Causes of almond yield variations

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Statistical analysis of regional, rainfall-related effects could help early-spring forecasting

California almond production is characterized by wide fluctuations in yield, due mainly to a combination of rainfall and a moderate alternate bearing effect. Because annual additions to acreage have been much smaller than the yield variations, the fluctuations have resulted in large swings in production (fig. 1). In this report, we discuss the variations in almond yield caused by rainfall, regional location, and alternate bearing.

Background

A previous report described a technique to improve the state’s objective almond survey prepared in June of each year (California Agriculture, March-April 1987). Although quite accurate at predicting crop size, the state’s survey and the improved estimate (the “Dorfman-Heien correction”) are not available until July. Because a significant proportion of the almond crop is exported, it is essential to be able to predict total crop production as early as possible. Even though the state forecast appears two months before harvest begins, an earlier forecast would be useful for pricing and for determining the optimal allocation between domestic and foreign sales.

We have developed a production function that allows a preliminary crop forecast in February with later adjustments through the state July forecast and the correction. Although an earlier crop forecast is possible, it should be cautioned that its predictions are not as reliable as the state July forecast or the Dorfman-Heien forecast. However, the estimates do allow for a study of the effects of rainfall and other factors on yield.

The production function was estimated as a pooled cross-section time-series model. Cross-section refers to the fact that data came from seven counties and two other regions composed of groups of counties. Time series refers to the fact that these cross-section data are for the years 1971-85. The estimation thus was based on a total of 135 observations. Dummy variables were employed for eight of the nine regions with Butte County as the base region. These variables were used to allow the average yield and rainfall sensitivity to vary by region. The variable for rainfall was inches of rainfall in February squared. Experimentation with rainfall and rainfall squared indicated that rainfall squared performed better. The relationship was estimated by Generalized Least Squares regression. The equation and results are presented in the boxed table.

We used county-level data on almond acreage, production, and rainfall from 1970 to 1985 for the estimation. The acreage and production data came from County Agricultural Commissioner’s Reports, and the February rainfall data from the National Oceanographic and Atmospheric Administration. We chose a weather station nearest the center of the almond-growing area in each county. The data were organized into nine regions: the seven counties (Butte, Fresno, Kern, Madera, Merced, San Joaquin, and Stanislaus) and two groups of counties that grow fewer almonds—North (Colusa, Contra Costa, Glenn, Solano, Sutter, Tehama, Yolo, and Yuba)—and South (Kings, San Luis Obispo, and Tulare).

Results

The results of this estimation (shown in the boxed table) allow two interesting effects to be calculated: the effect of rainfall during the pollination period and the magnitude of the alternate bearing effect in almonds. We found the alternate bearing...
phenomenon to be 12.2 percent of the past year's deviation from an average yield. If one year's yield is 10 percent higher than average, the next year's should thus be 1.22 percent below average, holding weather effects constant. Since the average deviation in yield (in absolute value terms) is 249 pounds per acre, the average alternate bearing effect is 30.4 pounds per acre 

This means that, in an average year, the yield is 30 pounds per acre (2 to 3 percent) larger or smaller than the yield expected, because of the physiological effect on the tree of the past year's crop. This 30-pound alternate bearing effect is in the opposite direction from the past year's deviation from the yield in the average year. From figure 1, it is easy to see how this effect was masked by the remaining variation. The rainfall effects are somewhat more complicated, because the coefficients involved are allowed to vary by region.

Table 1 presents some figures on the effects of rainfall and regional location on yield in almond years. Column 4 gives the estimated loss in yield from extra February rainfall squared for that region. Column 5 gives the estimated regional variation in yield. These figures are simply the values of the coefficients for the regional dummy variables for the amount of time lost to pollination (in days). This variation is due to differences in soil, climate, orchard age, and cultural practices. The final column presents the average yield for each region.

As indicated in table 1, the effect of rainfall varies by region. Different regions may receive rainfall at different intensities (that is, drops in one day or a slow drizzle for a week), the rainfall in inches does not necessarily represent the same number of days of rain in every region. Since it is primarily the amount of time lost to pollination during rainfall that matters, the differences in the effect of rainfall on the various regions are probably due to differences in the pattern of rainfall. Also, a higher average rainfall in a region can be partially translated into a lower region-specific average yield. This way, some of the effect that rain has on yield in a high-rainfall area can be hidden. For easy reference, these estimated regional variations in yield are also included in the table (in column 5).

To see more clearly how rain affects almond yields and how this effect varies by region, we calculated each region's estimated yield loss due to 1 inch of rainfall above normal in February. We used the estimated production function previously discussed. To calculate the values presented, the $\pi$'s (remembering to add in the value of $\beta$, the base sensitivity) from the regression are multiplied by the difference between 1 inch above average rainfall squared and average rainfall squared for each region, then converted to meat pounds from meat tons. For example, for Fresno County, the calculation is:

$$ \text{Loss} = (-0.003 - 0.006) \times (2.845^2 - 1.845^2) \times 2000 = -81.4 \text{ meat pounds per acre.} $$

It is evident that the loss in yield from an additional inch of rainfall can be quite large (table 2). Also, the loss from the first inch of rain past the normal amount is the largest in three counties with very low average rainfall (Madera, San Joaquin, and Stanislaus). It is interesting that the loss is smaller in the county with the lowest average rainfall, Kern. This result is due in part to this low average. Since the rainfall is squared, another inch or two would make the loss in yield from an extra inch of rainfall in Kern County just as large as those for Madera, San Joaquin, and Stanislaus.

**Conclusions**

By using statistical techniques, we were able to compute the relative magnitudes of the rainfall and alternate-bearing effects in almonds. The results show that, although almonds display an alternate-bearing pattern with an average difference of 30.4 pounds per acre between heavy and light crop years, this variation is often masked by the much larger effect of rainfall on yield. These rainfall effects proved to vary because of the amount and intensity of rainfall in a given region.

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