Assessment of the Economic and Social Impacts of Agricultural Technology: A Case Study

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Over the years, several studies have assessed the impacts of changes in agricultural technology. In most studies, the emphasis has been on evaluating the economic impacts of technological change with little consideration of the secondary and tertiary distributional impacts of such change. This article uses partial equilibrium analysis to estimate the gross and net social rates of return arising from proposed mechnization of strawberry harvesting in Oregon. The discussion considers other factors not explicitly accounted for in the economic model, (e.g., social and technical) but which are likely to have repercussions on the estimated social rates of return.

The primary objectives of this study are: (a) to briefly discuss the complex theoretical and empirical issues facing economists in assessing the economic and social impacts of technological change in agriculture; (b) in light of these issues, to evaluate the net social benefits arising from the proposed mechanization of strawberry harvest in Oregon. This case study demonstrates the strengths and weaknesses of the most contemporary economic models and methodologies used to evaluate the economic and social impacts of new and existing agricultural technologies.

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This paper was based upon research conducted under Oregon Agri. Exp. Sta. Project 128. Oregon Agri. Exp. Sta. Tech. Paper No. 5161.

Economic and Social Impacts of Technological Change in Agriculture

Over the years, two opposing views have emerged about the impacts of technology on society. For example, in 1970, Byerly wrote: "Continuing development and application of technology in production of food, fiber and forest products can supply the next generation abundantly. It can enable them to take the actions necessary to have clean air, sparkling water, and a green and pleasant world in which to live." In contrast to Byerly's optimistic view, Hightower criticized agricultural research carried out by land grant colleges and universities by stating that, "in terms of wasted lives, depleted rural areas, choked cities, poisoned land and maybe poisoned people, mechanization research has been a bad investment."

It is difficult to envision technological change which is Pareto Superior; that is, a condition(s) where none of the parties affected by the change are worse-off. At the same time it is also rare to find a technological change which is void of any value, even though the net value of some technology could be negative. Hence, it would be erroneous to perceive technology as being good or bad without some qualifications.

Technological change is manifested in changing r/oduction functions with either changes in factor shares and/or proportions whereby more output is generated from same or fewer inputs. For example,

> Since 1950, wheat yields have risen from 16.5 to 32 bushels an acre, corn from 38 to 90, soybean from 22 to 28, cotton yields have increased from 269 to 520 pounds an acre. Since 1950, the output per manhour in agriculture has increased at a rate of nearly 6 percent a year compared with 2.5 percent for all other industries. [Rasmussen]

Nevertheless, along with the positive impacts, technological change has had some deleterious impacts on society, such as, increases in rural poor, urban congestion, pollution, alienation, crime, deterioration of education, and so on.

> The number of farms in the United States declined from 6.5 million in 1920 to 5.6 million in 1950 and 2.8 million in 1975. The drop resulted primarily from machinery and other technology that permit a farmworker to handle larger acreages. In 1959, there were 9.9 million persons working on farms, compared with 4.3 million in 1973 .....this decline has been accompanied by a change in the rural social structure. Many villages and small towns, with their schools, churches, stores, and social life have declined and even disappeared .....Earlier, surplus farm workers supplied some of the manpower needed to industrialize America. Since the second American agricultural revolution, many have gone to the cities, some to a very uncertain future. Others are now part of the rural poor. [Rasmussen]

In view of the positive and negative results emanating from technological change, an analytical framework is needed to assess technology in terms of its *net*, instead of *gross*, social benefits.

Models and Methodologies Used for Technology Assessment

According to West, technological assessment entails, "the formal systematic examination of existing, newly emerging, or prospective technology with the objective of estimating first and second order costs and consequences (beneficial and adverse) over time in terms of the economic, social, demographic, environmental, legal, political, and institutional dimension of the impacts of the technology". Hence, technological assessment involves a careful and objective consideration of both the social and economic impacts of technology. In assessing agricultural technology, however, economic factors have been given unjustifiably heavy weight in the past, while the social (distributional) effects of technology received little consideration. In this regard, Hightower criticized the land grant colleges and universities for ignoring the effects of introducing new technology (mechanization) on the small family farms and the rural poor

The overemphasis on economic factors and the underemphasis on the secondary and tertiary impacts of technology are partly attributed to such facts as: (a) Until the last two decades, the distributional impact of introducing new technology appeared less severe because of the growing industrial sectors' ability to absorb labor leaving the small farms. However, even though past events have changed, economists have been assessing the effects of technology in conventional ways. (b) Economic impacts generally are easier to quantify and analyze using the tools and experiences most economic researchers acquire during their training.

A number of researchers have addressed the issues of the economic and social impacts of new and existing technology in the agricultural sector [Griliches; Schmitz and Seckler; Hertford and Schmitz; Martin and Johnson]. Since a comprehensive review of these works is not the primary goal here, only a brief illustration of the scope, models and methodologies is presented. Broadly speaking, researchers have used two approaches in analyzing the impacts of agricultural technology — statics and comparative statics.

Static Approach

This approach considers whether the new technology is economically beneficial (usually in terms of profits) to the producers of immediate concern and in some cases to a narrowly defined group of consumers [Parsons; Holtman; Hussen]. It assesses the cost effectiveness of a proposed or existing technology strictly from the viewpoint of the immediate beneficiaries. Factor and product prices are assumed constant and no distributional effects of the technology are considered. This limited scope does not allow for any definitive conclusions about whether a given technology is socially desirable or not.

Comparative Statics

This approach is broader than the static approach. The objective is to estimate the social return (gross, net, or both) arising from a given agricultural technology. The concepts of consumer's and producer's surplus are used to achieve this goal [Griliches; Peterson; Schmitz and Seckler].[1]

In most of these types of analysis, the secondary and tertiary distributional effects of technological change are simply overlooked [Griliches; Peterson]. Recently, however, researchers using similar approaches have attempted to account for the secondary and tertiary impacts of technological change [Schmitz and Seckler; Hertford and Schmitz; Martin and Johnson].

Even though some of the shortcomings of the static approach are lessened, the comparative static approach still falls short of comprehensive and well-integrated analysis which fully satisfies every one concerned with the subject. Among the major drawbacks of the comparative static approach are conceptual and theoretical problems arising from the use of the consumer's and producer's surplus as a measure of the social benefits. For example, are compensated demand curves used in measuring the consumers' surplus? Is a derived or final demand curve used? How small is the income elasticity of demand? Also, for producer's surplus, how elastic are the supply curves of the variable inputs? Other drawbacks are the lack of practically applicable criteria for compensating the losers who are negatively impacted by technological change, and the fact that the results from partial equilibrium analysis may not coincide with the results of a more general equilibrium analysis. This fact is especially true when a product with many substitutes is evaluated.

In the next sections of this paper, an attempt is made to evaluate the benefits and the costs arising from the proposed mechanization of strawberry harvesting in Oregon. Concerted effort is made to demonstrate the complexities and the magnitudes of the practical problems associated with the assessment of the social and economic impacts of technology.

Estimated Social Benefits and Costs for Mechanization of Strawberry Harvest

Problem Setting

The strawberry is one of the most popular and widely used small fruits in the United States. Although nearly all states grow strawberries of some kind, for the last two decades over 85 percent of the commercially-marketed processed strawberries are grown in California, Oregon and Washington (Figure 1). Climate and soil are the major contributing factors for the domination of the Pacific Coast states in strawberry production.

Besides being second in strawberry production, Oregon is a pioneer, having grown strawberries commercially since the early 1900's. In its peak, Oregon produced over 45 percent of the total U.S. processed strawberries (Figure 1).[2] However, since 1971, Oregon's share of strawberry production has been declining steadily. In fact, since 1973 strawberry production in Oregon constituted less than 20 percent of the nation's total processed strawberry production, which is the lowest since 1951. Increased harvesting

[1]For comprehensive treatment of the concept of economic surplus and its use in economic analysis, see J. M. Currie, et al.

costs, without an offsetting increase in the farm prices of strawberries, are the main causes for the continuing decline of strawberry production in Oregon.

Oregon's strawberry growers depend largely on children between the ages of 10 and 16 for harvesting their crop. However, in recent years, the enactment of child labor laws, has caused a shortage of strawberry pickers, resulting in a substantial increase in harvest costs which account for 30 to 40 percent of the price growers receive in Oregon [Martin]. Cost prospects for the future are even gloomier because of the continuing pressure from the various legislative bodies to extend the nation's minimum wage to farm workers. In order to alleviate the problems associated with increased harvest costs and by so doing regain its competitive edge, since 1967, Oregon has been actively seeking to mechanize its strawberry harvest.

Mechanization of strawberry harvest, requires, among other things, (a) change in the present strawberry varieties and (b) development of a technically sound and efficient harvester. In the last ten years, considerable progress has occurred in developing a mechanical harvester and new strawberry varieties suitable for machine harvesting. If the past achievement is indicative of the future, it will not be too long before Oregon strawberry harvesting is mechanized [Booster, *et al.*].

Framework of Analysis

Successful implementation of mechanical strawberry harvesting should create significant production economies.[3] However, it also may have a considerable negative effect on the livelihood of numerous agricultural laborers. To compute the gross and net social returns arising from the use of a strawberry harvester in Oregon, the framework used by Griliches, Peterson, and Schmitz and Seckler is employed.

To illustrate the main points of the analysis, in Figure 2 let S_1' and S_1, respectively, represent the supply curve with and without mechanization. The supply curve of the processed strawberry is assumed to shift from S_1 to S_1' because successful implementation of mechanical strawberry harvest in Oregon is expected to reduce the cost of harvesting (see Footnote 3). As a result of mechanization of strawberry harvest in Oregon, the equilibrium output and price of processed strawberries will change from Q_1 to Q_2 and P_1 to P_2. The area R + S + T represents the increment to the consumers' surplus as a result of mechanization of the strawberry harvest, and the increment to the producers' surplus is measured by the area −R + V + W. Thus, the benefit to society in terms of consumers' and producers' surplus is the area (R + S + T) + (−R + V + W) = S + T + V + W; that is, the area between the two supply curves and below the demand curve, as shown in Figure 2.

In addition, using the formula derived by Peterson, the area S + T + V + W in Figure 2 can be approximated by,

$$(1) \qquad \text{Gross Social Return (GSR)} =$$

$$K\,Q_2\,P_2 + \tfrac{1}{2}\,K^2\,P_2\,Q_2 / \eta -$$

$$\tfrac{1}{2}\,Q_1\,K^2\,P_2 \quad P_2/P_1 \quad \frac{\epsilon\eta}{\eta-\epsilon} \quad \frac{\eta-1}{\eta} \quad ^2$$

When $\epsilon = 0$, the above equation is reduced to:

$$(2) \qquad GSR = K\,Q_2 P_2 (1 + \tfrac{1}{2} K \frac{1}{\eta})$$

where the Greek letters ϵ and η represent supply and demand elasticities, respectively. K represents the relative shift in the supply function, i.e., $K = (Q_2 - Q_1)/Q_2$.

If there were no harmful effect to any member of society, the movement from the old equilibrium Y to the new equilibrium Z in Figure 2 would be considered an improvement in social welfare (Pareto Optimal).

[2]Almost all of Oregon strawberry production is marketed in the processing sector.

[3]In most instances the use of a mechanical strawberry harvester in Oregon is found to yield a significant positive return to the growers [Hussen].

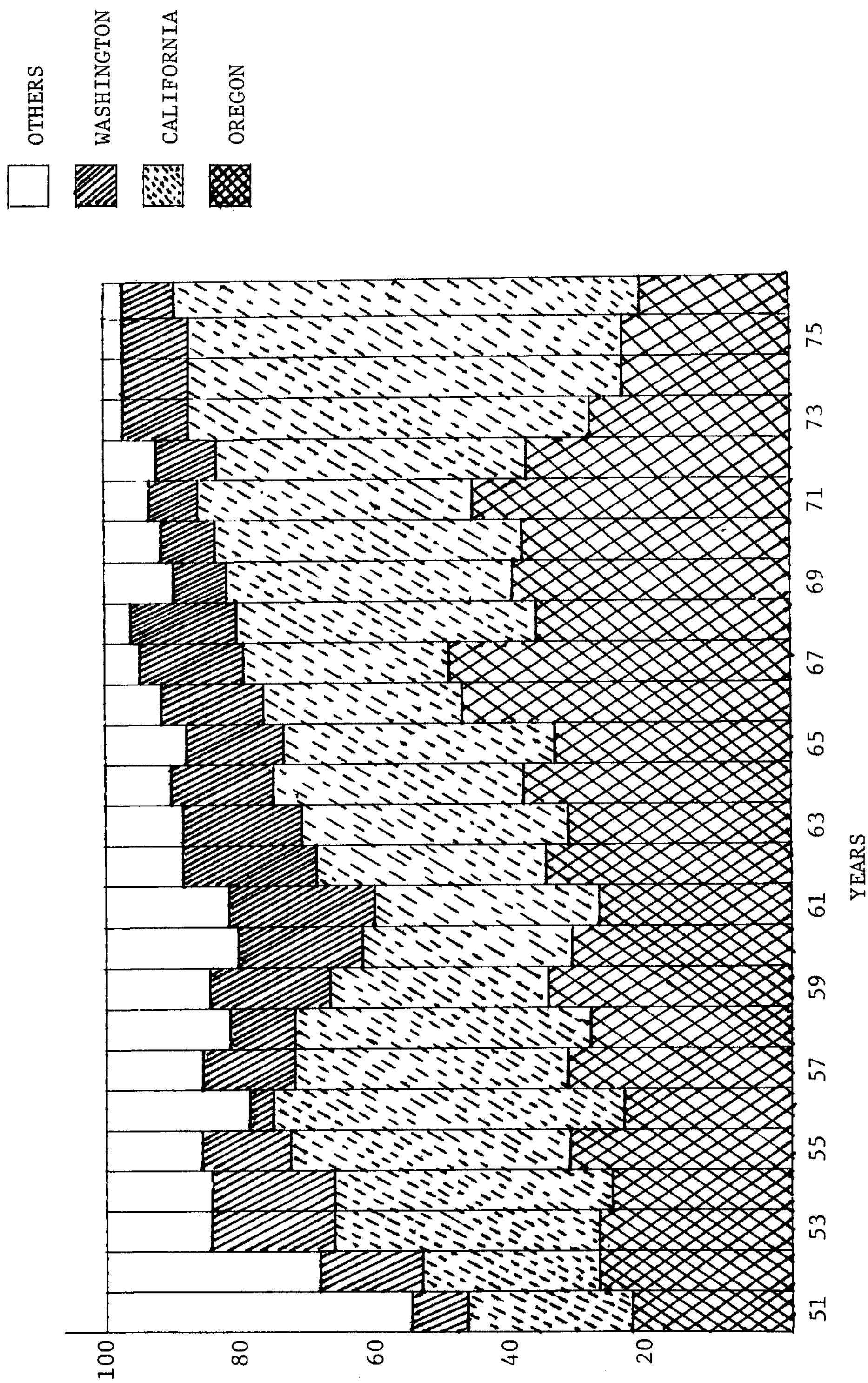

Figure 1. Relative market shares of processed strawberries, by major producing states.

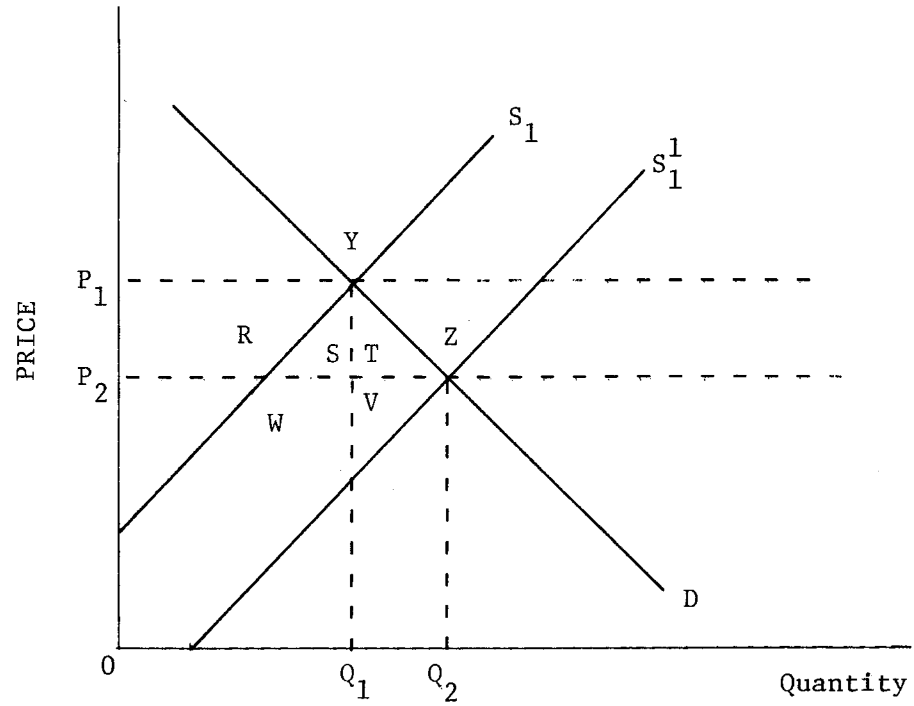

Figure 2. Estimation of gross social returns when the long run supply curve is positively sloped.

However, in cases where a technological change is expected to negatively affect some segment of society, in this case the strawberry pickers, the movement from Y to Z cannot be judged unequivocally as an improvement in social welfare. To measure the social benefits in this case, the Kaldor-Hicks (K-H) criterion is used. The Kaldor-Hicks criterion states that if the gainers (the consumers and producers of strawberries) can compensate the losers (strawberry pickers) out of their gain and still be better off in Z than they were in Y, then the movement from equilibrium Y to Z can be viewed as an improvement in social welfare. However, using the K-H criterion does not imply that actual compensation need be given to the losers. In other words, the movement from Y to Z would be considered as an improvement in social welfare if a potential positive social return occurs after accounting for all distributional effects.

To estimate the dollar value of the loss to the displaced strawberry pickers the following scheme is used. In Figure 3, prior to mechanization the demand for and supply of farm laborers were D_0 and S_0, respectively, and the equilibrium wage rate was W_0. With the introduction of the mechanical harvester, the demand is assumed to shift to D_1. Hence, the new equilibrium wage rate and employment level will be W_1 and N_1, respectively. For analytical convenience, let us assume farm laborers to be producers of a service so that we can estimate the change in producers surplus resulting from the shift in demand. This results in original surplus of area W_0 L O reduced to an area of W_1 M O by the shift in demand. The loss to the displaced workers (or the surplus from labor service) is then

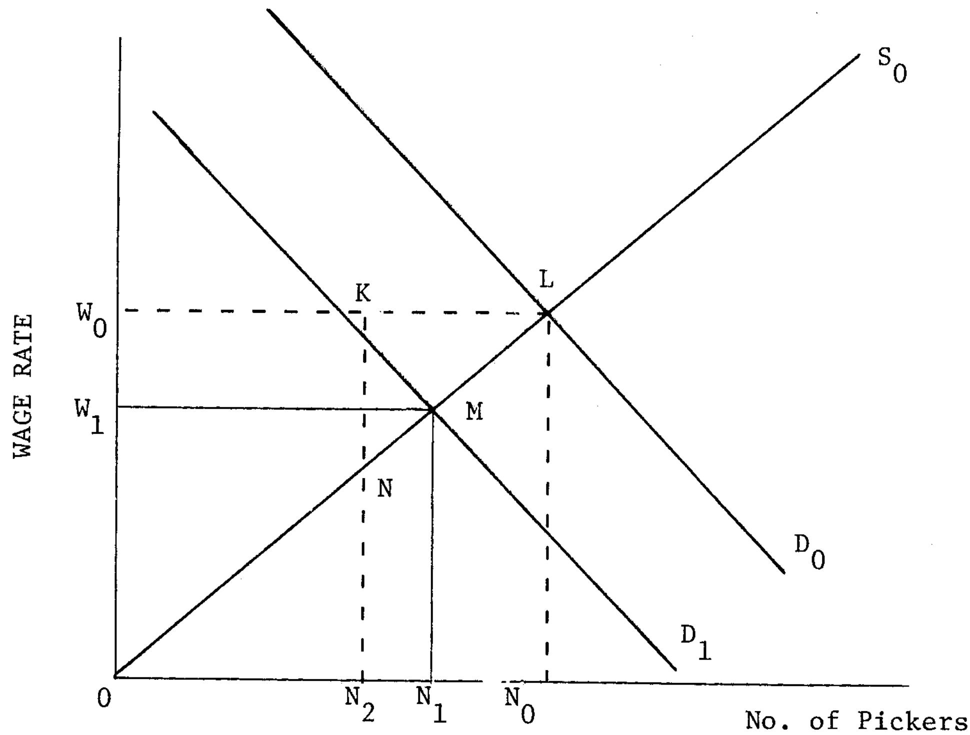

Figure 3. Estimation of the values of the displaced workers.

obtained by subtracting area W_1 M O from area W_0 L 0 which is equal to the area W_0 L M W_1. The area W_0 L M W_1 can be estimated as:

$$(3) \qquad (W_0 - W_1) N_1 + (N_0 - N_1) W_0 - \int_{N_1}^{N_0} f(Z)\, dZ$$

which can be reduced to:

$$N_0 W_0 - N_1 W_1 - \int_{N_1}^{N_0} f(Z)\, dZ$$

where:

$f(Z) \Rightarrow$ factor supply function.

On the other hand, if wage is fixed at W_0 (say, minimum wage), the value of the loss in surplus as a result of the shift in demand is the area K L M N which is obtained by subtracting the area W_0K N O from W_0 L O. The area K L M N can be estimated as:

$$(4) \qquad KLMN = W_0 (N_0 - N_2) - \int_{N_2}^{N_0} f(Z)\, dZ$$

and the estimate in Equation (4) can be approximated by,

$$(5) \qquad W_0 (N_0 - N_2)$$

The result in (5) is identical to the scheme used by Schmitz and Seckler. Moreover, since it assumes that no alternative employment possibilities exist, this estimate will be biased upward.[4] The use of this procedure will lead to an underestimation of the net social (NSR) since NSR will be estimated as,

$$(6) \qquad NSR \equiv GSR - W_0 (N_0 - N_2).$$

Estimation of Social Returns

Assumptions

This analysis is based on the following assumptions which were formulated after consulting with strawberry growers, processors and agricultural extension workers at Oregon State University who have worked with the strawberry mechanization project over the last ten years. (1) Without mechanization, it is assumed that strawberry production in Oregon will stabilize at 5,200 acres (present level). If the harvest trend of recent years continues, this assumption will probably overestimate the level of future harvests and, as will be evident later, lead to an overestimation of the value of the labor loss (in terms of wages) resulting from mechanization. (2) Commercial use of mechanical strawberry harvesting is expected to start by 1981, and by 1985, 50 to 70 percent of Oregon strawberry acreage is expected to be harvested mechanically. In addition, for lack of reliable information, a constant rate of adoption of the harvesting machinery is assumed. Under this assumption, the annual diffusion rate will be 10 percent or 14 percent depending on whether 50 or 70 percent of the strawberry fields in Oregon are mechanically harvested by 1985. (3) Under the assumption of a 50 percent adoption rate, annual harvest of Oregon is expected to reach 9,000 acres which is approximately the level of acreage harvested before the enactment of the child labor law of 1973. With a 70 percent adoption rate, 10,400 acres (or twice the present level) would be harvested. Provided that mechanization reduces harvesting cost substantially [Hussen], 9,000 to 10,400 acres of strawberry harvest by 1985 is a conservative estimate. (4) The acreage is assumed to increase at a constant amount over the five year period (1981-85); hence, annual increases are 760 acres $\left(\frac{9000 - 5200}{5}\right)$ with the adoption rate of 50 percent and 1,040 acres $\left(\frac{10400 - 5200}{5}\right)$ with the adoption rate of 70 percent. (5) The strawberry varieties to be harvested by machine are expected to have a "marketable yield" of 4 tons per acre. Again, in light of the experimental results from the Oregon State University strawberry breeding program, this yield estimate is fairly conservative [Lawrence]. (6) Aggregate U.S. processed strawberry production excluding Oregon remains at an annual level of 137 million pounds which is its recent four year average. This assumption is made to isolate the increment to the consumers' and producers' surplus resulting from the increase in Oregon strawberry production.[5]

Using these assumptions and the theoretical framework developed earlier, the annual gross social returns resulting from mechanization are estimated. Tables 1A and 1B present the annual gross social return assuming that the diffusion rates by 1985 are 70 and 50 percent, respectively. Except for this difference, the same approaches are used to estimate gross social returns in both tables.

Columns 1 and 2 of Table 1A present the expected total annual strawberry acreage in Oregon and the portion of the total acreage

[4]This estimation formula will overestimate the displacement cost of the strawberry pickers. Not all the strawberry pickers who are displaced will be unemployed. Some of the strawberry pickers will find new jobs and will earn income to compensate for their loss, and the above formula does not account for the economic effects of workers moving to their next best job.

[5]Note that mechanization is expected to affect only Oregon's strawberry production mainly for the following reasons: (a) success in mechanization depends on the development of strawberry varieties suitable for mechanical harvesting in which Oregon has a substantial lead over other strawberry growing states; (b) California, which is the leading strawberry growing state is not expected to mechanize without substantial time lag because the high yield that California growers enjoy presently can be sustained only if multiple harvesting is possible. The mechanical strawberry harvesters developed so far operate as once-over harvesters, and (c) the strawberry varieties developed in Oregon may not be easily adapted to other areas without losing some of their desirable characteristics.

TABLE 1A Estimated Values of Annual Gross Social Returns net of Extra Processing Costs Arising from the Proposed Mechanization of Strawberry Harvesting in Oregon[a]

	Expected Annual Strawberry Harvest in Oregon (Acres)	Expected Annual Machine Harvest (Acres)	Aggregate Processed Straw. Prod. Excluding Oregon (mill. lbs)	Aggregate Processed Straw. Prod. in Oregon (mill. lbs)	Estimated Value of K	Predicted Farm Price (¢/lb)	Estimates of Price Flexibility ($1/\eta$)	Gross Social Return (GSR) (mill.$)	Extra Processing Costs (EPC) $480/acre (mill.$)	Estimate of GSRNEPC (mill.$)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1976-80	5,200	-	137.0	41.0	-	23.0	-			
1981	6,240	874.0	137.0	50.0	0.0481	22.3	0.279	2.019	0.420	1.599
1982	7,280	2,038.0	137.0	58.0	0.0871	21.6	0.3006	3.717	0.978	2.739
1983	8,320	3,494.0	137.0	67.0	0.1274	20.75	0.3274	5.505	1.677	3.828
1984	9,360	5,242.0	137.0	75.0	0.1604	20.1	0.351	7.027	2.516	4.511
1985	10,400	7,280.0	137.0	83.0	0.1909	19.8	0.37	8.609	3.494	5.115

[a]The Gross Social Returns in the above table are estimated assuming that 70 percent of Oregon strawberry will be harvested mechanically by 1985 and that mechanization is expected to diffuse at a constant annual rate of 14 percent between 1981-85.

TABLE 1B Estimated Values of Annual Gross Social Returns Net of Extra Processing Costs Arising from the Proposed Mechanization of Strawberry harvesting in Oregon[a]

	Expected Annual Strawberry Harvest in Oregon (Acres)	Expected Annual Machine Harvest (Acres)	Aggregate Processed Straw. Prod. Excluding Oregon (mill. lbs)	Aggregate Processed Straw. Prod. in Oregon (mill. lbs)	Estimated Value of K	Predicted Farm Price (¢/lb)	Estimates of Price Flexibility ($1/\eta$)	Gross Social Return (GSR) (mill.$)	Extra Processing Costs (EPC) $480/acre (mill.$)	Estimates of GSRNEPC (mill.$)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1976-80	5,200	-	-	41.0		23.0				
1981	5,960	596	137	47.7	0.0363	22.4	.274	1.502	0.286	1.216
1982	6,720	1,344	137	53.8	0.0669	21.8	.291	2.810	0.645	2.165
1983	7,480	2,244	137	59.8	0.0957	21.4	.306	4.089	1.077	3.012
1984	8,240	3,296	137	65.9	0.1228	20.8	.325	5.389	1.582	3.807
1985	9,000	4,500	137	72.0	0.1483	20.3	.342	6.451	2.160	4.291

[a]The Gross Social Returns in the above table are estimated assuming that 50 percent of Oregon's strawberries will be harvested mechanically by 1985 and that mechanization is expected to diffuse at a constant annual rate of 10 percent between 1981-1985.

which is expected to be harvested mechanically. Column 3 shows the aggregate U.S. processed strawberry production excluding Oregon. The entries in column 4 are the total processed strawberry production in Oregon. The first entry in this column (41 mill. pounds) is the present level of Oregon processed strawberry production. Other entries in this column are found by multiplying the corresponding entries in column 1 by the assumed yield of 4 tons per acre. Column 5 presents the estimated value of parameter K which is the relative shift in the supply function resulting solely from the increased strawberry harvest in Oregon. For example, parameter K for 1981 is estimated as the ratio of the difference in Oregon strawberry production before and after mechanization (9 million pounds or 50−41) and the expected total U.S. strawberry production including Oregon (187 million pounds or 137+50). Entries in columns 6 and 7 are the predicted aggregate farm prices for processed strawberries and the estimate of the price flexibility, respectively. The predicted prices and the estimate of the price flexibilities are derived from the demand equation in Footnote 6. Finally, the annual gross social returns from the mechanization of Oregon's strawberry harvest are estimated using equation 2, where the elasticity of supply is assumed to be zero[7],

$$GSR_j = K_j Q_j P_j (1.0 + \tfrac{1}{2} K_j \frac{1}{\eta_j})$$

where K_j = the value of the parameter K for year j; Q_j = the estimate of the aggregate U.S. process strawberry production in year j (the sum of the entries in columns 3 and 4); P_j = the predicted price of processed strawberry in year j; and η_j = the point elasticity of demand associated with Q_j and P_j. The results of these estimates are shown in column 8 of Tables 1A and 1B.

Gross Social Returns Net of Extra Processing Costs (GSRNEPC)

Since the berries will be uncapped when they are harvested by machine, additional work is required to cap the berries in the processing sectors. Therefore, the value of extra processing cost must be subtracted from the estimate of GSR. Based upon experimental work in Michigan [Holtman], the value of the extra processing cost was estimated to be between 5 and 6 cents per pound or \$400 and \$460 per acre assuming a yield of 4 tons per acre. Hence, the upper bound of the value of the extra processing cost for any

[6]
$$\underset{}{PP^s} = \underset{(3.37)^*}{7.675} \; \underset{(0.00735)}{-.0333X_1} \; + \underset{(0.18624)^{**}}{0.844X_2} \; + \underset{(.91744)^*}{1.984X_3} \; - \underset{(0.7855)^{**}}{4.419X_4}$$

t R^2 = .82 DW = 2.1125 N = 26

where PP^S = average farm price for processed strawberries (¢/lb.) X_1 = total processed strawberries marketed (mill. pounds); X_2 = average farm price of fresh strawberries (¢/lb.); X_3 = average farm price of peaches (¢/bushel); X_4 = average hourly earnings for labor employed in the food and kindred products (\$/hour); and η and DW are demand elasticity (evaluated at the mean value) and the Durbin-Watson statistics respectively. In terms of expected signs of all coefficients and general "reasonableness" of results, the above specifications of the demand relationship was thought preferable to the other various alternatives considered, see Hussen.

[7]Equation (2) assumes that the supply elasticity for processed strawberries is zero, which is restrictive unless it is reasonably justified. In the beginning, I attempted to fit a supply equation for processed strawberries so as to derive the supply elasticity. However, I was unable to estimate a statistically meaningful supply equation for processed berries. Hence, due to lack of information about the precise magnitude of the supply elasticity for processed strawberries, I estimated GSR by assuming that the supply elasticity of processed strawberries is perfectly elastic. To estimate GSR when the supply elasticity is infinity, EQ (1) was used. For this problem the ratio of the value of GSR when the supply was perfectly elastic ranged from 1.012 to 1.019. Therefore, the difference between these two extreme assumptions implies less than a 2 percent difference in the final estimate of the GSR. Since this difference is so small, estimation of the supply elasticity for processed berries would not contribute much to the accuracy in estimating GSR.

given year will be \$460 times the expected total acres harvested by machine (column 2). These estimates of extra processing costs are shown in column 9 of Tables 1A and 1B.

The entries in the last column of Tables 1A and 1B are the value of the gross social returns net of extra processings costs (GSRNEPC).

Discounted Value of the Total GSRNEPC

Let $C_1, C_2, \ldots, C_5$ represent the values of the flow of GSRNEPC for the years 1981-85, respectively. Then, the cumulated GSRNEPC for the year 1981-85 discounted to the year 1980 is estimated by:

$$\sum_{t=1}^{6} \frac{C_t}{(1+r)^t} = C \tag{7}$$

Furthermore, if we assume the strawberry acreage in Oregon to stabilize at the level existing by 1985, then, the cumulated GSRNEPC for the year 1986 and thereafter discounted to the year 1980 is estimated to be:

$$\sum_{t=1}^{\infty} \frac{C_6(1+r)^{-6}}{(1+r)^t} = \frac{C_6(1+r)^{-6}}{r} = C^* \tag{8}$$

Therefore, the discounted value of the total cumulated GSRNEPC over an infinite planning horizon is estimated to be:

$$C + C^* = C^{**} \tag{9}$$

Using the above formulations and the information in column 10 of Tables 1A and 1B, the discounted value of the total cumulated GSRNEPC is estimated to be:

	Case 1: 70% Adoption Rate by 1985	Case 2: 50% Adoption Rate by 1985
1. Discounted value of the cumulated GSRNEPC 1981-85; C	\$12,154,000	\$9,861,000
2. Discounted value of the cumulated GSRNEPC 1986- and thereafter; C*	\$33,877,778	\$28,422,222
3. Total discounted value of GSRNEPC; C**	\$46,031,778	\$38,283,222

Net Social Returns (NSR)

Net social return is defined as the difference between gross social returns net of extra processing costs and the cost of displaced workers. Hence, an estimate of the cost of the displaced strawberry pickers is needed to derive net social returns. Based on a field study by Oregon State University Extension Service, the cost of handpicking strawberries with a yield of 4 tons per acre was estimated to be \$902.00 per acre. In this analysis, allowing for general price increases, the cost of hand harvesting is expected to be \$1,000 per acre. Using this estimate, the values of the estimated cost to the displaced pickers are computed (Tables 2A and 2B). Tables 2A and 2B show the cost of the displaced pickers corresponding to the gross social benefits estimated in Tables 1A and 1B, respectively. The entries recorded in column 1 of Tables 2A and 2B are obtained in the following manner: First, the total strawberry acreage that would be available for hand harvesting is obtained by subtracting the entries of column 2 from the corresponding entries of column 1 in Tables 1A and 1B. Then, 5,200 acres is subtracted from the above result since strawberry pickers would have harvested a total of 5,200 acres, assuming no mechanization. Finally, the net difference between acreage available for hand harvest with mechanization, and harvested acreage without mechanization (5,200 acres) is the loss or gain of acreage for hand harvesting as a result of mechanization (column 1 of Tables 2A and 2B). To estimate the cost of the displaced pickers, entries in column 1 of Tables 2A and 2B are multiplied by \$1,000 which is the per acre benefit foregone to the strawberry pickers. These results are indicated in column 2 of Tables 2A and 2B. From these results, using similar procedures as outlined in equations 7, 8 and 9, the total cost of the displaced strawberry pickers is estimated to be:

TABLE 2A Values of the Annual Estimated Loss to the Displaced Strawberry Pickers (70 percent adoption rate)

	Loss or gain of Harvestable Acreage to the Pickers	Value of the Loss or the Gain $1,000/acre (mill. $)
1976-80	-	-
1981	+166.0	.166
1982	+42.0	.042
1983	−374.0	−.374
1984	−1,082.0	−1.082
1985	−2,080.0	−2.080

TABLE 2B Values of the Annual Estimated Loss to the Displaced Strawberry Pickers (50 percent return rate)

	Loss or Gain of Harvestable Acreage the Pickers	Value of the Loss or the Gain $1,000/acre (mill.$)
1976-80	-	-
1981	164.0	0.164
1982	176.0	0.176
1983	36.0	0.036
1984	−256.0	0.256
1985	−700.0	0.700

	Case 1: 70% Adoption Rate by 1985	Case 2: 50% Adoption Rate by 1985
1. Discounted value of the cumulated cost of the displaced pickers 1981-85.	$ 2,036,200	$ 284,400
2. Discounted value of the cumulated cost of displaced pickers 1985 and thereafter	$13,780,000	$4,637,778
3. Total discounted value of the displaced pickers	$15,816,200	$4,922,178

Thus, the net social returns for case 1 and 2 are $30,215,578 or ($46,031,778−15,816,200) and $33,610,044 or ($38,283,222−4,922,178), respectively. It is important to note that accounting for the effects of displaced workers makes net social returns higher for the lower adoption rate. This result differs from the ranking based on GSRNEPC.

Social Returns Net of Research and Development Costs

Thus far, the various social returns are estimated and for making decisions with regards to the desirability of strawberry mechanization in Oregon, the estimated social returns have to be compared with the estimate of the total research and development costs associated with the overall strawberry mechanization project in Oregon. The total research and development expenditures estimate compounded to the year 1980 are expected to be $1,448,361 before mechanized strawberry harvesting is fully adopted for commercial use [Hussen, P. 97]. Therefore, when this estimate of total research and development costs is compared with the above estimates of the gross and net social returns, it suggests that an endeavor to mechanize strawberry harvesting is, indeed, a profitable venture with respect to the society as a whole. For the 70 percent adoption rate, the estimate of net social returns exceeds the research and development costs by $28,767,217 valued as of 1980. Similarly, for the 50 percent adoption rate, the estimate of net social returns exceed the research and development costs by $32,161,683.

However, while measures of gross or net social rates of return after accounting for the research and development costs can provide decision makers with criteria to assess projects, other factors that influence the desirability of mechanization should be considered.

Factors Affecting Social Rates of Return

1. Using the K-H criterion to estimate the loss of the displaced workers does not imply that actual compensation need be given to the losers. If, in fact, the strawberry pickers were compensated, then, depending on the source of the revenue for compensation, there could be an added social cost which is not accounted in the model above. Moreover, if compensation is effected, what is the criterion used for compensating the losers?

2. This analysis assumes that (a) strawberry varieties suitable for machine harvesting, as well as an efficient mechanical harvester, will become available; (b) the necessary adjustments, both in the farming and processing sectors, will be undertaken to accommodate the technological change in strawberry harvesting; and (c) the demand for strawberries will not change due to the introduction of new varieties or the technological change in strawberry harvesting. How realistic are these assumptions? For example, are the new varieties likely to be readily accepted by the consumers? If not, how would that affect demand?

3. Mechanization may favor large-scale farmers [Hussen]. If so, what is the distributional effect on small-scale farmers? In general, how significant is the adjustment cost? For lack of reliable information, this cost is not explicitly considered in the model.

4. This study uses the farm demand for processed strawberries to estimate the consumers' surplus resulting from mechanizing the strawberry harvest. This farm demand is a derived demand. Is the consumers' surplus estimated using this demand equivalent to an estimate based on final demand? The answer depends on the difference between the price elasticities of the derived demand and the final demand [Hertford and Schmitz]. The final demand is not estimated because there is no *one* final demand for processed strawberries; processed strawberries as a final product appear in different forms. Also, there is a difference in net social benefits calculated from a partial equilibrium analysis as opposed to those calculated from a general equilibrium analysis. For example, if there are close substitutes for strawberries, then social benefits are overestimated.

5. Oregon is expected to harvest no more than 10,400 acres which is slightly above the acreage harvested before the enactment of child labor laws in 1973. However, if mechanization occurs, the acreage allotted for strawberries could exceed the estimate used here. If so, the gross social return is underestimated.

6. In Oregon most strawberries are harvested in June when the processing and canning industry has substantial unutilized capacity. Increased production of strawberries resulting from mechanization would enable the processing and canning industry to operate at fuller capacity in the early part of the season. Since most processing and canning firms are located in rural areas, this increased use of capacity would also contribute to an increase in employment in the rural community.

[8]The cost estimates include, among others, the outlays incurred in developing and sustaining the research program by the farmers, the agricultural extension programs, and other organizations that are directly or indirectly involved in the program. For details on the expenditure for research and development of the harvester and new strawberry varieties, see Hussen.

7. Finally, mechanization of the strawberry harvest likely would end the use of child labor which is thought to be socially undesirable. This would have a positive social benefit that is not accounted for here.

Summary and Conclusion

Before the mid-sixties, economists gave little consideration to the distributional effects of technological changes. Hence, agricultural research tended to recommend or encourage technological changes which were favorable to large-scale farmers at the expense of small-scale farmers and farm laborers [Hightower]. In recent years, in response to the growing number of agricultural critics, economists attempted to specifically account for some of the distributional effects of agricultural technology [Schmitz and Seckler; Martin and Johnson]. Although recent attempts to account for the distributional impacts of technological change have significantly strengthened the credibility of economic models, these models still do not take into account all the distributional effects (social, economic or technical) arising from agricultural technology.

However the fact that the models are not complete enough to account for all distributional effects should not discourage a continuing effort to assess the economic and social impacts of agricultural technology when the need arises. It is important, however, to be aware of the inherent weaknesses of the models employed. With this in mind, this paper has been an attempt to evaluate the economic and social desirability of mechanical strawberry harvest in Oregon. Using a partial equilibrium analysis approach, the gross and the annual net social returns were estimated. In addition, other factors which were not explicitly accounted for in the model were also discussed because of their potential repercussions on the estimated social returns.

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