Economic Impacts on Consumers, Growers, and Processors Resulting from Mechanical Tomato Harvesting in California—Revisited

By C.S. Kim, Glenn Schaible, Joel Hamilton, and Kristen Barney

Abstract. *This article measures economic gains to consumers and processors of adopting mechanical tomato harvesters in California, recognizing the oligopsonistic behavior of processors in the raw tomato market It provides a theoretical basis for using a kinked longrun supply curve to measure producer surpluses when the estimated supply curve intersects the horizontal axis Consumer benefits are inflated approximately 25 percent when one misspecifies the raw tomato market as perfectly competitive Producer benefits from adopting mechanical harvesting are positive and exceed estimates in previous studies*

Keywords. *Economic surplus, technological change, imperfect competition, processors, tomatoes*

Mechanization has dramatically affected the harvesting method of processing tomatoes in California Between 1961 and 1969, the mechanical harvest of processing tomatoes jumped from a mere 4 percent to nearly 100 percent As a result, tomato acreage more than doubled from 130,000 acres in 1960 to 270,000 acres in 1977

Economic adjustments resulting from the adoption of mechanical tomato harvesters in California have been complex and far reaching A change of this magnitude and speed led researchers to estimate the change in benefits to both consumers and producers (*3*), the reduced harvesting costs of the mechanical tomato harvester, and the cost of displaced farmworkers (*15*) [1] These studies, however, failed to consider how imperfect competition in the raw product market affects the size and distribution of the welfare impacts Tomato processors in California buy tomatoes from growers under contractual arrangements in an oligopsonistic market (*2, 5, 6, 10*) Chern and Just claim

> There are few processors in the industry It is, therefore, plausible to consider that the processors may procure raw tomato supply in a so-called oligopsonistic market Informal interviews with growers (in this study) confirmed an earlier observation by Collins, Mueller, and Birch that most processors follow leadership pricing as a policy (*5*)

Thus, by failing to recognize the imperfect nature of the raw product market, past research has assigned too many welfare benefits to consumer surpluses rather than to processor profits

Furthermore, previous studies of the tomato market were based on the supply curve intersecting the horizontal axis This specification has generated controversy over the estimation of producer benefits The controversy arises from the failure of economists to reconcile economic theory and econometric results We need to discuss these theoretical problems and make alternative specifications of the supply curve that reflect fundamental economic theory more closely

We have two objectives here [2] First, recognizing the imperfectly competitive behavior in the processing sector, we estimate the economic gains to consumers and processors of adopting mechanical tomato harvesters in California We then compare the results with estimates made under misspecification that the raw tomato market is competitive

Second, we estimate producer benefits from adopting mechanical tomato harvesters in California by apply-

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[1]Italicized numbers in parentheses refer to items in the References at the end of this article

[2]This study did not estimate the cost associated with displaced farmworkers Other research has addressed this issue (*15*) The revised estimates of processor benefits provided for here are unaffected by any cost estimates of displaced farmworkers Such costs would alter net social benefits only By excluding the issue of displaced farmworkers, we do not diminish its importance, but we focus attention on the appropriate theoretical and empirical estimation of benefits to consumers, producers, and processors

ing an alternative specification of the longrun supply curve from that specified in previous tomato market studies Specifying a vertical shift in the supply curve, we estimate producer benefits and compare them with those estimated by Brandt and French (*3*)

Economic Gains to Consumers and Processors

We estimate the change in consumer benefits due to the adoption of mechanical tomato harvesters by summing the relevant areas under the consumer demand functions for tomato products However, consumer demand for all processed products is not available, and the processed product demand functions do not account for all the tomatoes processed (*3*) Therefore, an alternative approach is needed to estimate consumer benefits

In a path-breaking article, Just and Hueth explicitly show, by using the envelope theorem, that the area behind a general equilibrium demand curve in the input market measures quasi-rents to producers plus final consumer surpluses, therefore, consumer surpluses from the input markets equal consumer surpluses of output markets in the long run (*11*) Assuming longrun competitive equilibrium, Anderson (*1*) and Carlton (*4*) also show that consumer surpluses can be measured in either the input or the output market Therefore, the input demand curve can be used to measure consumer surpluses under a competitive market structure

Just and Chern used the perceived demand curve to represent the derived demand under an oligopsonistic market structure (*10*) Assuming competitive behavior on the supply side, Just and Chern (*10*) and French (*7*) show that, with parallel shifts in the linear supply curve, market observations of prices and quantities trace out a perceived demand curve The perceived demand intersects the vertical axis at the same point as does the derived demand curve that would apply under perfect competition, but the perceived demand curve lies below the derived demand curve The degree to which the perceived demand curve deviates from the derived demand curve depends on the structure and behavior of the oligopsony that exists in a particular market

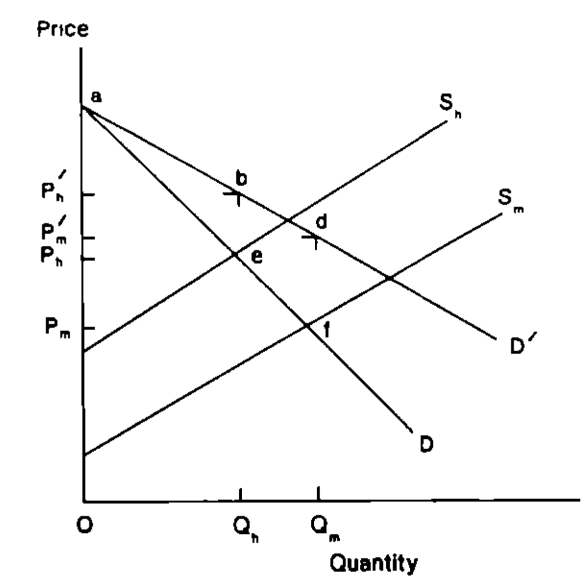
Because the input demand curve under imperfect competition lies below the derived demand curve under perfect competition, the area below the perceived demand curve, but above the equilibrium contract price, does not properly measure consumer surpluses in an oligopsonistic market Tomato processors in California purchase tomatoes from growers in an oligopsonistic market Therefore, measuring welfare impacts based on a perceived demand curve improperly allocates a greater share of welfare impacts to consumer surpluses, by incorporating a portion of processor profits

Figure 1 illustrates how consumer surpluses are measured (1) under the assumption of an oligopsonistic market using a perceived demand curve, and (2) under the assumption of perfect competition, but given the same input quantities supplied to the processing sector Curve D represents the perceived demand curve that is relevant under actual conditions of imperfect competition, whereas curve D′ represents the value of the marginal product (derived demand) curve under conditions of perfect competition Curves S_h and S_m are supply curves, assuming hand and mechanical harvest, respectively

Given quantities Q_h and Q_m and assuming hand and mechanical harvest technologies, respectively, under conditions of imperfect competition, grower prices are P_h and P_m, respectively Given the same quantities, Q_h and Q_m, under conditions of perfect competition, processors would pay growers P'_h and P'_m, respectively Under perfect competition, consumer surpluses are measured under the D′ curve as abP'_h and adP'_m, respectively However, previous studies measured consumer surpluses before and after tomato harvesting by areas under the perceived demand curve, aeP_h and afP_m, respectively

Figure 1

Changes in consumer and producer surpluses and processor profits resulting from mechanical tomato harvesting



The differences in these respective areas (for hand and mechanical harvest market situations separately) measure the gains that processors are able to capture because of the oligopsonistic nature of the industry. Area $P_h ebP'_h$ represents the gains in precessor profits prior to mechanical harvesting, whereas area $P_m fdP'_m$ measures the gain to processors after mechanical harvesting. Because the oligopsonistic market structure will prevail, processor benefits will not be driven to zero in the long run.

Consumer benefits (CB) resulting from adoption of mechanical tomato harvesters in California are represented by the trapezoid $P'_h bdP'_m$ in figure 1, therefore, CB are measured as follows:[3]

$$CB = 0.5(P'_h - P'_m)(Q_h + Q_m) \tag{1}$$

However, this equation still has two unobservables, P'_m and P'_h.

Under imperfect competition, P'_m and P'_h can be approximated by the following:[4]

$$P'_h = P_h(1 + F_h) \quad \text{or} \quad P_h = P'_h/(1 + F_h), \tag{2}$$

and

$$P'_m = P_m(1 + F_m) \quad \text{or} \quad P_m = P'_m/(1 + F_m) \tag{3}$$

where F_h and F_m are price flexibilities of supply for hand and mechanical harvest, respectively.

[3]Equation 1 would overestimate or underestimate consumer surplus in cases where the segment bd of the value of marginal product curve (D') is convex or concave, respectively. Because the value of the marginal product curve is more elastic than the perceived demand curve, the change in price for a given change in quantity is small. Therefore, the trapezoid area $P'_h bdP'_m$ can be regarded as the limit of actual consumer surplus for a decrease in price.

[4]Under imperfect competition, processors attempt to operate at a level of raw product utilization Q_i that maximizes their profits:

$$\pi = P_y{*}Y - P_i{*}Q_i \qquad i = h \text{ (hand) or } m \text{ (mechanical)}$$

given a processor production function $Y = f(Q_i)$ and the price of processed output P_y. The maximum is given by (see (5) for a complete analysis):

$$\frac{\partial \pi}{\partial Q_i} = P_y \frac{\partial Y}{\partial Q_i} - P_i - Q_i \frac{\partial P_i}{\partial Q_i} = 0$$

$$P_y \frac{\partial Y}{\partial Q_i} = P_i\left(1 + \frac{\partial P_i}{\partial Q_i}\frac{Q_i}{P_i}\right) = P_i(1 + F_i)$$

where $F_i = \frac{\partial P_i}{\partial Q_i}\frac{Q_i}{P_i}$

Since $P_{ci} = Py \frac{\partial Y}{\partial Q_i}$ under perfect competition, it follows that

$$P_{ci} = P_i(1 + F_i)$$

Therefore, consumer benefits in equation 1 can then be written as:

$$\begin{aligned} CB = 0.5[&(P_h - P_m)(Q_h + Q_m) \\ &- (P_m F_m Q_m - P_h F_h Q_h) \\ &+ (P_h F_h Q_m - P_m F_m Q_h)] \end{aligned} \tag{4}$$

Note that the last term $(P_h F_h Q_m - P_m F_m Q_h)$ in equation 4 becomes zero for the linear perceived demand curve.[5]

Processor gains (PG) may be represented by the difference between processor profits after mechanical harvesting $(P_m fdP'_m)$ and processor profits prior to mechanical harvesting $(P_h ebP'_h)$. This difference can be measured as:

$$PG = (P'_m - P_m)Q_m - (P'_h - P_h)Q_h$$

If one substitutes P'_h and P'_m from equations 2 and 3, respectively, and simplifies, processor gains are:

$$PG = P_m F_m Q_m - P_h F_h Q_h \tag{5}$$

The estimates of F_h, F_m, P_h, P_m, Q_h, and Q_m needed to estimate consumer benefits and processor gains, by use of equations 4 and 5, are available from Brandt and French who conducted simulation analyses based on a system of econometric models of the processing tomato industry in California (2). They estimated changes in acreage allocated to tomato production for processing and grower prices without mechanical tomato harvesting under four different scenarios with respect to labor costs. If we use the estimates of P_h and Q_h from Brandt and French, the computation of consumer benefits and processor profits reveal that consumer benefits are inflated by approximately 25 percent when one misspecifies the raw product market as competitive under the four scenarios (table 1). Overestimated consumer benefits range from nearly $70 million to $200 million, depending on different scenarios associated with labor costs.

It is interesting to observe how much the perceived demand curve under imperfect competition deviates from the raw product demand curve that would prevail under perfect competition. Because producer prices under imperfect competition are discounted by the price flexibility of supply as shown in equations 2 and 3, the producer price is less than it would be

[5]
$$\begin{aligned} P_h F_h Q_m - P_m F_m Q_h &= P_h Q_m \frac{Q_h}{P_h}\frac{dP_h}{dQ_h} - P_m Q_h \frac{Q_m}{P_m}\frac{dP_m}{dQ_m} \\ &= Q_h Q_m \left(\frac{dP_h}{dQ_h} - \frac{dP_m}{dQ_m}\right) \\ &= 0 \text{ since } \frac{dP_h}{dQ_h} = \frac{dP_m}{dQ_m} \text{ for the linear demand curve} \end{aligned}$$

Table 1—Consumers' benefits from adopting mechanical tomato harvesters in California, 1960-77

Scenario[1]	1	2	3	4
	1,000 dollars			
Consumer benefits	296,857	444,332	578,930	732,979
Amount attributed to processor profits	69,721	108,439	146,228	196,778
Consumer benefits under the misspecification that the factor market is competitive[2]	366,578	552,771	725,158	929,757

[1]Scenario 1 assumes labor fully available at wage rates experienced with mechanical harvest development. Scenario 2 increases effective wage costs by 30 percent over scenario 1. Scenario 3 increases effective wage costs by 60 percent over scenario 1. Scenario 4 increases effective wage costs by 100 percent over scenario 1.

[2]Brandt and French's estimates of consumer benefits (*3*, p. 271).

under perfect competition. According to Brandt and French, the elasticity of raw tomato supply is 1.627 and real grower price was \$32.06 per ton in 1977 (*2*). The deviation between the perceived demand curve and the raw product demand curve under perfect competition in 1977 (that is, $P'_m - P_m$ in figure 1) can be measured as

$$\begin{aligned} P'_m - P_m &= P_m(1 + F_m) - P_m \\ &= P_m \times F_m \\ &= \$19.70 \end{aligned} \quad (6)$$

Therefore, had a perfectly competitive market existed in the factor market, growers would have received \$51.76 per ton of tomatoes. The difference of \$19.70 per ton represents processor gains and the degree to which the perceived demand curve deviates from a raw product demand (D') curve under perfect competition.

Producer Benefits

Mechanical harvesters are generally assumed to reduce harvesting costs by substituting capital for labor, but not to change yield per acre (*9*). Thus, in our analysis, any increase in supply results from an expansion in acreage, which in turn is explainable by a technology variable (the adoption rate of mechanical tomato harvesting), explanatory price variables, and the reduction of uncertainty associated with harvest by handpickers. Thus, with the introduction of mechanical tomato harvesting in California, producers who realize lower harvesting costs will expand acreage devoted to producing tomatoes for the raw product market (for example, $Q_m - Q_h$ in fig. 2).

Producer surpluses before and after adoption of the mechanical tomato harvester are represented by the areas P_hE_hA and P_mE_mB, respectively, in figure 2. Therefore, producer benefits, represented by the change in producer surpluses, are measured by the area $P_mE_mTP_t$. These producer benefits (PB) can be estimated as[6]

$$PB = 0.5(P_m - P_t)(Q_m + Q_h) \quad (7)$$

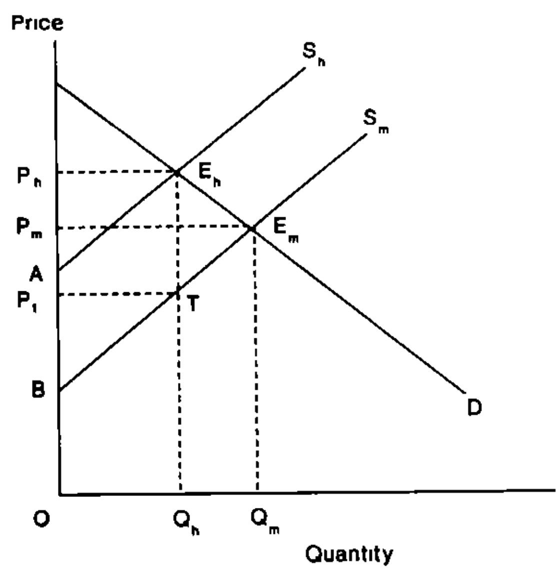
where the value P_t represents that price at which the area of producer surpluses P_tTB equals P_hE_hA (the area of producer surpluses prior to mechanical harvesting) in figure 2. The remainder of the producer surpluses after mechanical harvesting represents producer benefits. To apply the formula in equation 7, we needed information on P_t. We, therefore, applied the acreage response function estimated by Brandt and French (*2*, p. 52)

$$\begin{aligned} A_t = {} & \underset{(20.30)}{56.70} + \underset{(0.0681)}{0.2551}\left[YMAC_t(GP_t)\right] - \underset{(0.0681)}{0.2551}\, GC_{t-1} \\ & + \underset{(0.1767)}{0.1982}\, TC_t + \underset{(0.1445)}{0.5978}\, A_{t-1} \end{aligned} \quad (8)$$

[6]Producer benefits measured with equation 7 implicitly assume that the supply shift is parallel. Therefore, results would either overestimate or underestimate producer surpluses, depending on whether the supply shift is pivotal or convergent. However, Rose pointed out that the only realistic strategy is to assume that the supply shift is parallel (*14*).

Figure 2

Changes in consumer and producer surpluses resulting from technological change



where YMAC measures the 3-year lagged moving-average of California yield (tons/acre), GP represents raw tomato contract price ($/ton), GC measures representative average growers' cost of producing tomatoes in California ($/acre), and TC measures the adoption rate of mechanical tomato harvesters in California The numbers in parentheses below coefficients are estimated standard errors

The longrun acreage response function obtained by solving the first order difference equation 8 is represented in the following form

$$A_t = a_t + 0\ 6343(YMAC_t)(GP_t) \quad (9)$$

where a_t is an intercept term One can obtain a supply equation by multiplying the longrun acreage response equation 9 by yield per acre, YLD, as follows

$$Q_t(s) = a_t^* + [0\ 6343(YMAC_t)(YLD_t)]GP_t \quad (10)$$

where $a_t^* = a_t(YLD_t)$ and $Q_t(s) = (YLD_t)(A_t)$ Partial differentiation of equation 10 with respect to GP is given by $dQ_t/dGPt = 0\ 6343\ [(YMAC_t)(YLD_t)]$ When one then solves for $d(GP_t)$, the distance between P_m and P_t in figure 2 is measured by $dQ_t/\ [0\ 6343(YMAC_t)(YLD_t)]$ where $dQ_t = Q_m - Q_h$ By substituting $(P_m - P_t)$ for $d(GP_t)$, one can estimate the unknown variable P_t by

$$P_t = P_m - (Q_m - Q_h)/[0\ 6343(YMAC_t)(YLD_t)] \quad (11)$$

If one inserts equation 11 into equation 7, producer benefits resulting from mechanical tomato harvesters in California range from $70 million to nearly $200 million, depending on the scenario specified with respect to labor costs (table 2)

Supply Specification and Producer Surpluses

Brandt and French obtained empirical linear supply curves that intersected the horizontal axis for several scenarios they considered (2) Their results included several instances of negative producer benefits (table 2) If the longrun supply curve intersects the horizontal axis, this situation violates Euler's theorem, the fundamental economic theorem that total output would be exhausted in the long run

Several authors have attempted to explain the phenomenon of a longrun supply curve intersecting the horizontal axis Lindner and Jarrett showed that a statistically estimated supply curve may not provide reliable information on the intercept term because the intercept usually falls well outside the range of the data used to estimate the curve (*12*) Pindyck and Rubinfeld also demonstrated that the interpretation of the intercept depends on whether sufficient observations near the point where all explanatory variables are zero are available to yield statistically meaningful results (*13*) In cases where enough observations are unavailable, one can draw no valid conclusions

Table 2—Producers' benefits from adopting mechanical tomato harvesters in California, 1960-77

Scenario[1]	1	2	3	4
		1,000 dollars		
Producer benefits	70,058	108,586	146,338	197,036
Producer benefits with the supply curve assumed to intersect the horizontal axis[2]	-61,952	-9,945	77,551	164,010

[1]Scenario 1 assumes labor fully available at wage rates experienced with mechanical harvest development Scenario 2 increases effective wage costs by 30 percent over scenario 1 Scenario 3 increases effective wage costs by 60 percent over scenario 1 Scenario 4 increases effective wage costs by 100 percent over scenario 1
[2]Brandt and French's estimates of producer benefits (*3*, p 271)

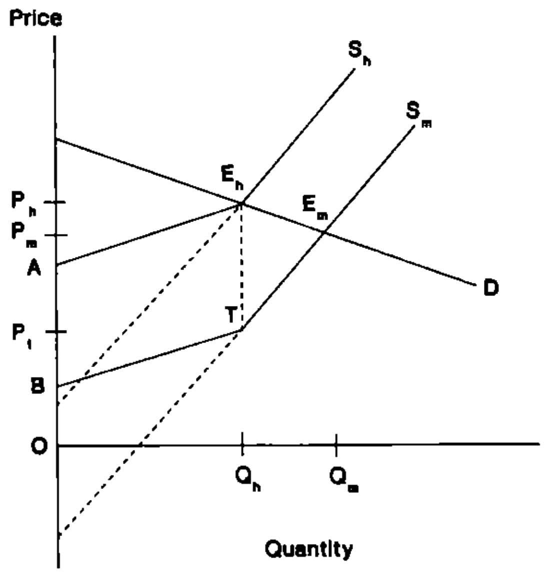
To deal with this problem conceptually, a few authors have assumed that the longrun supply curve asymptotically approaches the horizontal axis in cases where the statistically estimated supply curve intersects the horizontal axis Figure 3 illustrates a case that uses a kinked supply curve as assumed by Groenewegen and Cochrane (*8*), Lindner and Jarrett (*12*), Rose (*14*), and Wise and Fell (*16*) Groenewegen and Cochrane for example, assumed that the U S grain supply curve intersects the vertical axis at the loan rate (*8*)

Estimates of producer benefits are clearly subject to the assumptions one makes about the shapes of the supply curves and how they shift If one assumes a horizontal shift of the supply curve, then the estimated producer benefits would approach those estimated by Brandt and French (*3*) Although the implication of Lindner and Jarrett's work (*12*) is that the true shape and shift will not be revealed by econometric means, we suspect that Brandt and French's estimates (*3*) of producer benefits are biased downward

We estimated producer benefits under the assumptions that the supply curves were kinked, and that the introduction of mechanical tomato harvesters results in a vertical supply curve shift (fig 3) Based on these assumptions, producer benefits (table 2) from adopting mechanical harvesters are positive and are sub-

Figure 3

Welfare changes with the kinked supply curve



stantially larger than the estimates of Brandt and French (*3*)

Conclusions

We have estimated economic gains to growers (producers), processors, and consumers from adopting mechanical tomato harvesters in California, using a model that recognizes that processors purchase raw tomatoes from growers under contractual arrangements within an oligopsonistic market Both consumers and producers are better off from the use of mechanical tomato harvesters Consumer benefits range from a low of \$296 9 million to a high of \$733 0 million, and producer benefits range from a low of \$70 1 million to a high of \$197 0 million, depending on which set of labor costs one assumes Consumers receive more benefits than producers by approximately 4 1 under the different scenarios

We have shown that earlier estimates of consumer benefits, under the misspecification of the factor market, are overstated by approximately 25 percent because they include amounts that should be attributed to processor profits Processor gains range from a low of \$69 7 million to a high of \$196 8 million under the different scenarios Producer benefits were probably underestimated by Brandt and French because of a misinterpretation of empirical linear supply curves that intersected the horizontal axis

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Gordon E Rodewald, Jr and Raymond J Folwell
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