Data Aggregation and Information Loss

By

Gregory McKee*
Assistant Professor
Department of Agribusiness and Applied Economics
205A Morrill Hall, Fargo, ND, 58102
North Dakota State University
E-mail: Gregory.mckee@ndsu.edu
Phone: 701-231-8521

Dragan Miljkovic
Associate Professor
Department of Agribusiness and Applied Economics
221G Morrill Hall, Fargo, ND, 58102
North Dakota State University
E-mail: dragan.miljkovic@ndsu.edu
Phone: 701-231-9519

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Portland, OR, July 29-August 1, 2007

*Corresponding Author

Abstract

Analysts often use a single average or otherwise aggregated price series to represent several geographic or product markets even when disaggregate data are available. We hypothesize that such an approach may not be appropriate under some circumstances, such as when only long-term relationships hold among price series or when homogeneous but relatively perishable products are considered. This question is of particular relevance in agriculture because of seasonality in production and harvest across various production regions, and the effect of changes in demand as substitute crops become available. We analyze this question in the context of fresh strawberry production. We find that in the case of the strawberry market, aggregate series are appropriate for long-term decision analysis, but some information loss occurs when conducting short-term decision analysis.

Keywords: strawberry, price, cointegration, Granger causality, average price

1. Introduction

It is common practice in the field of agricultural economics to use a single, aggregate, price series as an appropriate representative of multiple markets even though data from each of the disaggregate markets exist. For example, Herrmann, Moeser, and Weber (2005), and Han (2003), use aggregate price series, based on available individual series, to analyze historical relationships between price and other factors, while McKee (2006), and Bazoche, Giraud-Heraud, and Soler (2005) use aggregate price series to examine optimal behavior over a single season or in response to spot prices, respectively. Although this approach is convenient and parsimonious in its use of data, we hypothesize that such an approach may not be appropriate under some circumstances, such as when only long-term relationships hold among price series and/or when homogeneous but relatively perishable and non-storable products are considered. If instead there is information available in the disaggregate data series the analyst should consider whether or not these should be used instead of aggregate data.

This question is of particular relevance in agriculture for at least two reasons. One reason deals essentially with conditions of supply. If crops are produced in geographically distinct regions, but sold in a common market, then differences in climate may cause production activities, such as planting and harvest, to occur at different periods of time for crops that are considered nearly identical by the market in terms of its physical attributes. A second reason deals essentially with conditions of demand. If crops are produced over time, then production of complimentary or substitute crops can affect demand for any single one. Since demand and supply conditions change as the production season advances, it is important to discover whether information is lost when an aggregate series is used instead of available disaggregate data, a common analytical technique.

The objective of this paper is to determine whether information is lost when a single average data series is used to represent price series of geographically distinct production regions, whose activities occur at different points of time and whose output encounter changes in market demand over time. We analyze this question in the context of US fresh strawberry production. Section Two provides a background of strawberry production in California. Section Three describes the data and statistical methods used to obtain our empirical results. Section Four presents our empirical results. Section Five contains concluding remarks.

2. California Strawberry Production

Strawberries are grown commercially in five geographically distinct regions along the California coast. From south to north, these are the San Diego area, Orange County, which are typically combined for data recording purposes, the Oxnard plains in Ventura County, the Santa Maria Valley, and the Watsonville/Salinas area.

Variations in climate across California's strawberry growing regions allow production of strawberries at partially overlapping times of year. Early warm temperatures in southern California allow harvesting of summer-planted strawberries in September through December, and fall-planted berries to begin in late December and January. The harvest of fresh-market strawberries in the state then moves north, ending in the Watsonville/Salinas region, which accounts for most of California's production. The range of climates and available plant cultivars allows strawberry production somewhere in California virtually year round.

Strawberries are produced at various rates during the life of the plant. Strawberry plants begin by producing relatively slowly, requiring 4 to five weeks for a flower to mature into a commercially viable fruit. The production rate increases until a peak rate, which occurs in March in the Orange County and Oxnard regions, and in June in the Santa Maria and Watsonville regions. From this time forward, the number of degree-days available decreases the amount of time required to produce commercially viable fruit to approximately three weeks (Galletta and Bringhurst, 1990). The rate of production steadily declines after the peak until the end of the planting season.

The combination of the progression of strawberry harvest northward along the coast, and decline in strawberry yield and quality over time, affects how each region participates in the strawberry market over the course of the year. Strawberries are sold to two markets: first to the fresh market, and then to the relatively low-valued processed market. Each region starts by producing fruit for the fresh market, dominating that market until the next region begins to produce. At this point in time, the first region has fruit of relatively poor quality, compared with more northerly regions, so fruit from the first region is then sold to the processed market. For example, the fresh-market harvest from fall-planted fields ends around April or May for Oxnard, at which time berries are sold to the processed market. In contrast, since the Watsonville/Salinas is the northernmost production region, harvest for the fresh market lasts as late as December and sales to the relatively lower-priced processed market never exceed 10% of production. The strawberries in the processed market are mostly sold as frozen strawberries, but are also used as inputs for frozen foods and other products.

When the FOB prices of all production regions are plotted together, a cycle of high prices in the fresh market at the beginning and end of the year and low prices mid-year is observed. This cycle is driven by several factors. First, fresh strawberries are highly perishable. Since they cannot be stored, the current price represents demand and harvest conditions at the time. Second, yields from any given field start small, peak, and then decline again. A third reason for lower prices in the middle of the season is the increased availability of substitute fruits such as grapes and cherries. Fourth, the increase in the supply of fresh strawberries relative to early in the year, which occurs as southern growing regions are steadily harvesting and northern regions are coming into full production. We use daily FOB price of fresh strawberries between 1989 and 2003 for each production region reported by the USDA Agricultural Market News Service.

Although the composition of strawberry varieties grown in each region varies somewhat, the market appears to consider all fresh strawberries as homogenous. Wholesale market data, observed at several locations throughout the United States, do not regard differences in production region or variety when reporting price (USDA-AMS). The California Strawberry Commission annually reports the distribution of acreage for each strawberry variety planted that season. In any given year, growers devote more than 25% of total acreage to a single variety. In addition, when sold at retail no distinction is made to the consumer about which variety of strawberry is contained within the package. Finally, a review of sample budgets (Takele, Klonsky and DeMoura, 2006; Daugovish, et al., 2004) indicates that, although input costs vary by production region, production practices are similar throughout the state, with minor differences in field preparation and irrigation practices.

3. Data and Methods

FOB fresh strawberry market price and volume data were obtained for the years 1988 to 2004 from daily regional wholesale price reports published by the Agricultural Market News Service of the USDA found in *National Berry Report*. FOB Prices are aggregated into weekly averages by region, and the volumes are aggregated into weekly totals. We then use total weekly regional prices and volumes of fresh strawberries to create a weekly, volume-weighted average price per pound for each region. We deflate each price series using the annual average Consumer Price Index for all items for all urban consumers between 1988 and 2004. These average prices should be reasonably good measures of the price expected by growers, since none of the years had particular or unusual price patterns that would have a misleading influence on the calculation of an average or expected price. The deflated prices smooth out any year-specific market conditions, leaving a representative price for the analysis.

In each of the studies mentioned at the start of this paper, only level FOB price data were used; no differencing was done to remove any trend or seasonality in the data. The first step of our statistical analysis, therefore, is to verify the stationary nature of the data. We conduct an augmented Dickey-Fuller (1979) test to detect unit roots in each regional FOB strawberry price series. The presence of unit roots in any series would indicate that it is non-stationary. This implies that shocks to the price in the strawberry producing region with a non-stationary price series would affect each region in an unpredictable way, since no series would have an equilibrium price information to return to. In such a case, no long- or short-term relationship can be present among all of the fresh price series and an average price series could not be used for long- or short-term decision analysis.

If all the FOB price series are stationary it is possible that their values may wander over time in such a way that they never drift very far apart. In other words, any disequilibrium forces present in the market would tend to keep the prices in production region *i* similar to those in production region *j*, much like the movement of household income and expenditures. In this case, the FOB price variables in each region would be cointegrated and contain an equilibrium relationship. A series made up of a linear combination of these series will preserve this common trend and preserve the long-run equilibrium price information in the data. In the case of regional fresh strawberry prices, if these series are cointegrated, then any long-run analysis based on a linear combination of these series, such as an average price, will not lose any information about changes in long-run equilibrium fresh market price for strawberries.

The assessment of cointegration amongst the regional fresh strawberry FOB price series has practical value. To the extent that the series are not cointegrated, then any or all of the series must then have some sort of unique trend or seasonality in the data. If the unique information in one or more of the series was not noticed, then any analysis using a linear combination of the price series, such as an average, would provide misleading results. For example, if a steady trend of increases prices is overlooked in the price series of any one production region, then an average of these regions would inappropriately suggest that the average price of all regions may be steadily increasing. To the extent this oversight is ignored, buyers may forecast higher prices than are actually realized in production regions where the trend is not present in the series.

We estimate the following VAR models to detect a long-run relationship among these price series:

$$p_{Orange\ County\ region} = \beta_0 + \beta_1 p_{Oxnard\ region} + \beta_2 p_{Santa\ Maria\ region} + \beta_3 p_{Watsonville\ region} \quad (1),$$

where *p* refers to the observed FOB price of fresh strawberries in the selected region.

We use the Johansen multivariate cointegration test (Johansen, 1988) to detect cointegration among all possible combinations of the four FOB price series (Table 3). Each price series is modeled as a function of the prices in one, two, or all three other regions. In order to conduct tests of cointegration among the prices of all possible combinations of strawberry producing regions, only observations for which a non-zero price was observed in all regions were retained. We test for the presence of instantaneous cointegration, hence current data are used.

Cointegration among the price series would justify using an average price series to study agricultural production decisions in the long-run. If prediction of current FOB price values strawberry production region *i* is enhanced by using lagged values of FOB prices in other regions, then the prices in the other regions can be said to Granger-cause (Granger, 1969) FOB prices in region *i*. The presence of causality suggests short-run relationships in the FOB price data and a single series generated from the separate series may be appropriate for use in short-run decision-making analysis.

The assessment of causality also has practical value. To the extent that one price Granger-causes another, we can verify whether the sequence in production is also duplicated in price determination. For example, since the Orange County production region begins its harvest prior to the Oxnard production region, does the Orange County production region Granger-cause the price in the Oxnard region, or is the Orange County price exogenous to the Oxnard region price? Alternatively, we can detect whether a simultaneous, or two-way, causal relationship exists among the series and interpret whether specific changes in market conditions, such as changes in relative production quality, may contribute to this relationship. More interestingly, we can determine whether one- or two-way relationships develop over disappear as the number of lags changes. If this information is overlooked in analysis of short-term decision making, perhaps within a single growing season, then using an average price may misstate the true pricing pattern of any one production region.

To detect the presence of one-way or simultaneous Granger-causality among the price series, we perform the simple bivariate test of whether the set of current or past values of FOB price in region *j* test with significance when regressed on the FOB price of region *i*. To detect the presence of Granger causality we estimate the following:

$$p_{production\ region\ i,t} = \beta_0 + \beta_1 p_{production\ region\ j,t-n} + \varepsilon_t \,, \qquad (2)$$

where *p* refers to the observed FOB price of fresh strawberries in the selected production region *i*, with *i* and *j* being the Orange County, Oxnard, Santa Maria, and Watsonville production regions, *t* the current observed week, *n* the number of lagged weeks, and ε_t a white-noise residual innovation in price in region *i* that is not correlated with region *j*.

4. Empirical Results

Graphical analysis of the FOB fresh strawberry price series for each production region suggested little trend in the data, but rather a cyclical pattern of high and low prices which return to approximately the same high and low prices at the same point in time each year. Nevertheless, to verify that long-run information about relationships in price movements across different production regions could be gathered from the data, we test for the presence of unit roots in the price series. We use the augmented Dickey-Fuller procedure on the level price series with no lags. The test statistics reject the null hypothesis of unit roots with at least 99% confidence in every case (Table 1). Since we can conclude that there are no unit roots in any of the price series, the possibility of cointegrative relationships among the price series exists. If such relationships are found we can interpret our cointegration analysis as characterizing long-run relationships among the price series.

The Johansen (1989) procedure is used (Table 3) to determine if the prices of any or all of the eleven possible combinations of production regions in Equation 1 tend to move together. Since we fail to detect unit roots in the data, the data was not differenced when testing for the presence of cointegration. The results of the Johansen procedure are shown in Table 2. Based on maximum eigenvalue statistics, all fresh strawberry price series are cointegrated. We also find as many cointegrative vectors as the number of variables used in the estimating equation. Hence the empirical relationship in Equation 1 is supported by the data.

Since the relationship in Equation 1 is supported by the data, we conclude that the FOB price series of all of the producing regions have some common stochastic trend and tend to move together. This means that, since a linear combination of all price series contains the same information about innovations in price as any individual price series, in the long-run, no information about changes in price is lost when using an average of all of these regions together instead the price series for each region. Hence, we also conclude that occasions arise in which it can be appropriate to use average price series for analyzing long-run behavioral responses to market prices when homogeneous agricultural commodities are produced in geographically isolated regions, and price series for each of these regions exist.

We use the Granger (1969) procedure to detect the presence of short-term relationships among the FOB price series of the four California strawberry production regions. Both current and lagged fresh price observations are used in our Granger causality tests. We examine Granger-causal relationships at three different time intervals: instantaneous causality, or the presence of instantaneous correlation of FOB prices in the same week; and Granger causality based on lagged data, including lags of one to three weeks, and another set of tests to detect longer-term causality based on lags of four weeks or more. Table 3 reports the minimum, maximum, and average number of observations for which a non-zero price occurred for all combinations of strawberry producing regions between 1988 and 2004. Each combination of two, three, or all four production regions had at least 7 weeks during which a non-zero price was observed in all selected regions during the calendar year, and 17 weeks on average.

An important observation of the data Table 3 is that as the number of regions included in the comparison increased the number weeks during which a non-zero price was observed in all selected regions during the calendar year decreased. This is explained by the sequential start of production beginning in the Orange County production region and then in successively more northern production regions. Harvest for fresh strawberries occurs simultaneously in all four regions for only about three months. Combinations of two or more production regions had simultaneous harvests for 17 weeks on average, as determined by the number of non-zero price observations during the same week between 1988 and 2004 (approximately 289 observations per region combination). Given the regular pricing pattern in the data, we assume these are sufficient data from which to draw meaningful inferences about whether a feedback system exists among the price series for the selected production regions.

The first set of tests were done to detect instantaneous causality, or in other words, regressing current values of FOB fresh price in region *i* on the current FOB price in region *j*, for all *i* and *j* (Table 4). All t-statistics on the coefficients of these regressions indicate that individual price series from all pairwise comparison jointly Granger cause each other, suggesting two-way Granger causality among any pair of fresh strawberry price series from any two production regions. Hence innovations in price in one region are Granger-cause innovations in price in other regions. This result may be explained by the homogeneous nature of strawberries harvested at the same point in time, as suggested by their pricing at the retail level.

Tests of Granger causality using current FOB price values in region *i* and lagged values of FOB price in region *j* of one to three weeks also indicate that price series may Granger cause each other. We observe simultaneous, or two-way, causality relationship in four cases: Orange County and Oxnard, Orange County and Watsonville, Oxnard and Santa Maria, and Oxnard and Watsonville. This result indicates that past values of prices in the Orange County production region, for example, explain current prices in the Oxnard region, and vice versa. The relationship in the direction as written makes sense by virtue of the sequential nature of fruit production, with the first named region in each pair acting as the first “price making” region of the calendar year.

The reverse relationship, in which past values of prices in the second named production region explain current prices in the first region are likely explained by the biology of strawberry production. These results come from FOB price observations made when the two regions are producing simultaneously. As explained above, strawberries take approximately three weeks to develop from a flower to a commercially viable fruit ready for harvest as the season progresses. The one to three week lags used in these tests encompass sufficient time to allow all fruit sold to have developed and matured at the same time. Hence, the market would regard all the fruit as homogeneous. The presence of Granger causality among the four FOB price series indicates that using an average price series that combines all four series will not lose any information about how each series moves about the market equilibrium price.

For the other two pairs of regions, Orange County and Santa Maria and Santa Maria and Watsonville, only a one-way Granger causality relationship exists. This result indicates that past values of prices in the Orange County production region, for example, explain current prices in the Santa Maria region, but not the reverse. The reason for these results may be entirely due to the sequential nature of the production from these regions, with the first named regions being first to produce. We are unable to explain why a simultaneous relationship does not exist among these regions. The first two are separated geographically by several hundred miles. The second two regions differ in total acreage, with the Watsonville region being several times larger than the Santa Maria region.

Tests of Granger causality using current FOB price values in region *i* and lagged values of FOB price in region *j* of four or more weeks also indicate that price series may Granger cause each other. In a few cases only three annual observations were available to conduct this test. We find no evidence in the data to suggest that the price series were unusual in any single year, but sufficient observations between 1988 and 2004 to accept that the results of the tests, though based on an unbalanced panel of data, can be accepted as reasonable.

The nature of the causal relationships changed for three pairs of regions after increasing the number of lags, as compared to one to three lags. The two-way relationships between the Orange County and Watsonville production regions and between the Watsonville and Oxnard production regions change into one-way relationships. The results in Table 4 show that FOB prices in Orange County Granger cause FOB prices in Watsonville, and that FOB prices Watsonville Granger cause FOB prices in Oxnard. The first result suggests that since Orange County is the first region to produce in the calendar year that these price influence the prices throughout the entire state, since the Watsonville region is the last to begin production. The second result suggests that there is a “carryover” effect from the FOB price in the Watsonville production region during the previous year into the FOB price in the Oxnard production region the next year, even though it is a different calendar year. Alternatively, this suggests that relative quality differences in the two regions force the change in the Oxnard production region from sales to the fresh market to sales to the processed market.

The third causal relationship to change as more lags are added is between Santa Maria and Watsonville. In this case the one-way relationship changes into a two-way relationship. Can most likely be interpreted using the same biological explanation for the other two-way relationships as above.

5. Conclusion

When considering whether to use price series from geographically isolated production regions it is not immediately obvious whether or not information about the movement of any individual price series about equilibrium will be lost of these are combined into an average price series. The loss of this information could have practical implications, such as foregone arbitrage opportunities when regular patterns about an equilibrium price are ignored. Our analysis indicates that linear combinations of time series can be used for long-term decision analysis, but depending on the question pursued, some or no information loss may occur when conducting short-term decision analysis.

We examined whether any price movement information was lost when combining the FOB fresh strawberry price series from four geographically separate production regions in California into a single average price. We found that the FOB fresh price series for strawberries in the four production areas of California are stationary and cointegrated. We conclude that linear combinations of these cointegrated series, such as an average price, will not lose any of the long-run equilibrium price information contained in the region-specific series.

We also found that any pair of price series from any two production regions also has a causal relationship. We observed that in most pairs of regions a simultaneous causal relationship exists. We conclude that situations can exist for which a scientist could combines multiple price series into an average or other aggregate series and not lose any information about how each series moves about the market equilibrium price.

The results of our causality analysis also reveal that the type of question the data are used for may dictate whether or not the individual series can be combined without loss of information. Our results showed that the causal relationship among some production regions changed from two-way into one-way as the number of lags increases. We interpret this result as either an indication of a change in relative quality or as an intertemporal price signal over multiple crop years, with the last region to produce in calendar year *t* to Granger cause the price in the first region to produce in year *t*+1. This information would have been lost if an average series were used to detect similar results.

References

Bazoche, P., E. Giraud-Héraud, and L. Soler (2005) "Premium Private Labels, Supply Contracts, Market Segmentation, and Spot Prices." *Journal of Agricultural & Food Industrial Organization*: 3 (1). Available at: http://www.bepress.com/jafio/vol3/iss1/art7

Daugovish, O., E. Takele, K.M. Klonsky, and R.L. De Moura. "Sample Costs to Produce Strawberries: South Coast Region, Oxnard Plain." University of California Cooperative Extension Report ST-SC-04-2. 2004. Online: http://www.agecon.ucdavis.edu/uploads/cost_return_articles/strawscvent2004.pdf Downloaded May, 2007.

Dickey, D.A. and W.A. Fuller 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association* 74:427–431.

Galletta, G.J. and R. S. Bringhurst 1990. "Strawberry Management." In G.J. Galetta and D.G. Himelrick eds. *Small Fruit Crop Management.* Englewood Cliffs, NJ: Prentice Hall, pp 99.

Granger, C.W.J. 1969. "Investigating Causal Relations by Econometric Models and Cross Spectral Methods." *Econometrica* 37:424-438.

Han, F. 2003. "Seasonal and Weekly Price Determination in a Market for Perishables: An Econometric Model of the California Strawberry Industry." Ph.D. dissertation, University of California, Davis.

Johansen, S. 1988. "Statistical Analysis of Cointegrating Vectors." *Journal of Economic Dynamics and Control* 12:231-54.

Herrmann, R., A. Moeser, and S. Weber 2005. "Price Rigidity in the German Grocery-Retailing Sector: Scanner-Data Evidence on Magnitude and Causes." *Journal of Agricultural & Food Industrial Organization*: 3 (1). Available at: http://www.bepress.com/jafio/vol3/iss1/art4

MacKinnon, J.G. 1996. “Numerical Distribution Functions for Unit Root and Cointegration Tests.” *Journal of Applied Econometrics* 11:601-618.

MacKinnon, J.G., A.A. Huang, and L. Michelis 1999. “Numerical Distribution Functions of Likelihood Ratio Tests for Cointegration.” Journal of Applied Econometrics 14:563-577.

McKee, G. 2006. “Pesticide Resistance, Population Dynamics, and Invasive Species Management.” Ph.D. dissertation, University of California, Davis.

Owen, K., G. Griffith, and V. Wright. 2002. “One Little Lebanese Cucumber Is not Going to Break the Bank: Price in the choice of fresh fruits and vegetables.” *The Australian Journal of Agricultural and Resource Economics* 46(2):209–231.

Takele, E., K.M. Klonsky, and R.L. De Moura. “Sample Costs to Produce Strawberries: South Coast Region, Santa Barbara County, Santa Maria Valley.” University of California Cooperative Extension Report ST-SC-06. 2006. Online: http://www.agecon.ucdavis.edu/outreach/cost_return_articles/strawberryscsmv06.pdf. Downloaded May, 2007.

U.S. Department of Agriculture, Agricultural Marketing Service. 1988-2004. *National Berry Report*. USDA / AMS, Agriculture Market News Branch, Fresno, CA.

Table 1. Unit Root Test, by Production Region

Production Regions	t-statistic	P-value*
Orange County	6.4001	0.0000
Oxnard	6.1933	0.0000
Santa Maria	-6.3000	0.0000
Watsonville	-6.8733	0.0000

*MacKinnon (1996) one-sided p-values.

Table 2. Test of Cointegration, by Production Region Combination

	Null Hypothesis Rank at most = *r*	Maximum Eigenvalue Statistic	P-value*
Orange County and Oxnard	0	0.4851	0.0001
	1	0.1296	0.0000
Orange County, Oxnard and Santa Maria	0	0.4652	0.0000
	1	0.3352	0.0001
	2	0.1036	0.0000
Orange County, Oxnard, Santa Maria and Watsonville	0	0.4189	0.0000
	1	0.3702	0.0000
	2	0.2358	0.0000
	3	0.1647	0.0000
Orange County, Oxnard and Watsonville	0	0.3592	0.0000
	1	0.3442	0.0000
	2	0.1715	0.0000
Orange County and Santa Maria	0	0.4156	0.0001
	1	0.1212	0.0000
Orange County, Santa Maria and Watsonville	0	0.3690	0.0000
	1	0.2662	0.0000
	2	0.1646	0.0000
Orange County and Watsonville	0	0.3503	0.0000
	1	0.1653	0.0000
Oxnard and Santa Maria	0	0.3308	0.0001
	1	0.0517	0.0005
Oxnard, Santa Maria and Watsonville	0	0.3388	0.0000
	1	0.2607	0.0000
	2	0.0706	0.0002
Oxnard and Watsonville	0	0.2446	0.0000
	1	0.0749	0.0001
Santa Maria and Watsonville	0	0.2294	0.0001
	1	0.0756	0.0000

*MacKinnon-Haug-Michelis (1999) p-values

Table 3. Simple Statistics of the Number of Non-Zero Fresh Strawberry Price Observations each Year, by Production Region.

Production Regions	Minimum	Maximum	Average
Orange County and Oxnard	15	26	20
Orange County, Oxnard and Santa Maria	11	20	16
Orange County, Oxnard, Santa Maria and Watsonville	7	18	11
Orange County, Oxnard and Watsonville	7	18	11
Orange County and Santa Maria	11	22	16
Orange County, Santa Maria and Watsonville	7	18	12
Orange County and Watsonville	7	18	12
Oxnard and Santa Maria	15	33	22
Oxnard, Santa Maria and Watsonville	10	25	17
Oxnard and Watsonville	10	25	17
Santa Maria and Watsonville	31	36	33

Table 4. Test of Granger Causality, by Production Region Pair

Region		One-way	Two-way	Region		One-way	Two-way
Orange County, Oxnard				Oxnard, Santa Maria			
Lags:	0		x	Lags:	0		x
	1		x		1		x
	2		x		2		x
	3		x		3		x
	4		x		4		x
	5		x		5		x
	6		x		6		x
	7		x		7		x
	8		x		8		x
Orange County, Santa Maria				Oxnard, Watsonville			
Lags:	0		x	Lags:	0		x
	1	OC causes SM			1		x
	2	OC causes SM			2		x
	3	OC causes SM			3		x
	4	OC causes SM			4		x
	5	OC causes SM			5	Wat causes Ox	
	6	OC causes SM			6	Wat causes Ox	
	7	OC causes SM			7	Wat causes Ox	
	8	OC causes SM			8	Wat causes Ox	
Orange County, Watsonville				Santa Maria, Watsonville			
Lags:	0		x	Lags:	0		x
	1		x		1	SM causes Wat	
	2		x		2	SM causes Wat	
	3		x		3	SM causes Wat	
	4	OC causes Wat			4		x
	5	OC causes Wat			5		x
	6	OC causes Wat			6		x
	7	OC causes Wat			7		x
	8	OC causes Wat			8		x

OC=Orange County production region

Ox=Oxnard production region

SM=Santa Maria production region

Wat=Watsonville production region