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Gleaning After Citrus Mechanical Harvesters – Labor Productivity

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ABSTRACT.
Canopy and trunk shakers in properly prepared Florida orange groves recover between 85 and 93 percent of the available fruit. Whether a grower should "glean" the remaining fruit depends on if the unit cost of gleaning is less than the on-tree fruit value. Labor productivity of gleaners is an important component in determining the unit cost of gleaning. Previous work by Polopolus and Emerson indicates that worker productivity of orange harvesters averages between 8 and 10 boxes per hour. Their data, however, are restricted to hand crews working in blocks averaging between 300 and 500 boxes per acre. Workers, or gleaners, who follow mechanical harvesting systems have access to far less fruit, perhaps only between 25 and 75 boxes per acre. The objectives of this paper are to test the hypothesis that worker harvest productivity is positively correlated with crop yield, and if true, estimate the overall effect of crop yield on worker productivity. A data set was assembled from 47 Hamlin orange blocks harvested in southwest Florida between 27 November 2007 and 10 January 2008. Each block was characterized by its total production (boxes per acre), the total boxes harvested by either hand crews or mechanical systems, and the average hourly productivity of hand harvesting crews. A linear model of worker productivity as a function of the log-transformed value of fruit availability was estimated by OLS. The estimated parameter coefficient on fruit availability was positive and statistically significant. The model predicts that worker productivity falls from ten to nearly five boxes per hour when fruit availability decreases from 500 to 25 boxes per acre. In order to for all workers to earn at least $8 per hour, the harvesting piece rate must increase from 80-cents for hand harvesters to $1.50 per box for gleaners.

KEYWORDS: gleaner productivity, citrus mechanical harvesting

INTRODUCTION

Problem Statement and Research Objectives

Citrus harvesters, like most workers who harvest fruit and vegetable crops, are paid on the basis of a piece rate. A worker's daily earnings are calculated by multiplying the piece rate by his productivity. Productivity of citrus harvesters is measured as the average number of 90-pound boxes collected per hour. For example, if the piece rate is 70-cents per box and the worker picks 80 boxes during the course of one day, total earnings will be $56. If the same worker spends 8 hours harvesting, his average productivity is 10 boxes per hour and his average hourly earnings is $7. The harvester's responsibility is to strip the tree of its fruit and collect the fruit into tubs positioned among the trees being harvested.

Harvest piece rates are influenced by grove conditions and the requirement that workers earn at least minimum wage. Florida's minimum wage, as of January 1, 2008, is $6.79 per hour. Therefore, if the piece rate is 70-cents per box, a harvester must collect 9.7 boxes an hour to earn the minimum wage. If grove production (defined as boxes per tree or boxes per acre) in a particular block is lower than average, productivity may suffer as a worker must travel farther to collect the same amount of fruit. If a harvesting crew, which can pick 10 boxes per hour in an average yielding block, can only pick 6 boxes per hour in a poorly producing block, the piece rate must be adjusted from 68-cents to $1.14 per box just to ensure that the average worker earns minimum wage.

Previous work by Polopolus et.al (1996) indicated that productivity of citrus hand harvesters averaged between eight and ten (90-pound) boxes per hour. These data were based on 1992-95 payroll records of harvesting crews during the first week of February, defined to be the peak harvesting period for citrus in Florida. Payroll records provided Polopolus et.al with a daily accounting of total boxes picked by a specific crew along with the total number of hours the crew worked. Average productivity by crew was calculated by dividing total boxes by total hours of labor. The Polopolus study documented differences in worker productivity by variety. Average worker productivity while harvesting Hamlins (early variety) was higher than while harvesting Valencia (late variety). While the authors speculated that worker productivity differences could be related to grove productivity, the payroll data to which they had access did not allow any testable hypothesis.

The purpose of this paper is to develop a model predicting worker productivity as a function of available yield per acre. A model that predicts worker productivity would provide a basis to estimate the piece rate needed to meet minimum wage requirements, or any other hourly earnings goal. This paper extends the previous work of Polopolus et.al by estimating a functional relationship between worker productivity and available citrus yield by including citrus blocks that were "gleaned" after mechanical harvesting.

MATERIALS AND METHODS

Trunk and canopy shakers, which collect removed fruit, have been shown to "recover" between 80 and 95 percent of the on-tree fruit (Roka, 2004). Hence, a block that yields 500 boxes per acre will have between 25 and 100 boxes of fruit remaining in the grove after a mechanical harvesting operation. An important question associated with mechanical harvesting is whether the remaining fruit should be harvested or "gleaned" by manual labor. As with harvesters who work in hand-picked blocks, gleaners must earn at least minimum wage. More importantly, in order to entice workers to shift from hand-picking to gleaning after a mechanical system, they must be assured that expected hourly earnings would remain the same. If productivity in a gleaned block is less than the productivity in a hand-picked block, a higher piece rate would be needed to maintain equal expected hourly earnings across the blocks. Before a reasonable piece rate can be established, there needs to be a reliable estimate of worker productivity under "gleaning" conditions and extent to which productivity is less than under "hand-picked" conditions.

The model to be estimated for this paper can be represented as,

$$P = f(Y),$$

where Y are the boxes per acre of oranges available for hand harvest and P is a measure of a worker's average hourly productivity. It is expected that the productivity (P) varies directly with available yield (Y), or,

$$\Delta P/\Delta Y > 0.$$

Available Yield Data for Hand Harvest

Yield data were collected from 47 Hamlin (early season orange variety) blocks in southwest Florida harvested between November 27, 2007 and February 3, 2008. On 17 blocks, the oranges were harvested completely by hand. On the remaining 30 blocks, a mechanical system (continuous canopy shake and catch, Oxbo Inter. Corp.) initially harvested the block. Fruit prices during the early 2007-08 season were in excess of $1.50 per pound-solid, providing growers with the financial incentive to pay hand crews to glean all fruit not harvested by the mechanical system. Grower records identified the method of harvest on each block (i.e. hand or machine pick). For those blocks mechanically picked, yield records separated the boxes harvested by gleaners from boxes harvested by the mechanical system. The total quantity of gleaned boxes divided by the net tree acreage of a block provided the per acre estimate of "available yield" for manual labor to glean.

Hand picked blocks averaged 331 boxes per acre, while machine picked blocks averaged 394 boxes per acre. Given the yield variability among the blocks, the difference in yield between hand and machine picked blocks was not statistically different (Table 1). As expected, "available yield" was significantly different between hand and machine picked blocks. On average, mechanical systems harvested 83-percent of the crop, leaving an average of 65.8 boxes per acre to be gleaned. For hand picked blocks, it was assumed the average yield equaled available yield (Table 1).

Worker Productivity Data

Growers typically hire a labor contractor to harvest their fruit. A contractor records all information relevant to worker productivity on daily payroll sheets. A payroll sheet is specific to an individual crew and indicates the grove and block where the crew was assigned. The daily payroll sheet lists the name of the crew leader and the names of all crew members working that day. For each worker, total boxes harvested and their respective work hours are recorded. Usually, all members of the crew start and stop at the same time on a given day. Hence, from the daily payroll sheet, total hours worked and the total boxes harvested by the entire crew can be tabulated.

Demographic data by individual worker were not available. Therefore, worker productivity was calculated as a crew average, total hours divided by total harvested boxes. Blocks ranged in size from 16 to 151 net tree acres. If a block required several days to complete its harvest, payroll sheets of all days when the crew exclusively worked in that particular block were combined to calculate average worker productivity. A daily payroll sheet of a crew working in more than one block was excluded from the data set because hours worked and boxes harvested could not be allocated to their respective blocks.

Worker productivity among the 17 hand-picked blocks averaged 9.9 boxes per hour. Worker productivity to glean behind the 30 mechanically picked blocks averaged 6.6 boxes per hour (Table 1). The difference of 3.3 boxes per hour was statistically significant at the 90-percent confidence level.

Data Analysis

A data plot suggests a nonlinear relationship between available yield and worker productivity. An analysis of residuals suggested a logarithmic transformation of the independent variable, available yield to linearize the relationship (Neter, et.al, 1989). OLS was performed on the transformed data using the Linear Model function within the SAS statistical package (SAS Institute, Cary, NC). The "no-intercept" option forced worker productivity to be zero with zero available yield.

RESULTS AND DISCUSSION

The parameter estimate on the transformed values of available yield was positive and significantly different from zero (Table 2). Nearly 95-percent of the change in worker productivity was explained by the model.

Table 3 presents a numerical example of how worker productivity is predicted as available yield increases from 25 to 500 boxes per acre. Piece rates, roadside charges, total harvesting costs, and break-even prices are all dependent upon predicted values of worker productivity. Piece rates are determined by dividing a wage goal ($8/hr) by the predicted value of worker productivity (column 4, Table 3).

If a mechanical system harvest 90-percent of a lock yielding 500 boxes per acre, workers have 50 boxes per acre available to be gleaned. Their estimated productivity is slightly more than 6.5 boxes per hour. If their wage goal is $8 per hour, the piece rate must be $1.23 per box. As the recovery efficiency of a mechanical system increases from 90 to 95 percent, predicted productivity of gleaners declines by more than 1 box per hour to 5.36 boxes per hour. In order to maintain the same hourly earnings ($8/hr), piece rates must increase by more than 20% to $1.49 per box.

A reliable estimate of worker productivity has important economic implications in deciding whether gleaning should occur after mechanical harvesting. Typically, a piece rate equals 40-percent of total hand harvesting cost including hauling charges to a processing plant. If gleaners are paid $1.50 per box, then an estimate of total harvest costs to deliver gleaned fruit to a processing plant is $3.75 per box. Assuming there is 6.0 pound-solids per box, a grower would have to receive at least $0.63 per pound-solid as a delivered-in price. While the current market for processed oranges is in excess of $1 per pound-solid, the market price for early season fruit in 2003 was below 60-cents. Under those market conditions, a grower would have been advised to leave unharvested fruit in the grove after mechanical harvesting.

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Table 1. Summary statistics of study blocks by harvest method. A different letter indicates that average values corresponding to harvest method (Hand and Machine/Glean) are significantly different.

		Hand	**Machine/Glean**
Number of blocks	(n)	17	30
Average Yield (std deviation)	(bx/ac)	331.5 **(a)** (130)	394.0 **(a)** (123)
Available Yield (std deviation)	(bx/ac)	331.5 **(a)** (130)	65.8 **(b)** (24.7)
Worker Productivity (std deviation)	(bx/hr)	9.9 **(a)** (1.184)	6.6 **(b)** (2.036)

Table 2. Parameter estimate, standard error, and model statistics for the predicted model of labor productivity.

Independent variable	Ln(AvailYield)
Parameter Estimate	1.66734
Standard Error	0.0568
Adj. R2	0.9482
F-value	861.37

Table 3. Predicted hourly worker productivity and implied piece rates to meet hourly earnings of $8. Productivity Model: P' = 1.666 * (LnY)
Wage goal: $8.00/hr

Yield	Transformed yield	Estimated Productivity (P')	Implied Piece Rate
Box/ac	**Ln(Y)**	**Box/hr**	**$/box**
25	3.219	5.36	$1.49
50	3.912	6.52	$1.23
75	4.317	7.19	$1.11
100	4.605	7.67	$1.04
150	5.011	8.35	$0.96
200	5.298	8.83	$0.91
250	5.521	9.20	$0.87
300	5.704	9.50	$0.84
400	5.991	9.98	$0.80
500	6.215	10.35	$0.77