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MECHANIZED AGRICULTURE AND SOCIAL WELFARE: THE CASE OF THE TOMATO HARVESTER*

by

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INTRODUCTION

At the beginning of the industrial revolution in the 19th century, gangs of workmen roamed England systematically destroying machinery. These were the Luddites. To their compatriots in the Netherlands we owe the word "sabotage." The "sabot" is the heavy wooden shoe which the Dutch workmen threw into the grinding gears of the new technology.

The other side of the coin is well illustrated by the lament of John M. Horner, one of the inventors of the wheat combine.¹ Writing to his friend, Colonel Warren, editor of the *California Farmer*, in July, 1869, Horner said [3, p. 22]:

"... we were brought more particularly to reflect upon our position by the burning of one of our machines on the night of the 11th [of July]. We ask ourselves: Have we injured anyone so that personal vengeance is pursuing us, and this burning was done to gratify a revengeful feeling? No. We have had no misunderstanding with anyone, in fact, not an enemy in the world, a conscience void of offence to all men. We entered that neighborhood to perform honest labors, and harvested [1,600] acres in a good workmanlike manner to the entire satisfaction of our employers--so much so that most of them wanted us to consent to harvest their next crops."

Colonel Warren responded with an editorial in his paper, July 29, 1869 [3, p. 23]:

"Such acts as the one named upon a man like Mr. Horner because he had invented a labor-saving machine should arouse the spirit of the lion among all good men and they should unite and hunt up the offenders and make them feel the heaviest penalties of the law for damages and then be driven from every civilized community."

The rhetoric of this ancient conflict has changed but not its substance. "Technological displacement"--as it is now euphemistically called--remains the source of some of our greatest social problems. This is particularly true in agriculture. We point with justifiable pride to the fact that now only a small percentage of the total population produces our food needs. But we tend to forget the painful process of adjustment which accompanied the transition from a rural to an urban society. We have forgotten that for many people the transition is not really complete; many people have been forced off the farm only into an economic and social limbo in the rural towns and urban ghettos of the nation.

In this paper we estimate the "rates of return to research and development" (henceforth, R and D) expenditures on the mechanical tomato harvester. This device has created important economies in the production of tomatoes. However, it has also threatened the means of life of a significant number of agricultural laborers. We shall attempt to appraise both effects in order to evaluate the social desirability of the tomato harvester. In this respect we have attempted to carry the pioneering work of Schultz [9] and Griliches [2] one step further--into an appraisal of agricultural innovations which may entail important social costs as well as social benefits.

THE DEVELOPMENT OF THE TOMATO HARVESTER

The history of the development of the tomato harvester is a subject of great interest in itself. It is a classical instance of the parallel development of separate innovations dovetailing into a viable system. As Rasmussen [8, pp. 532 and 533] states:

"The invention of the mechanical tomato harvester contrasted decidedly with the development of the cotton picker. The tomato harvester resulted from the 'system approach.' A team made up of an engineering group and a horticultural group, with advice and assistance from agronomists and irrigation specialists, developed suitable plants and an efficient harvester at the same time. The necessary changes in planting, cultivation, and irrigating were developed concurrently...."

The systems approach was also followed through in the development phase of the harvester. It was truly an industry-wide effort. Manufacturers, scientists, and Extension personnel worked closely with farmers, first in growing the new tomato varieties, then in getting the tomatoes harvested. Processors subsidized the first crops by lowering their purchasing standards on the new tomatoes and by adjusting their production techniques to accommodate the changed inputs. In the opinion of E. Blackwelder of the Blackwelder Manufacturing Company, which produced one of the first commercially feasible harvesters, it would have been virtually impossible to develop the harvester without this industry-wide integration of efforts. Thus, the harvester represents a social as well as a scientific and engineering success. Through coordinated efforts on many fronts, the industry was able to create and capture benefits not economically available to any individual member.

ASSUMPTIONS AND LIMITATIONS OF THE ANALYSIS

We have used certain assumptions and have neglected certain factors which significantly influence our estimates of returns and costs of the tomato harvester. It is best to have these limitations firmly in mind at the very outset of the analysis:

1. We have assumed that all costs and returns of the harvester are relevant only insofar as they impinge within the political boundaries of the United States. Several important consequences follow:
 - a. We neglect benefits accruing to foreign countries as a result of the harvester. Germany, the USSR, and Israel, for example, have imported these machines and will obtain benefits from their use which we do not estimate.
 - b. It is a commonly held notion that, had the harvester not been invented, the American tomato industry would have succumbed to competition from foreign nations--particularly Mexico. We have not included the benefits to the U.S. tomato industry nor the costs to Mexico stemming from this consequence of the harvester.
 - c. Many of the workers employed in the tomato fields are Mexican nationals. We have not discriminated between their welfare and the welfare of American workers.
2. We do not know how the tomato industry would have developed had the harvester not been invented. Therefore, we assume that costs, prices, output, employment, and other important variables would have remained the same as before the impact of the harvester.
3. We cannot predict the ultimate impact of the harvester on wages, prices, and output so, unless otherwise stated, have assumed these to remain the same as in the period 1965-1969.
4. Certain costs are understated. We have estimated only direct R and D costs on the harvester. Costs of transition to the new technique incurred by farmers and processors are not included.² Nor have we been able to tell if the net impact of the harvester on processing costs has been positive or negative. Finally, we have not attempted to include the long history of investment in basic research contributing to development of the harvester nor the costs of any previous attempts to devise a harvester that failed. As Griliches [2, p. 426] has observed, neglecting these factors is like estimating the rate of return to oil exploration solely on the basis of the successful wells. All "dry holes" are neglected.

5. Some of the benefits of the harvester have not been included in our estimates. Profits made by manufacturers on the sale of the machines have not been independently estimated and enter our analysis as a cost of the machines. The University of California holds a patent on one of the machines. Royalties on this patent amounted to \$224,782 by 1969. These royalties, too, show up as a cost of the machines. Finally, some of the putative "benefits" of the harvester may be regarded either as a cost or as a benefit depending on one's value judgments. This is true, for example, of the impacts of the harvester on international trade in tomatoes and the welfare of Mexican nationals employed in the United States. Similarly, it is a commonly recognized fact that much of the impetus behind R and D expenditures on the harvester was provided by the threat of unionization of the workers and similar "labor troubles." We have not evaluated the impact of the harvester on this objective.

GROSS SOCIAL RETURNS

We shall use the phrase "gross social returns" (GSR) to mean the value of the reduced costs of harvesting tomatoes by the mechanical harvester. These returns differ from "net social returns" by the value of the costs incurred by workers displaced by the harvester--the subject of a later section.

There exist definitive studies on the comparative costs of hand and mechanical methods of tomato harvesting [11, 12].³ According to these studies, mechanical harvesting results in reduced costs of from \$5.41 to \$7.47 per ton. It is important to note that these estimates include amortization and interest (at the rate of 6 percent on the machines) so that these are cost reductions after the machines have been paid for.

In order to estimate GSR from the harvester for the United States as a whole, it is necessary to estimate its rate of adoption. These estimates are presented in Table 1. The results in Table 1 are based on a total United States tomato acreage of 322,010. This is obtained by averaging the years 1966-1969 inclusive.⁴ California is estimated to harvest 95 percent of its acreage by mechanical methods by 1970. We estimate the maximum rate of adoption at 60 percent for states other than California. In a separate study, Webb [10, pp. 1-5] estimates the total U. S. average rate of adoption to be 80 percent.⁵

With the estimates of Table 1, an average yield of 22 tons of tomatoes per acre, and the above cost reduction figures, we are now in a position to compute the GSR to the harvester for the United States.

We have carried all estimates to the year 1973 when, by assumption, tomato acreage attains a constant amount. Thus, the annual GSR for each year, 1965-1973, are calculated at 6 percent interest to 1973 and then converted to an annual perpetual sum. This, together with the annual GSR in 1973 and thereafter, constitutes the annual value of GSR to the harvester. The results are shown in Table 2.

TABLE 1
The Rate of Adoption of the Tomato Harvester for the
United States, 1965-1973

Year	California	Other states	Total harvested acreage
1965	25	0	48,302
1966	60	0	112,704
1967	80	0	144,905
1968	85	10	161,005
1969	90	20	193,206
1970	95	30	209,307
1971	"	40	225,405
1972	"	50	241,508
1973	"	60	257,608

TABLE 2

Gross Social Returns to the Tomato Harvester

Returns	Estimated per ton cost reduction	
	\$5.41	\$7.47
	dollars	
Cumulated GSR, 1965-1973	199,124,897	274,792,805
Annual value of cumulated GSR, 1973	11,947,494	16,487,568
Annual GSR, 1973	30,660,524	42,335,299
Total annual value of GSR, 1973	42,608,018	58,822,867

R AND D COSTS OF THE TOMATO HARVESTER

A variety of universities and private firms contributed to R and D of the tomato harvester. We were able to obtain reasonably good information on the costs incurred by two of the major parties to this invention--the University of California at Davis and Blackwelder Manufacturing Company of Rio Vista, California. Other universities--the University of Michigan, the University of Florida, and the University of Maryland--have engaged in research and development on different varieties of the harvester. And other firms, such as H. D. Hume Company, Food Manufacturing Corporation, Massey-Ferguson, and Button Manufacturing Company, have incurred significant R and D costs in the development of tomato harvesters. Our information on costs incurred by "other" universities and firms is little more than an educated guess based on interviews with people knowledgeable in the field. The above data are given in Table 3.

GROSS SOCIAL RATE OF RETURN TO R AND D ON THE TOMATO HARVESTER

Given the above data on benefits accruing from the tomato harvester and the R and D costs to make the harvester a reality, it is possible to calculate the gross social rate of return (GSRR) to R and D costs on the harvester. The equation used is:

$$\text{GSRR} = \frac{\text{total annual value of gross social returns}}{\text{research and development costs}} (100).$$

For example, the rate of return, assuming the low cost saving of \$5.41 per ton, is:

$$\text{GSRR} = \frac{\$42,608,018 \text{ (Table 2)}}{\$4,585,320 \text{ (Table 3)}} (100) = 929 \text{ percent.}$$

For the cost saving of \$7.47 per ton resulting from the tomato harvester, the rate of return using the above formula is 1,288 percent. Therefore, the gross social rate of return from costs incurred in developing the harvester varies from a low of 929 to a high of 1,288 percent.

WELFARE CRITERIA

If the workers experience a loss in welfare because of the use of the harvester, this loss is properly considered a social cost of the harvester. Thus, we have entitled the above estimates of return "gross" estimates. In this section we shall discuss net returns to the harvester, but first we must discuss welfare criteria relevant to this expanded view.⁶

TABLE 3

Research and Development Expenditures on the Tomato Harvester

	Expenditures ^a
<u>Universities (to 1967)</u>	
University of California, Davis	\$ 588,000
Extension and related activities	100,000
Other universities (including extension)	<u>600,000</u>
Total universities	\$1,288,000
<u>Private firms (to 1967)</u>	
Blackwelder Manufacturing Company	\$ 491,000
Other firms	<u>1,473,000</u>
Total firms	\$1,964,000
Total 1967 value	\$3,252,000
<u>Total R and D costs 1973 value (cumulated at 6 percent)</u>	\$4,585,320

^aFigures rounded to the nearest thousand.

The concept of Pareto optimality implies that one cannot recommend a change from a state "A" to a state "B" unless "everyone" is better off in B than in A—that is, no one is worse off in B and at least one person is better off than in A.

A major problem in the use of the concept of the Pareto optimality is that it favors the *status quo ante*. Since almost every conceivable change leaves someone worse off, "whatever is is right." On the other hand, making recommendations on grounds other than this involves the inextricable difficulties of interpersonal comparisons of utility. If, for example, one is willing to recommend a change that will leave someone worse off than before, one is implying that he can cardinally evaluate the increase in welfare of the beneficiaries, subtract the decrease in welfare of the losers, and find a net increment in welfare. This is indeed a heroic presumption.

As a kind of halfway house between these extremes, the "compensation" test has been proposed by Kaldor and Hicks. This test may be stated as follows: It is a necessary condition to recommending a change that the gainers should be able to compensate the losers and still be better off. Strictly, this means that the gainers should be able to bribe the losers into voting for the change. If the benefits of the change are not sufficiently large to pay its ordinary costs and the amount of the bribe, it cannot be considered socially desirable. It may be noted, finally, that, contrary to original thinking about compensation, it is not sufficient that the bribe could be paid—it must actually be paid if a change from the status quo is to be recommended. Otherwise, one is back in the problem of interpersonal comparisons of utility.

The implications of this general analysis to the specific problem of the tomato harvester is clear. In order to determine the potential value of the harvester, we have to determine if the gainers (the producers, consumers, etc.) could compensate the losers (the workers) and still be better off than before.

NET SOCIAL RATE OF RETURN TO R AND D ON THE TOMATO HARVESTER

The tomato harvester displaces roughly 91 man hours per acre harvested [6, pp. 1-9].⁷ Using the acreage and adoption rates of Table 1, we find that 478,637 man hours were displaced in 1965 and that this figure rises to 19,477,227 in 1973 and for every year thereafter. (See Appendix I for calculations.) The average wage of harvest labor is \$1.65 per hour (exclusive of fringe benefits, such as transportation and room and board where provided). With these figures we are prepared to compute the net social rate of return (NSRR) under varying assumptions of compensation (C):

$$\text{NSRR} = \frac{\text{GSR}-\text{C}}{\text{TRD}} (100).$$

The results are presented in Table 4. Thus, NSRR varies between 929 percent and -8 percent at the low estimate of cost savings as the amount of compensation varies between 0 and 100 percent of the estimated displaced wage bill.

It is highly unlikely that the workers would be unwilling to settle for less than their perpetual lost wages. It is almost certain that the gainers would not be willing to pay this much in compensation because no feasible group of gainers could capture a sufficient amount of returns from the harvester to pay it. Is it possible to estimate the settlement terms of such a negotiation between gainers and losers?

If it is, we are certainly not prepared to do it here. Such an estimate would involve difficult problems of interpersonal comparisons, specification of the economic and institutional setting, and examination of problems intrinsic to real compensation, such as bargaining groups, balances of power, game strategies, and so on.

We would, however, argue that certain facts about the workers indicate demands for a fairly high settlement:⁸

1. The workers' annual incomes are low--thus, they would be reluctant to trade leisure for income.
2. Their average age is rather high and their skill levels low so that alternative employment opportunities are limited.
3. Mechanization of other crops, such as grapes and cucumbers, is proceeding rapidly so that employment opportunities in other areas of "stoop" labor is diminishing.
4. They may have to move to urban areas to find alternative employment in which case both pecuniary and psychic opportunity costs are high.

TABLE 4

Net Rates of Social Return to R and D
in the Harvester

Percent of displaced wage bill paid in compensation	Annual 1973 amount of compensation	Net social rate of return to R and D on the tomato harvester	
		Estimated cost savings	
		\$5.47	\$7.51
	dollars	percent	
0	0	929	1,288
25	10,746,610	694	1,048
50	21,493,262	460	814
75	32,239,892	226	579
100	42,987,523	- 8	345

5. Finally, the whole problem is surrounded with a heavy degree of uncertainty for which the workers would rationally demand a premium.

CONCLUDING OBSERVATIONS

We have shown that the rates of return to R and D expenditures on the tomato harvester are highly attractive when measured in the conventional way. More important, we have shown that the rates of return remain attractive after deducting reasonable amounts of compensation for costs incurred by workers displaced by the harvester. We do insist, however, that, since compensation has not actually been paid, it cannot be concluded that society as a whole has benefited from the invention of the tomato harvester.

This is, of course, in no way an indictment of those involved in the development and use of the harvester. On the contrary, the harvester stands as a triumph of individual initiative and private enterprise. Social costs simply are not their business.

Social costs are, however, the business of society as a whole (through its governmental agencies) and the business of the workers themselves. Compensation should be paid; the question is how? Two devices readily come to mind.

First, some form of state intervention in the tomato industry is possible. The state could impose a tax on each ton of tomatoes harvested by the mechanical harvesters, the proceeds going to displaced labor as compensation.

Secondly, much the same effect could be achieved through labor unions (assuming they had the bargaining power now that the mechanical harvester is operational). There are some precedents for this in cases such as the Longshoremen's Union. The longshoremen faced a very similar problem. The development of modern containerization and transportation techniques threaten wholesale unemployment in that industry. The Union negotiated with management to vote for the use of these new technologies on condition that a certain amount be paid to the Union for each unit of freight loaded by these means. The proceeds from this source have been used mainly to finance retirement and retraining activities of the Union.

These are two means of attaining compensation. But before embarking on ad hoc programs of this type, it would be wise to see if there are not available more general solutions to this class of general problems. Specifically, we might see if there are not general social programs which would significantly reduce the need for compensation itself. We believe there are.

The process of adjustment is particularly painful for displaced tomato workers because they are highly immobile. They are immobile mainly because they are poor and because their parents were poor. If only some portion of the great economies generated by technological innovations, such as the harvester, were allocated out of general taxes to destroying these "vicious cycles of poverty," immobilities and thus the social costs accompanying such innovations would be substantially reduced. They may be reduced to the point where social costs and benefits would fall more or less randomly on the population as a whole and thus, in a sense, cancel each other out. If this were to occur, "everyone" would be much better off by technological change. That, to us, is the moral of the tomato harvester.

APPENDIX I

Total Man-Hour Displacement by the Tomato Harvester

In our calculations the base acreage used prior to 1965 (that is, prior to the year when the harvester was used substantially) is 297,289. This figure is the average from 1958 to 1964. The base acreage used subsequently is 322,010 obtained by averaging acreage from 1966 to 1969. Also, in the calculations California is assumed to harvest approximately 55 percent of the processing tomatoes grown in the United States. Using the computations of Parsons [6], prior to the harvester 163 man hours were employed per acre; this reduced to 72 man hours when the harvester was used.

1. Prior to the harvester, the number of man hours employed was $(297,289)(163) = 48,458,127$.
2. After the harvester the man hours employed, for example, in 1965 equals $322,010 [(163 \times .85) + (72 \times .15)] = 47,979,490$; but the man hours used prior to 1965 equal 48,458,127. Therefore, the man hours displaced equal $48,458,127 - 47,979,490 = 478,637$.
3. For 1973 the hours employed equal $322,010 [(163 \times .20) + (72 \times .80)] = 28,980,900$; but the man hours used prior to 1965 equal 48,458,127. Therefore, total displacement equals 19,477,227.

FOOTNOTES

*Many have contributed to this study. We appreciate the data made available from various departments at the University of California, Davis, and the University of Michigan. Also, E. Blackwelder, C. Kelly, P. Parsons, G. Rowe, L. Sammet, and R. Schuler have provided valuable information. We thank Roy Born for computational assistance. Any errors remaining in this paper are, of course, the sole responsibility of the authors.

1. We are indebted to Paul Barkley for this reference.
2. See discussion, *supra*, p. 4.
3. These cost savings of \$5.41 and \$7.47 are not given explicitly in the studies. These were computed from Zoebel and Parsons work [11, 12]. The detailed calculations are available on request from the authors. Also, the detailed calculations underlying the remaining part of the paper are available on request.
4. Total 1969 acreage is estimated to be 80 percent the 1968 figure.
5. Accurate estimates on the rate of adoption do not exist. It appears, however, that for California at least 90 percent of the acreage is now mechanically harvested. On the other hand, several people have expressed the opinion that our 60 percent adoption figure for other states is too high. It may well be, however, that more of the processed tomatoes may be grown in California than the 55 percent of the acreage figure used. Therefore, we feel that the total acreage of 257,608 mechanically harvested of a possible 322,010 acres is a conservative estimate.
6. We cannot go into all the complexities of welfare theory here. The interested reader is recommended to Little's excellent discussion [4].
7. The amount the labor saved by the mechanical harvester is given in Parsons [6, p. 8]. The man hours saved per acre vary from 29 for excellent workers to 178 for poor workers. The figure used of 91 man hours while substantially above that for poor workers is only slightly below the man hours displaced for the category labelled good workers.
8. For an interesting study of farm workers and mechanization, see Padfield and Martin [5].

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