Farm-Level Price Formation for Fresh Sweet Cherries

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We estimate price formation in the sweet cherry market using an inverse demand system with farm-level price and quantity data from states in the Pacific Northwest and California. Between 0.60 and 0.78 of the variation in annual cherry price is explained by the states' production, domestic consumption, and exports. Washington and California prices are most responsive to their own quantity. Output flexibilities indicate that Oregon is responsive to a change in quantity supplied to the domestic market. Results also indicate that cherry price is most sensitive to quantity supplied to the export and domestic markets.

The Pacific Northwest (PNW)—Washington, Idaho, Oregon, and Utah—and California are leading producers of fresh sweet cherries in the United States and the world. Washington is the largest producer of sweet cherries for the fresh market in the U.S. Cherries are a high-value commodity, and cherry crops from the above states typically command some of the highest prices in the world.[1] However, cherry prices also are very volatile, depending on production levels in different geographical regions, weather conditions (e.g., freeze, rain split), pollination, and domestic and international markets. The purpose of this research is to model cherry price formation at the farm level across different states in the PNW and California. This regional approach allows U.S. to draw comparisons and inferences about the marketing forces affecting each state, and determine if a particular state is able to differentiate its product relative to the others. Moreover, own- and cross-quantity flexibilities are estimated to examine the impact of production levels among the states and examine output to domestic and international markets.

Domestic and international marketing of cherries have changed dramatically over the last several decades. Cherry production in the PNW has attained all-time high levels, raising the question of how regional production levels impact markets for fresh sweet cherries. In addition, U.S. exports of cherries increased 50% percent between 1989 and 2004, illustrating the region's increased access to foreign markets for its cherry crop. In recent years, economic recessions in the U.S.'s major export markets have led to more stagnant foreign exports. Because producer prices are subject to production changes and the volatility of domestic and international markets, determining how these market forces interact is important in understanding what drives price formation in the fresh sweet cherry market.

Unlike much of the previous literature on sweet cherry markets (e.g., Schotzko and Swanson 1989; Schotzko and Wilson 1995), this study analyzes PNW cherry price at the state level using an inverse-demand system. This method is conceptually and empirically different from previous studies, which analyzed cherry price using more aggregate single-equation pricing equations (Miller, Casavantes, and Buteau 1983, 1986).[2] By analyzing price at the state level, it is possible to delineate characteristics of cherry markets by state and to empirically model any contemporaneous correlation between the states. Product differentiation by state may occur because of geographical differences, consumer preferences, marketing seasons, marketing orders (e.g., minimum quality and container marketing requirements), political boundaries, and environmental conditions. Agronomic practices, soil characteristics, and climatic conditions also determine cherry varieties and quality grown in different regions.[3]

The paper will proceed in the following man-

[1] From this point forward, "cherries" will be used to mean fresh sweet cherries.

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[2] Schotzko and Wilson (1995) found at the transaction level that cherry markets were influenced by current market conditions, product quality, and knowledge of individual buyer and seller marketing strategies.

[3] In general, trade practices such as credit terms, delivery dates, and ancillary services add to the overall potential product differentiation (Dong, Marsh, and Stiegert 2005).

ner. First, background information about the cherry market in the PNW and California will be presented. Second, data and estimation procedures for the demand system will be provided, along with empirical results and discussion. The paper will conclude with implications and closing remarks.

Background

The United States ranks as the world's second largest cherry producer, with sweet cherry production historically making up more than half that volume. The U.S. is also the world's largest sweet cherry exporter. The National Agricultural Statistics Service (NASS) forecasted U.S. cherry production to be about 276,550 tons in 2004, a 17 percent increase from 2003 and a 52 percent increase from 2002. This places the U.S. second only to Iran in terms of total production volume and slightly ahead of Turkey. According to the 2002 Census of Agriculture, the largest sweet cherry producing states in the U.S. are, in descending order, Washington, California, and Oregon. Figure 1 shows production of cherries for the top five states from 1986 to 2004. Even though California and PNW cherries have different growing seasons (discussed in more detail below), it is likely that cherry market conditions in California could influence cherry market conditions in the PNW and have a significant impact on prices received in the PNW. Schotzko and Swanson (1989) provided evidence through cross-price flexibilities between California and the Northwest (Washington and Oregon) that California production has a statistically significant impact on the Northwest. They estimated that a one-ton increase in California production yielded a decrease in Northwest price by 0.32 cents per ton.

As can be seen in Figure 2, nominal cherry prices fluctuate greatly both over time and across states. On average, California and Washington exhibited the highest dollars-per-ton revenue, while California exhibited the greatest variation in price. Miller et al. (1986) analyzed the Japanese market for fresh sweet cherries, reporting that U.S. cherries in Japan were price inflexible (–0.2255) and strongly price elastic (–4.4352).

Rising per-unit export prices coupled with increasing domestic production have led to speculation that U.S. producers may be relying more on foreign exports to move their cherry crop. During the 1980s exports accounted for approximately 21 percent of production levels, and by the end of the 1990s exports accounted for 34 percent of total domestic production (USDA - ERS 2004). The largest markets for U.S. fresh sweet cherries are Japan, Canada, Taiwan, and Hong Kong, in descending order (Figure 3). Japan is the largest of all foreign importers, accounting for approximately 40 percent of all U.S. exports from 1986 to 2004.

The increasing cherry supply, sporadic domestic consumption, and heavy reliance on foreign imports all coincide to characterize the sweet cherry market. This becomes abundantly clear when examining the state of Washington, which relies very heavily on foreign exports to move its cherry crop. From 2001 to 2002, when U.S. exports reached an all-time high, the price of Washington fresh sweet cherries increased from $1,580 per ton to $1,990 per ton. When foreign demand fell off in 2003, Washington cherry prices moved back down to $1,640 per ton. Similar trends can be seen in Idaho, Utah, and California. Oregon was the lone Pacific Northwest state not to feel the effects of the loss in foreign demand. Oregon cherry price increased steadily, from $1,000 per ton in 2001 to $1,190 in 2002 and to $1,320 by 2003. This suggests that while Washington, Idaho, Utah, and California cherries markets might be more sensitive to exports, Oregon cherries could possibly be more responsive toward domestic consumption or processing.

Of the sweet cherries produced in the U.S., roughly 60 percent are used fresh. Fresh sweet cherries are very seasonal, and as a whole are typically marketed between May and early August. California cherries are typically marketed between May and June, while the Washington cherry market typically begins shipments in June and continues through August. As individual cherry quality is very important, cherries that are meant for the fresh market are typically harvested manually to minimize damage incurred during the harvesting process. Cherries meeting these stringent quality standards command the highest prices in the foreign markets. Cherries that are blemished or undersized are more likely to be processed.

Data

The Fruit and Tree Nut Outlook from the USDA - ERS (2003) is the primary data source for the

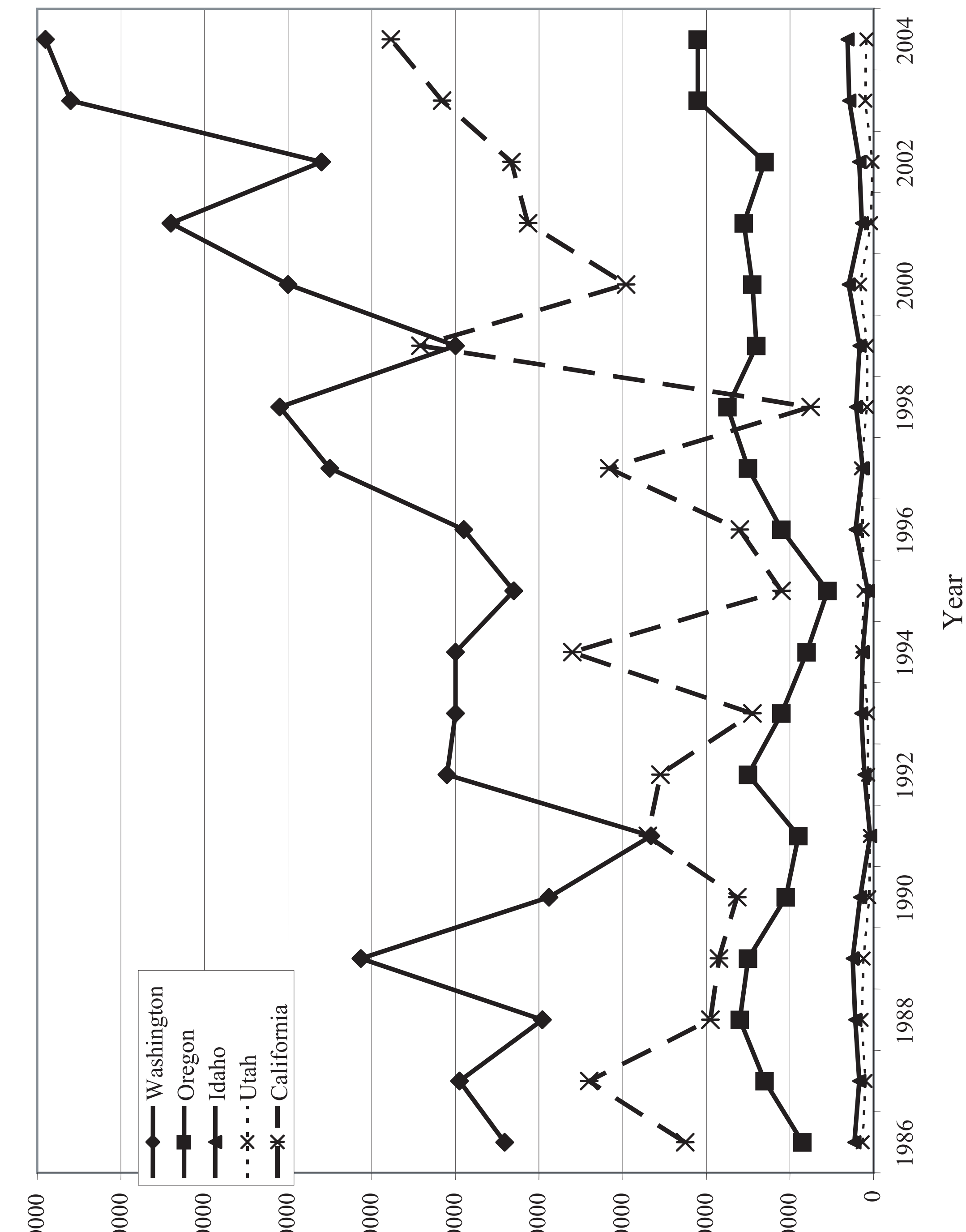

Figure 1. Cherry Production by State, 1986–2004.

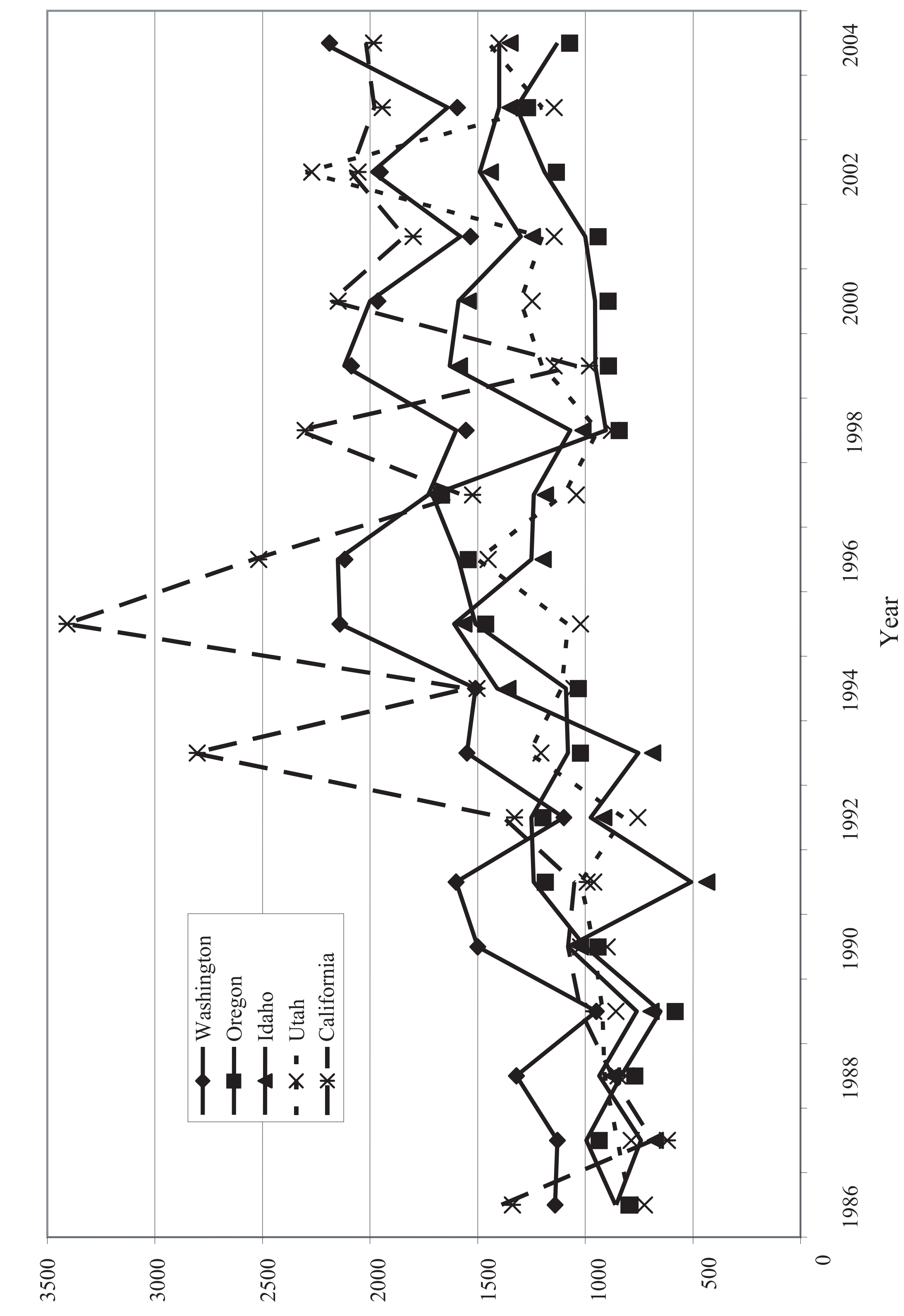

Figure 2. Sweet Cherry Price by State, 1986–2004.

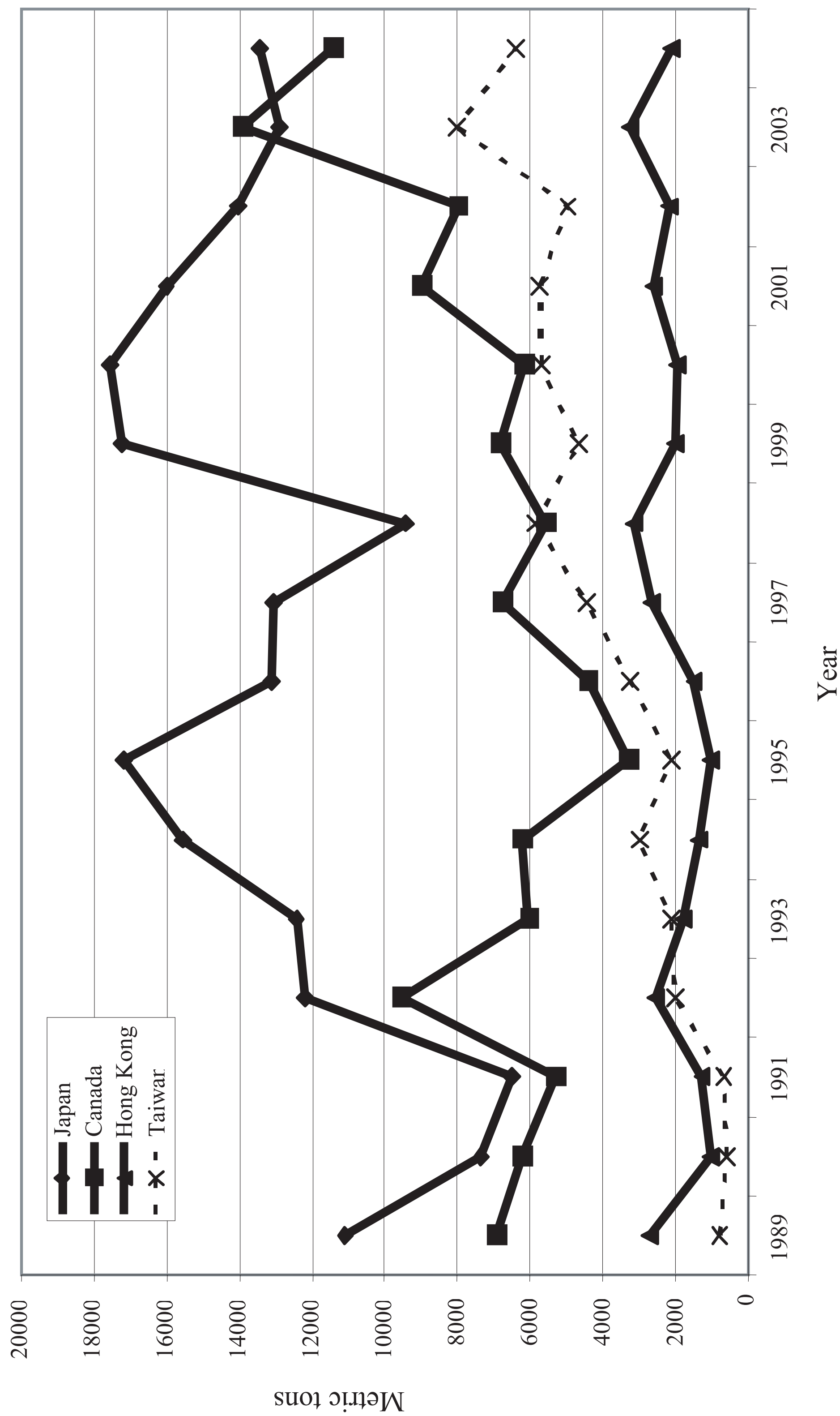

Figure 3. U.S. Cherry Exports by Country, 1989–2004.

study; annual per-capita consumption of cherries, as well as aggregate annual production and grower price received were collected from this publication. Data for each individual state were collected from the Quick Stats database (USDA - NASS 2004). The study period ranged from 1986 to 2004, the most recent data available for fresh sweet cherries over all varieties (variety differences are not measured in this analysis). Trade statistics were taken from the Foreign Agricultural Service's FATUS system (USDA - FAS 2004). Exports (in metric tons) to the top four importers of U.S. fresh sweet cherries—Japan, Canada, Taiwan, and Hong Kong—are used. These four countries account for an average 84 percent of total U.S. sweet cherry exports. Therefore these countries' aggregate U.S. imports should represent a reasonable indicator of demand for U.S. cherry exports. Descriptive statistics of the relevant variables used in the analysis are presented in Table 1.

Price Formation

The data collected for this analysis are consistent with those of the farm-level (the point of market interaction between the producer and the packer/shipper) rather than consumer-level market activity. Hence the focus is on price formation on the input side of the packing and shipping industry. The packing and shipping industry is conceptualized to have inputs (the raw product; i.e., fresh sweet cherries) and value-added outputs (i.e., packaged fresh sweet cherries) targeted to either the domestic market or the export market. An inverse demand system, wherein prices are adjusting to quantities, is appealing because of the inherent nature of the cherry market. Production acreage is relatively fixed over time, with narrow marketing seasons. Moreover, fresh cherries are highly perishable.

For this analysis, an input-distance function is specified and inverse demand functions derived. Consider the normalized quadratic input-distance function (Dong, Marsh, and Steigert 2005)

$$(1)\quad \begin{aligned} D(x^*, y) = b_0 + \sum_{i=1}^{n-1} b_i x_i^* + \frac{1}{2}\sum_{j=1}^{n-1}\sum_{i=1}^{n-1} b_{ij} x_i^* x_j^* \\ + \sum_{j=1}^{m}\sum_{i=1}^{n-1} b_{iy_j} x_i^* y_j + \frac{1}{2}\sum_{i=1}^{m} b_y y_i^2 + \sum_{i=1}^{m} b_{iy} y_i \end{aligned}$$

with n-1 inputs (x_i) and m outputs (y_i). Homogeneity of degree zero is imposed by normalizing quantities $x_i^* = (x_i/x_n)$ for i = 1,…,n–1. From Gorman's Lemma, $((\partial D(x^* y))/\partial x_k) = p_k^*$, where p_k^* represents cost-normalized prices. The inverse input-demand functions are given by

$$(2)\quad p_k^* = b_k + \sum_{i=1}^{n-1} b_{ik} x_i^* + \sum_{i=1}^{m} b_{ky_i} y_i \quad k=1,\ldots,n-1\ ,$$

Table 1. Descriptive Statistics for Prices and Quantities, 1986–2004.

Variable	Mean	St. dev.	Max	Min
WA price ($/ton)	1629.947	392.1565	2220	949
OR price ($/ton)	1119.053	270.3949	1710	650
ID price ($/ton)	1157.947	337.044	1630	508
UT price ($/ton)	1153.158	343.3504	2300	790
CA price ($/ton)	1728.947	726.531	3410	686
WA prod (tons)	58100	19355.33	99000	26600
OR prod (tons)	13366.11	4133.597	21000	5500
ID prod (tons)	1815.789	742.2886	3100	400
UT prod (tons)	948.4211	427.3076	1600	140
CA prod (tons)	29347.37	14888.26	57700	7500
Domestic consumption (tons)	45277.1	17126.30	19190	84067
U.S. exports to world (tons)	28953.22	8228.027	44339.8	10607.94

where the b_i's and b_{ij}'s are parameters to be estimated; x_i^* represents a state's annual production (1= Washington, 2= Oregon, 3= Utah, 4= California), and y_i represents outputs.[4] Here, y_1 is supply to the domestic market and y_2 is the supply to the export market (i.e., Japan, Canada, Taiwan, and Hong Kong). The Hessian matrix is given by the second-order derivatives of the distance function (Antonelli matrix):

$$(3)\quad A = \begin{bmatrix} \frac{\partial^2 D(\mathbf{x},\mathbf{y})}{\partial \mathbf{x}\partial \mathbf{x}'} & \frac{\partial^2 D(\mathbf{x},\mathbf{y})}{\partial \mathbf{x}\partial \mathbf{y}'} \\ \frac{\partial^2 D(\mathbf{x},\mathbf{y})}{\partial \mathbf{y}\partial \mathbf{x}'} & \frac{\partial^2 D(\mathbf{x},\mathbf{y})}{\partial \mathbf{y}\partial \mathbf{y}'} \end{bmatrix}.$$

Appealing to Young's Theorem, symmetry is imposed such that $\frac{\partial^2 D}{\partial x_i \partial x_j} = \frac{\partial^2 D}{\partial x_j \partial x_i} \Leftrightarrow b_{ij} = b_{ji}$.

To remain consistent with economic theory (e.g., a downward-sloping demand curve), a negativity constraint can be tested and imposed on the model. The model in Equation 2 is reparameterized using Cholesky decomposition into the negative semi-definite matrix, **B** = **-AA'**, where **A** is a lower triangular matrix such that

$$(4)\quad \textbf{-AA'} = -\begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{12} & a_{22} & 0 & 0 \\ a_{13} & a_{23} & a_{33} & 0 \\ a_{14} & a_{24} & a_{34} & a_{44} \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ 0 & a_{22} & a_{23} & a_{24} \\ 0 & 0 & a_{33} & a_{34} \\ 0 & 0 & 0 & a_{44} \end{bmatrix}.$$

The elements of the matrices in Equation 4 are the new parameters to be estimated (Lau 1978). The above distance function is homogenous of degree one, nondecreasing, and concave in input quantities **x**, as well as nonincreasing and quasi-concave in outputs **y** (Shephard 1970)**.**

Own and cross flexibilities were constructed by

$$(5)\quad f_{ij} = \frac{\partial \ln w_i}{\partial \ln x_j} = \frac{\hat{b}_{ij}\,\mathrm{x}_j^*}{\hat{w}_{ij}} \text{ for } i, j=1,\ldots, n_k,$$

using the estimated $\hat{b}_{ij}$ and the predicted $\hat{w}_{ij}$.

Empirical Issues

The empirical estimation proceeds in several steps. First, Idaho is used to normalize quantities as in Equation 2, yielding the four remaining equations (Washington, Oregon, Utah, and California). Second, to account for contemporaneous correlation, Feasible Generalized Least Squares (FGLS) is used to estimate the demand system (Greene 2000). Empirical estimation is completed in GAUSS and follows standard methods for estimating a system of nonlinear seemingly unrelated regression models.[5]

A log-likelihood statistic is used to test concavity restrictions on inputs in Equation 5. The LR test value is LR = 9.36, which is less than the critical value 18.307 (chi-square with ten degrees of freedom). Hence the null hypothesis for concavity of inputs could not be rejected at the 0.05 level.

A log-likelihood test is also constructed to test the null hypothesis for joint significance of the quantity variables (i.e., $b_{ij} = 0 \; \forall \; i, j$). The calculated test statistic is 32.44 with a critical value of 18.307 (chi-square with ten degrees of freedom) at the 0.05 level. The null hypothesis is rejected, indicating that the input-quantity variables are jointly significant at the 0.05 level.

Results

Parameter estimates and test statistics for the inverse demand system with curvature imposed are presented in Table 2. Thirteen of the 22 estimated coefficients are significant at the 0.05 level, while two coefficients are significant at the 0.10 level. Table 3 presents R^2 values. Production, supply to domestic and export markets accounted for 0.60 to 0.79 of the variation in fresh sweet cherry price, with Utah having the highest R^2 and California the lowest.

[4] In preliminary analysis we tested the impact of other commodities on cherry prices and found little or no statistical significance. Among the commodities examined were pears, strawberries, grapes, and plums. Hence these commodities were not included in the final model.

[5] Alternative model specifications for outputs were estimated and compared. Based on goodness of fit and significance of parameters, the preferred choice is a model in which outputs are delineated by domestic and international exports.

Table 2. Parameter Estimates from Normalized Non-Linear Inverse Demand System.

Coefficient	Variable[a]	Coefficient estimate	T-stat	
b_1	X_1	0.22793	12.53	*
b_2	X_2	0.15920	11.11	*
b_3	X_3	0.17102	12.63	*
b_4	X_4	0.22399	6.53	*
a_{11}	$X_1 * X_1$	0.03001	6.09	*
a_{12}	$X1 * X_2$	-0.00806	-0.68	
a_{13}	$X1 * X_3$	0.00725	0.70	
a_{14}	$X1 * X_4$	-0.02818	-2.94	*
a_{22}	$X_2 * X_2$	-0.01560	-0.99	
a_{23}	$X_2 * X_3$	0.01424	0.19	
a_{24}	$X_2 * X_4$	0.03429	2.04	**
a_{33}	$X_3 * X_3$	0.14523	4.63	*
a_{34}	$X_3 * X_4$	-0.00377	-0.23	
a_{44}	$X_4 * X_4$	0.00000	0.00	
$b_1 y_1$	$X_1 * y_1$	-0.01653	-2.42	*
$b_2 y_1$	$X_2 * y_1$	-0.02167	-3.72	*
$b_3 y_1$	$X_3 * y_1$	-0.01521	-3.53	*
$b_4 y_1$	$X_4 * y_1$	-0.01590	-1.34	
$b_1 y_2$	$X_1 * y_2$	-0.01173	-3.45	*
$b_2 y_2$	$X_2 * y_2$	-0.00638	-2.23	*
$b_3 y_2$	$X_3 * y_2$	-0.00760	-3.42	*
$b_4 y_2$	$X_4 * y_2$	-0.01244	-2.03	**

* Significant at the 0.05 level
** Significant at the 0.10 level
[a] $X_i = x_i^*$ normalized input quantities (X_1= Washington, X_2= Oregon, X_3= Utah, X_4= California); y_1 is output to the domestic market and y_2 is exported outputs (Japan, Canada, Taiwan, and Hong Kong).

Table 3. R-Square Estimates for Normalized Inverse Price Equations.

	WA	OR	UT	CA
Model I R^2	0.756	0.873	0.797	0.592
Model II R^2	0.749	0.770	0.788	0.600

Model II - Curvature imposed. Log-Likelihood value 207.14.
Model I - Curvature not imposed Log-Likelihood value 211.82.

Table 4 contains price flexibilities for each state's cherry inverse demand function calculated at the sample means. As is consistent with imposing curvature on the model, all own-price flexibilities are negative. This indicates that cherry price falls as producers increase quantity supplied. In addition, own-price flexibilities are inflexible (i.e., < 1).

All cross-price flexibilities are also inflexible. Pairs with negative cross-price flexibilities are classified as substitute products, while pairs with positive flexibilities are complements. With respect to the Washington equation, cross-price effects between are negative for Utah and positive for California (largest cross-effect magnitude at 0.263) and Oregon. This indicates that as California production increases one percent, producer price in Washington tended to increase 0.263 percent. Utah cross-price flexibilities are similar in sign to those for Washington: Oregon and California effects are positive, while the Washington effect is negative. All cross-price flexibilities are positive for the Oregon and California equations.

Output flexibilities are also provided in Table 4. The output flexibilities show the percentage change in price given a one-percent increase in quantity to the export or domestic markets. All domestic-market coefficients are negative, which is consistent with economic theory, and all are significant except for California (see Table 2). Oregon is the most price flexible at –1.23, while the remaining states range from –0.62 (California) to –0.87 (Utah). Export-price coefficients are negative and significant for all states (Table 2). All states are price inflexible, with very similar magnitudes ranging from –0.23 in Oregon to –0.31 in California.

Discussion

Some of the inherent attributes of the cherry industry provide sufficient information to justify anticipated expectations. First, cherry production acreage within a year is exogenous; planting decisions must be made years in advance to allow sufficient time for new trees to mature. On the other hand, cherries are very susceptible to adverse climatic conditions. As such, it is interesting that a change in quantity produced has a small effect on cherry price. While all flexibilities are inelastic, we anticipated that the two states with the largest share of the market, California and Washington, would have the largest magnitude and most responsive flexibilities, which they do, at –0.33 and –0.29, respectively.

Another interesting result is the positive cross-price flexibilities for Washington, Utah, and Oregon relative to California. California is a complement for every state; one possible explanation for this

Table 4. Price and Output Flexibilities at Sample Means.

	Price flexibilities			
	Washington	Oregon	Utah	California
Washington	-0.290	0.110	-0.100	0.263
Oregon	0.018	-0.033	0.030	0.022
Utah	-0.001	0.002	-0.166	0.001
California	0.146	0.075	0.065	-0.332

	Output flexibilities	
	Domestic	Export
Washington	-0.664	-0.301
Oregon	-1.228	-0.231
Utah	-0.871	-0.278
California	-0.619	-0.310

is seasonality. California fresh sweet cherries are marketed during June and July, while PNW cherries are marketed slightly later, during July thru August.[6] California and PNW cherries could act like complements since in years where cherry demand is high, it will likely be high during both the California and PNW cherry seasons. So California and the PNW are not marketed directly against each other, and most likely would not be substitute commodities. This could also explain why some of the PNW states (Washington and Utah) are substitutes in terms of their cross-price effects, since fresh sweet cherries in this region have the same growing season and would be marketed directly against each other. Additionally, it was proposed above that Oregon cherries might typically be used to "fill gaps" in demand; this hypothesis is further strengthened by the signs on the positive cross-price effects Oregon has with the other PNW states. The positive sign indicates that Oregon cherries are complements to California and Utah and could likely be used to complement supplies from those states.

It is also interesting to note the signs and magnitudes of the output effects on cherry price formation. As quantity supplied to the domestic market increases (all else held constant), price falls for all states. Domestic output effects for the PNW states are all very different, ranging from –0.641 in Washington to –1.23 in Oregon. For the export market, all output effects are negative and very similar. Foreign output effects range from –0.023 in Oregon to –0.31 in California. Output effects differ most for Oregon, which moves from –1.23 in the domestic market to –0.23 in the export market. For all states, the output effects are greater for the domestic market than for the export market. Another interesting result is the similarity between California and Washington. Domestic effects are –0.62 and –0.66, respectively, and export market effects are –0.31 and –0.30, respectively, indicating that both states have similar market responses in both the domestic and export markets.

The above results have practical implications for cherry growers. Results indicate California cherries are complements to Washington and Utah cherries at the farm level. This indicates that if Washington and Utah producers are concerned with differentiating their product, they should be more concerned with each other than with California. In fact, if California cherries are complements, and have an earlier marketing season, Washington and Utah producers may be using demand for California cherries as a benchmark for the success of their upcoming season. Results also show that California and Washington prices are most responsive to a change in their own quantities. This is likely due to the dominant market share othe two states. These two states are most likely driving the fresh sweet cherry market, and changes in quantity have larger effects on producer price received. In contrast, Utah and Oregon do not face as much risk of a price variation from a change in production. Additionally, it appears that California and Washington cherries producers face greater price responsiveness from a change in quantity supplied to the international market.

[6] An interesting direction for future research would be to test for price leadership, which was suggested by an anonymous reviewer.

Conclusions

This study specified farm-level price-formation equations for the PNW and California. From a normalized quadratic distance function, an inverse demand system was derived that was estimated for states in the PNW and California. The model was estimated with symmetry and curvature imposed, yielding a non-linear demand system. Flexibilities were also calculated for both production inputs and outputs (domestic and international), and the implications of these flexibilities addressed. The study period was from 1986 to 2004, and annual data were used.

Demand-system results indicate that between 0.60 and 0.79 of the variation in annual fresh sweet cherry price could be explained by production inputs and outputs. All own-price effects are negative and inelastic, with California and Washington being the most elastic. This study finds that California and PNW cherries are complements at the farm level. Meanwhile, Washington and Utah cherries are substitutes for one another. In addition, it was found that a change in supply to domestic markets has a highly significant impact on all states' prices (except California). Oregon price was most responsive to a change in supply to domestic markets. California and Washington exhibited the most similar market responses. A change in supply to export markets was significant and negative for all states and of considerably less magnitude than the domestic effects.

This study is not without limitations. First, only 19 years of data were available for analysis. A more comprehensive data set (e.g., monthly data) could have helped with the robustness of estimates. Second, cherries are a very seasonal commodity by nature, and this seasonality deserves attention. Given the nature of cherries, understanding how seasonality affects cherry price would be valuable, as it would allow for better comparisons between the PNW, California, and other areas that market during different seasons. Third, there are additional issues with the data. For example, marketing orders tending to be different from state to state could affect how data was reported. In addition, it is likely that arrangements such as forward contracting could influence price. However, even with such limitations this study demonstrates how different marketing conditions affect the producer price for cherries in the PNW and California.

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