such as million raw product equivalent (RPE) and cents per pound. The outcomes for the two-year and four-year moving average OSFs are given as a percentage change from the current OSF outcomes.

The mean values in Table 4 indicate that outcomes for two-year and four-year OSFs are mostly within a fraction of a percent of the outcomes for the current OSF. Exceptions to the similarity of outcomes are the changes in net surplus under the alternative OSFs. Average net surplus with the two-year moving average OSF is about 3 percent larger than with the current OSF. Average net surplus with the four-year moving average OSF is about 2 percent less than the baseline.

The three right-hand columns in Table 4 list variability measures for outcomes under the three OSFs. Standard deviation is a measure of volatility. The column labeled "Minimum" lists the minimum value obtained for an outcome measure across the 1000 thirteen-year sequences. The "Maximum" column lists the maximum value of an outcome across the 1000 thirteen-year sequences.

The three variability measures show that outcome variability is quite different across the three OSFs. Sales volatility as measured by the standard deviation is about 7 percent greater with *2y-OSV* than with the current OSF, but it is about 4 percent lower with the *4y-OSV*. The lowest level of sales is about 14 percent less with *2y-OSV* than with the current OSF; minimum sales with *4y-OSV* are 2.5 percent greater than with the current OSF. A similar pattern holds across the other outcome measures for *2y-OSV* and *4y-OSV*. The outcome measures for *2y-OSV* are uniformly more variable and those for *4y-OSV* are uniformly less variable than those for the current OSF.

Table 4. Two-year and Four-year Moving Average OSVs.

Base case: 3-Year Average OSV	Average	Standard deviation	Minimum	Maximum
Total sales (million RPE)	255.89	10.99	88.42	293.69
Optimal supply volume (million RPE)	258.07	9.93	98.20	293.54
Price (cents/pound)	24.7	0.9	21.6	38.8
Net surplus (million RPE)	35.87	8.80	10.4	184.6
Restricted (percent)	20.0	3.0	10.0	98.9
Free (percent)	81.0	3.0	1.1	90.0
Change from Base Case				
2-Year moving average OSV: *2y-OSV*	Average	Standard deviation	Minimum	Maximum
Total sales (percent change from base)	-0.22	7.36	-13.7	-0.3
Optimal supply volume (percent change from base)	-0.11	11.16	-17.0	0.4
Price (percent)	0.19	7.36	0.4	2.6
Net surplus (percent)	2.91	3.98	25.8	9.2
Restricted (percent)	0.37	0.35	0.0	0.1
Free (percent)	-0.37	0.35	-0.1	0.0
Change from Base Case				
4-year moving average OSV: *4y-OSV*	Average	Standard deviation	Minimum	Maximum
Total sales (percent change from base)	0.17	-4.26	2.5	-0.4
Optimal supply volume (percent)	0.16	-7.99	9.9	-1.1
Price (percent)	-0.14	-4.26	0.5	-0.5
Net surplus (percent)	-2.09	-2.20	15.2	-5.6
Restricted (percent)	-0.28	-0.14	0.0	0.0
Free (percent)	0.28	-0.14	0.0	0.0

3.c. Deleting Extreme Production Shortfalls

The 2002 production shortfall had a significant impact on target cherry sales, both in the year of the shortfalls and in subsequent years. In 2002, the production shortfall was so extreme that the calculated OSF could not be achieved even with withdrawals from reserves. This led to lost sales in 2002 and the loss of market share to competing products. In years subsequent to 2002, the 2002 sales shortfall entered the calculation of the three-year moving average OSF. The arithmetic of a moving average ensured that the 2002 sales shortfall not only dampened sales in the three years subsequent to 2002 but also was a permanent damper on the OSV in all years subsequent to 2002. The effect of an extreme shortfall diminishes over time as annual adjustments are added to free sales, but the effect never entirely disappears.

One approach to dealing with an extreme shortfall in subsequent calculations of the OSF is simply to delete it. Deletion may be appropriate when the loss of market share in the shortfall year is temporary and buyers come back to tart cherry suppliers when production returns to normal levels.

The effects of deleting an extreme shortfall are evaluated with *DXS*. With DXS, an extreme shortfall is defined as a shortfall that has a one-in-10-year chance of occurring (One event in 10 years is the approximate frequency of production shortfalls, based on tart cherry production from 1982 to 2010). The production threshold associated with a one-in-10 event was computed using a normal distribution and the mean and variance of historical production from 1982 to 2010 (NASS, various years-c). Using the latter definition, an extreme shortfall is a production level in the regulated seven states less than 172.4 million pounds.[4] The *DXS* rule omits years where grower production declines below 172.4 million pounds.

Table 5 compares market outcomes for *DXS* and the base case with the current OSV. The results show that deleting extreme events from *DXS* has no effect on average total sales and leaves market prices unaffected. Average DXS OSV is 2.9 percent larger than the base case. Volatility of OSV as measured by the standard deviation is 16 percent less than that of the base case. Average DXS net surplus is 12.9 percent less than with the base case.

Table 5. Deleting Extreme Shortfall Year from the Three-Year Moving Average OSV.

Base case: include 1-in-10-years outliers	Average	Standard deviation	Minimum	Maximum
Total sales (million RPE)	244.06	10.46	179.33	282.68
Optimal supply volume (million RPE)	248.65	9.49	186.52	282.04
Price (cents/pound)	25.7	0.9	22.5	31.2
Net surplus (million RPE)	37.91	8.31	16.6	87.3
Restricted (percent)	21.0	2.9	10.0	49.5
Free (percent)	79.0	2.9	50.5	90.
Change from Base Case				
Delete-extreme-shortfall OSV: *DXS*	Average	Standard deviation	Minimum	Maximum
Total sales (percent)	0.0	0.2	10.6	0.2
Optimal supply volume (percent)	2.9	-16.0	4.9	2.7
Price (percent)	0.0	0.22	-0.2	-5.1
Net surplus (percent)	-12.9	-1.8	-46.4	-14.5
Restricted (percent)	-2.1	-0.3	0.0	-0.1
Free (percent)	2.1	-0.3	0.1	0.0

For comparison, a second scenario was carried out in which the delineation between a normal and an extreme event is made more restrictive by setting an excludable event to a one-in-20-year level of production. For the production levels from 1982 to 2010, a one-in-20-year event is a production level less than 15.6 million pounds. The outcomes, though not presented here, are consistent with those under the once-in-10-year definition of extreme events.

3.d. Optimal Supply Based on an Adjusted *OSV*

This section evaluates an OSF, *AdjX*, that leaves an extremely low sales year in the calculation of the three-year average but adjusts the OSV upward by 50 percent of the difference between long-term trend sales and the calculated three-year average. *AdjX* is calculated in year *t* as:

[4] Calculated as the lower bound of the normal probability distribution (z=-1.285) such that a lower value will occur only once every 10 observations.

$$AdjX_t = \left(\sum_{i=1}^{3} \frac{TS_{t-i}}{3}\right) + \propto \cdot (\bar{X} - OSV_t),$$

where TS_t is total sales, α is a speed of adjustment parameter, $\bar{X}$ is the long-term mean of trend sales, and OSV_t is the OSV based on the three-year average of prior sales. The speed of adjustment parameter, α, is set to 0.50, indicating that for each year, the *AdjX* reduces the gap between trend sales and OSV_t by 50 percent.

Adjustment factors other than 0.5 are possible. An adjustment factor of 0.25 in place of 0.5 brings the OSV back to trend sales more slowly than 0.5. An adjustment factor of 0.9 brings OSV back to trend sales very quickly. For purposes of price stabilization, the choice of an adjustment factor depends largely on how quickly market share may be recovered after a production shortfall. A smaller adjustment factor is warranted when market share recovery is slow; a larger adjustment factor is appropriate when recovery of market share is rapid.

Table 6. Partial Deletion OSV.

Base case: Three-year average OSV	Average	Standard deviation	Minimum	Maximum
Total sales (million RPE)	255.90	11.41	214.56	287.74
Optimal supply volume (million RPE)	258.08	10.21	218.62	286.23
Price (cents/pound)	24.7	1.0	22.1	28.2
Net surplus (million RPE)	35.81	8.51	12.5	67.7
Restricted (percent)	19.5	3.2	10.0	30.0
Free (percent)	80.5	3.2	70.0	90.
Change from Base Case				
Supply/sales balance OSV: *AdjX*	Average	Standard deviation	Minimum	Maximum
Total sales (percent)	-0.4	6.41	-2.1	0.2
Optimal supply volume (percent)	-0.47	11.19	-2.9	0.7
Price (percent)	0.34	6.41	-0.2	1.3
Net surplus (percent)	5.12	2.49	17.0	12.6
Restricted (percent)	0.67	0.23	0.0	0.0
Free (percent)	-0.67	0.23	0.0	0.0

Table 6 lists the results for AdjX and the base case of the current OSF. The mean results for the AdjX differ only slightly from those of the base OSV case. Total sales and the OSV are about 0.5 percent less than with the current OSF. The free percent declines by less than 1 percent, and the RPI net surplus increases by 5 percent. Variability of each variable is greater with *AdjX*, however. The standard deviations of total sales and tart cherry prices increase by 6.41 percent, the standard deviation of OSV increases by 11.19 percent, and the standard deviation of net surplus increases by 2.49 percent. The standard deviations of restricted and free sales increase by only 0.23 percent.

Overall, the results indicate that adjusting the current OSV by 50 percent of its difference with trend adds variability into the market, especially into total sales, the OSV and prices. These results are similar to those found using the two-year moving average, 2y-OSV. Because the *AdjX* rule tends to generate larger annual variability in the market, simply omitting extreme events may prove to be a better approach to controlling for large spreads between supply and demand.

3.e. Price Stabilization

This section evaluates an OSF designed to stabilize tart cherry prices by anticipating consumer responses to supply conditions. The current moving-average OSF establishes an OSV based on past sales but does not take into account current market conditions. Historical relationships between price and sales can be used to generate an OSF that anticipates price and supply relationships and may potentially contribute to the overall stability of market prices. The VSP rule is a price stabilization rule that incorporates how aggregate tart cherry demand responds to changes in available tart cherry quantities.

The development of the VSP rule begins with the price elasticity of aggregate tart cherry demand. The price elasticity describes how a percentage change in tart cherry price affects the percentage change in the quantities that demanders are willing to purchase. Price elasticity is a negative number, η, meaning that, as price increases, the quantity that demanders are willing to purchase falls. Algebraically, the relationship between the percentage change quantity demanded, r_q, and the percentage change in price, r_p, is proportional to the price elasticity of demand, η,

$$r_q = \eta r_p.$$

The proportional relationship means that a 1 percent change in price reduces quantity demand by η percent. It also means that a 10 percent change in price reduces quantity demanded by 10η percent.

The proportional relationship between the change in quantity and the change in price can be used to derive a price stabilization rule between a targeted year-to-year percentage change in price and a percentage change in year-to-year sales. We begin the derivation by writing out the percentage change in price and percentage change in quantity in terms of the year-to-year change in OSV, *VSP*, and the year-to-year change in price,

$$\frac{VSP_t - S_{t-1}}{S_{t-1}} = \eta \frac{p_g - p_{t-1}}{p_{t-1}},$$

where VSP_t is the OSV in a given year t, S_{t-1} is the quantity supplied in the previous year, p_g is the price target in the given year, and p_{t-1} is the average price level in the previous year.

The price-stabilizing supply volume, VSP_t, is derived by rearranging the previous equation to obtain:

$$VSP_t = S_{t-1}\left[1 + \eta\left(\frac{p_g - p_{t-1}}{p_{t-1}}\right)\right].$$

The price-stabilizing OSV, VSP_t, is therefore a function of the supply in the previous year, the price elasticity of demand, S_{t-1}, price in the previous year, p_{t-1}, and the price target in a given year, p_g.

The simulation uses the price elasticity listed in Table 3 of -.49 and grower price target, p_g, set at 23 cents per pound. With these data, the price-stabilizing supply volume is:

$$VSP_t = S_{t-1}\left[1 - 0.49\left(\frac{23 - p_{t-1}}{p_{t-1}}\right)\right].$$

This rule generates the amount of free tonnage that would be released to return grower prices to the desired level of 23 cents per pound. When the price is higher than 23 cents, the OSV, VSP_t, is less than sales in the prior year, S_{t-1}. When the price is less than 23 cents, the OSV, VSP_t, is greater than sales in the prior year, S_{t-1}.

Table 7 compares results for *VSP* with those of the current three-year moving average *OSV*. The results show that *VSP* reduces total sales and OSV by about 2 percent. Average price, however, increases by 11.25 percent. The average net surplus is larger by 24.54 percent, though the average restricted and free percentages are about the same as in the base case. With the *VSP*, the variability of the OSV and net surplus increase, but the variability of price declines. Hence, the *VSP* achieves the objective of reducing market price variability compared to the base case with the three-year average OSF.

Table 7. Price Stabilization.

Base case: three-year average OSV	Average	Standard deviation	Minimum	Maximum
Total sales (million RPE)	255.94	10.96	219.42	301.19
Optimal supply volume (million RPE)	258.16	9.84	220.90	296.47
Price (cents/pound)	22.13	1.86	15.52	29.23
Net surplus (million RPE)	35.89	8.54	13.13	68.06
Restricted (percent)	0.19	0.03	0.11	0.38
Free (percent)	0.81	0.03	0.62	0.89
Change from Base Case				
Price-stabilizing OSV: *VSP*	Average	Standard deviation	Minimum	Maximum
Total sales (percent)	-2.07	-1.30	-2.51	-5.46
Optimal supply volume (percent)	-1.82	18.07	-7.79	-5.05
Price (percent)	11.25	-19.81	31.95	0.98
Net surplus (percent)	24.54	62.13	-4.62	62.79
Restricted (percent)	0.04	0.02	-0.01	0.06
Free (percent)	-0.04	0.02	-0.06	0.01

The VSP experiment was repeated using a lower target price to see if the lower target price might result in greater total sales and lower net surplus than in the base case. In this experiment, the target price was reduced from 23 cents per pound to 21 cents. The results were as expected: the lower target price increased average total sales by 1.28 percent and decreased net surplus by 14.6 percent compared with the base case of the three-year moving average OSF.

Overall, the VSP achieves the objective of increasing price stability relative to the base case. It also allows a degree of control over total sales and net surplus. A higher target price decreases sales and increases net surplus; a lower target price increases sales and decreases net surplus.

3.f. Conclusions of Simulation Model Results

The five alternative supply rules evaluated above incorporate four strategies for modifying the current optimal supply formula. The four strategies and respective conclusions are:

i. Increasing the length of the moving average used in the OSF.
   A longer period of averaging results in less year-to-year variation in the OSF and moderates the impact on the OSF of very good and very poor harvests. A longer period of averaging also lengthens the gradual upward adjustment of the OSV from a poor harvest year.

ii. Removing extreme production shortfalls from the OSF.
   This substantially reduces the impact of supply shocks on the OSV. The average restricted percent is 10 percent less than with the current three-year average rule. The annual increase in reserves is 10 percent less. Price and total sales effects are negligible compared with the current rule. Though annual variations in price and sales were similar to those of the current three-year average OSF, the annual variations of the calculated OSV and reserves decline under the drop-the-extreme-shortfall rule, *DXS*.

iii. Applying a 50 percent OSV trend adjustment following an extreme harvest shortfall.
   This rule is a compromise between the current three-year average rule and simply dropping an extreme shortfall from the OSF. The effects on the OSV, restricted and free percentages, price and addition to reserves fall between those of the current OSV and removing-extreme-event rules. Because this rule results in an OSF that is more responsive to market changes, it tends to increase year-to-year variations in sales and the OSV.

iv. Stabilizing market price using a price elasticity rule and target price.
   A rule that aims at price stabilization has the most pronounced effects on the performance measures among the rules considered. With the targeted price used in the simulations, the annual OSV and total sales are about 5 percent larger with the price stabilization rule, and the average price, restricted percent and annual contribution to reserves are lower. Because the price-stabilizing OSF is more resistant to market changes, the annual variation in sales and price is lower than that of the current three-year rule.

The results indicate that increasing the number of years used in the OSF results in greater stability in sales and price but also prolongs the negative effect on sales of extreme shortfalls in production. To gain the benefit of stability without the negative effects of extreme shortfalls, a revised OSF could extend the number of years in the average from three to four and omit extreme shortfalls whenever they occur. A second alternative is a price-stabilization rule that anticipates consumption responses to price change and calculates an OSV for market stability. Such a rule can be established with a target price for the industry.

4. Conclusions

The findings indicate that market instability in the tart cherry industry is brought about by random changes in grower yields, which appear to be largely weather-related. Though bearing acres of tart cherries have seen modest declines since 1997, year-to-year variation in bearing acres is not sufficient to generate the year-to-year variation in production recorded by the USDA. In contrast to supply, demand for tart cherry products is stable over time.

Tart cherry demand is inelastic. Even though demand is relatively stable, the inelasticity of demand compounds the market effects of supply instability. Demand inelasticity means that users of tart cherries do not find it easy to substitute away from tart cherries as the tart cherry price increases. As a result, a small reduction in quantity results in a larger increase in market price. In numeric terms, the tart cherry demand elasticity is about -0.5 percent. This means that the price increase is about twice the size of the supply reduction, so a 10 percent reduction in supply results in a 20 percent increase in price.

Demand for processed tart cherries is derived from the downstream demands for food products such as frozen desserts, juice and juice drinks, and fruit and nut snacks. Aggregate demands for these food categories are relatively stable over time, but each presents potential subcategories for tart cherry sales growth by the development and sale of new products. Competition for market share in these food categories is vigorous, and maintenance of tart cherry market share requires product innovation and well-designed market strategies. Sales strategies need to be grounded in accurate information about quantities sold, prices by product line and product category, and the characteristics of buyers and consumers of tart cherry products.

The demand analysis using publicly available data shows that the various tart cherry product lines have very different characteristics and determinants. For example, demand for pie-fill is unresponsive to changes in its own price but does shift with consumer income and the prices of substitutes such as apples and sweet cherries. IQF demand readily responds to market prices but is unresponsive to changes in income and the prices of substitute fruits. These demand differences between product lines create opportunities for market strategies that differ by product line. Further research is needed to identify the types of strategies that may fit different product lines. It may also be possible to develop OSFs that support distinct product line strategies.

Alternative specifications of the OSF have potential for reducing the negative effect of an extreme harvest shortfall on future supplies.

i. The simplest alternative rule is simply to delete the extreme shortfall year from the calculation of the OSV and replace it with sales from a prior year. A deletion rule increases long-free percentages by about 2 percent and reduces the buildup of reserves by about 13 percent per year.
ii. It is also possible to compromise between deleting an extreme shortfall and keeping it in the OSF. The simulation examined one such compromise rule by which the OSV was adjusted upward by an amount equal to 50 percent of the gap between the three-year average rule with and without the extreme shortfall. As one might expect, the compromise rule results lie between those of the current OSV and a simple deletion rule.
iii. A market price stabilization rule that anticipates supply requirements to meet market demand increases average free percentage and reduces restricted percentage more than the other rules considered. Though a range of price targets can be specified, targeting price as equal to the average processed tart cherry prices from 1997 to 2009 reduced average market price and average annual contribution to reserves while increasing average total sales by almost 5 percent.

A significant benefit of the FMO is the extent to which it allows growers, processors and industry stakeholders to share market information. The FMO sets up collaborative institutions for the development of the OSV, collection and distribution of market statistics, and discussion of industry issues and opportunities. The Cherry Industry Administrative Board (CIAB) compiles and publishes market statistics that give stakeholders an opportunity to study and understand market-level trends and influences. These FMO institutions and activities provide growers and processors better information about sales and investment prospects than would likely be the case without the FMO.

The analysis finds that the tart cherry industry has significant opportunities for improving its OSF and for developing market strategies that better reflect the sales and growth opportunities of various product lines and consumer demand categories. Better data is needed to take advantage of these opportunities. Better data is needed to evaluate how product line prices respond to changes in marketed quantities and whether OSFs for specific product lines would improve sales, net returns and industry growth. Existing data reveals too little information about price, quantity and quality relationships to support the high reliability needed for designing OSFs specific to the major product lines. To develop better data, the industry needs to give careful consideration to how data that is now proprietary to individual firms may be shared and analyzed at the industry level.

5. Appendix A: Estimating Demand Price Response

The approach to estimates of aggregate tart cherry sales follows the approach used to estimate segment demands. However, segment sales entail the simultaneous estimates of all segments within a seemingly unrelated regression (SUR). SUR estimation takes into account co-movements in the sales of all segments and is considered a superior estimator to single-equation regression when estimating factors that drive demand across multiple related segments. This is because SUR does not assume segments are unrelated and takes advantage of a more general estimator that does not assume relationships exist across segments. Using single-equation regression will implicitly assume that 5+1 and IQF sales are not related. However, one can conceive that 5+1 and IQF sales are related because either may be used as a substitute for the other. SUR's recognition of this in estimation affords greater precision of estimated relationships.

However, aggregate tart cherry sales are the sum of segment sales, and, therefore, the co-movements are circular. Hence, regression analysis of aggregate tart cherry sales cannot benefit from SUR within this context. Alternatively, single-equation regression is used. A potential drawback of single-equation regression of sales is that economists view sales as the point where supply equals demand. That is, sales may decline because supply is constrained or because demand is curtailed. Similarly, sales may increase if supply increases or demand expands.

Economists have developed statistical approaches to separate demand from supply in sales data. They have also developed a battery of tests for determining when such approaches are required for valid estimates. A Hausman test is used in determining whether aggregate supply changes will confound demand estimates. The Housman tests whether variables that economic theory posits will shift supply but not demand will actually show shifts in demand. As discussed in the text, growers have limited capacity to respond to market changes in the short run. Therefore, long-term trends are considered the dominant determinant of supply. That is, sales are regressed against its own past sales, its own past prices and a time trend, with an indicator variable to control for the 2002 freeze. This equation is fitted to the actual sales data. The differences between the fitted values and actual sales are then regressed along with a demand equation to determine if supply variables impact demand estimates. A Wald test indicates that supply factors do not influence sales, after accounting for demand factors, within a standard 5 percent confidence interval. Hence, the findings suggest that suppliers do not respond to short-term market conditions, and single-equation regression is sufficient for precise estimates of aggregate demand.

6. Appendix B: Structure of the Simulation Model

The simulation model builds on the calculations necessary to determine market supply of processed tart cherries, which take into account free and restricted tonnages by adding demand trends that in combination determine total market sales. Prior-year sales are then used in calculating the OSV used to determine subsequent years' free and restricted tonnages. Completing the model's cycle requires estimating relationships that capture total sales over time.

Figure 8 on page 13 shows a diagram for the flow. The flow of the model starts with total grower supply of tart cherries. Total supply is the sum of production from restricted and unrestricted regions and carry-in. The OSV is calculated as the supply desired to meet expected market demands. The current OSF is calculated as the average of the past three years' total sales. The optimum supply volume less carry-in determines the total tonnage required to meet expected market demand. Net surplus is calculated as the difference between total supply and tonnage required. Net surplus plus adjustments divided by the total grower production from restricted regions determines the gross restricted percentage. The free percentage is calculated as 1 minus the restricted percentage. Free and restricted percentages affect the supply for processed cherries, which interacts with demand in determining total sales, and past total sales determine future optimum supply calculations, thus completing the cycle. The discussion below describes the estimates used to determine sales.

Restricted sales: Restricted sales values are estimated using data within the marketing order. *Restricted sales* are estimated via regression equation against past values of restricted sales, the current restricted percent and the OSV. Estimates using historical data provided from 1997 to 2009 provided by the CIAB are shown in Table B-1. The estimates suggest that, as more tonnage is directed toward restricted tonnage, restricted sales increase. Additionally, if the past year's restricted sales are high, this year's restricted sales are also expected to be high. This also captures a trend effect with a positive growth over time. The positive coefficient for OSV is not statistically significant and is a bit counterintuitive, in that higher OSVs generally result in lower restricted percentages. However, a higher OSV can also suggest a growing trend in sales, giving rise to an increase in opportunity costs of not releasing restricted tonnage to the market.

Table B-1. Equation for Estimating Restricted Sales.

R-squared= 0.803

Variable	Coefficient	Standard error	t-Statistic	Probability
Restricted percent	110.435	20.782	5.314	0.001
Restricted sales(-1)	0.420	0.172	2.439	0.041
OSV	0.140	0.089	1.575	0.154
Intercept	-35.943	22.626	-1.589	0.151

Export sales: Exports sales are generated from both free and restricted sales. Regression provided a best fit when export sales were regressed against total sales with a trend. Ordinary least squares estimate the relationships in Table B-2, where "Export sales" is tonnage exported per year, "Total sales" is total sales of the year, and "Year" is the year. Table B-2 essentially asserts that, on average, 28 percent of the change in total sales goes toward exports.

Table B-2. Equation for Estimating Export Sales.
R-squared= 0.894

Variable	Coefficient	Standard error	t-Statistic	Probability
Total sales	0.278	0.042	6.538	0.000
Year	-0.687	0.450	-1.527	0.158
Intercept	1,329.705	906.382	1.467	0.173

Market expansion: Market expansion captures total tonnage allocated toward expansion efforts. The CIAB provided annual market expansion sales for use in this analysis. Annual tonnage of expansion sales is estimated on the basis of past expansion efforts and annual net surplus, and along a time trend as shown in Table B-3, where "Expansion sales(-1)" is the total tonnage allocated to market expansion activity in the prior year, "Net surplus" is the tonnage of net surplus and "Year" is the numerical year of observation for capturing a time trend. This relationship explains nearly 93 percent of the overall annual expansion sales, as shown in the R-squared.

Table B-3. Equation For Estimating Market Expansion Sales.
R-squared= 0.930

Variable	Coefficient	Standard error	t-Statistic	Probability
Year	1.804	1.026	1.758	0.129
Expansion sales(-1)	1.045	0.302	3.457	0.014
Expansion sales(-2)	-0.708	0.299	-2.367	0.056
Net Surplus	0.059	0.033	1.806	0.121
Intercept	-3,609.99	2,052.75	-1.759	0.129

Total sales: Total sales are estimated using regression. Rather than estimating free sales and adding free and restricted sales to derive total sales, total sales are estimated and free sales are derived as the difference between total and restricted sales. The total sales equation is inspired by the demand estimates discussed in Appendix A. However, the specification used to estimate total demand does not work within the simulation model. Rather, a reduced form is estimated on the basis of total production and free percentages, where total production tends to move in the opposite direction of price. Regression results are shown in Table B-4, which shows how total sales tend to increase with supply and free percentages.

Table B-4. Equation for Estimating Total Sales.
R-squared= 0.806

Variable	Coefficient	Standard error	t-Statistic	Probability
Projected production	0.500	0.119	4.185	0.002
Free percentage	61.804	49.123	1.258	0.240
Intercept	63.733	58.601	1.088	0.305

Price: Several metrics by which to measure the effects of alternative OSVs were considered. Some metrics are derived directly from the FMO, including free and restricted percentages and net surplus.[5] Others are derived from estimated sales responses including exports, restricted sales, market expansion

[5] Net surplus is estimated as reserve release plus adjustment and surplus and minus the market growth factor. This metric measures the average annual change in net surpluses over the simulation horizon (1997-2009).

and total sales. One additional metric, price, is estimated on the basis of econometrically estimated demand responses.

Because the quantity of cherries released to market has the potential to affect price, a price metric is also included in the simulation metrics. Price is determined on the basis of the equation estimated in Table 3 of the text, which specify that sales decrease by 0.49 percent for every 1 percent increase in the aggregate price. The converse of this relationship is that price will decrease by 2.04 (=1/.49) percent for every 1 percent increase in quantity sold, or,

$$Price_t = (-2.04 \cdot \%\Delta(Quantity_t) + 1) \cdot Price_t^*,$$

where *Price** is the calculated long-term average or desired level of price. An increase in output reduces price and a decrease in output increases the price.

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