AN ABSTRACT OF THE THESIS OF

Chong S. Kim for the degree of Doctor of Philosophy

in Agricultural and Resource Economics presented on July 23, 1980

Title: Projected Impacts on Growers, Processors and Consumers from Mechanical Strawberry Harvesting

Abstract approved: Redacted for privacy

William G. Brown, Professor

Oregon has grown strawberries commercially since the early 1900's. More than 90 percent of strawberries produced in Oregon has traditionally been delivered to processors. The strawberry acreage has declined from a high of 18,300 acres in 1957 to the lowest level of 5,000 acres in 1978. The increasing harvest costs and the difficulties in procuring hand-pickers are hypothesized to be the main reasons for decreasing the Oregon strawberry acreage and production. In an attempt to solve these problems, since 1967 Oregon has put considerable efforts into mechanization of strawberry harvesting. The objectives of this thesis are to estimate the economic feasibility to Oregon growers of mechanically harvested strawberries, and to estimate net social benefits (or costs) that could be expected from adopting this new technology in strawberry harvesting.

The structural model consisting of supply and demand for strawberries for processing are derived based upon the assumption that growers sell strawberries under perfect competition, and processors purchase straw-

berries under oligopsonistic imperfect competition.

Cross-sectional data across eight major strawberry producing counties over the period 1962 - 1978 were pooled in the estimation of the parameters. The estimated supply and demand equations for strawberries were used for estimating net social benefits (or costs).

Present values of net social benefits are estimated and compared by applying formulas used by Lindner and Jarrett, Griliches, and Peterson. The results indicated that the distribution of welfare resulting from adopting new technology in strawberry harvesting vary, depending not only on the nature of the supply shift but also on the price elasticity of demand. Since the demand for strawberries for processing was very inelastic, the shift of the supply curve to the right would result in greater benefits to processors than to growers, and growers could even be worse off if a pivotal shift in the supply curve should occur.

The present values of net social benefits which would be expected from mechanization of strawberry harvesting ranged from $39 million to $918 million depending upon the nature of the supply shift and the formula used to estimate social benefits. The results also indicated that mechanization of strawberry harvesting may be more profitable to growers than hand-picking under certain assumed conditions. However, some caution is needed in interpreting the results obtained in this thesis. For instance, specific prices for some grades of mechanically harvested strawberries have not yet been officially established, which adds uncertainty to the economic comparisons between mechanical harvesting versus hand-picking.

Projected Impacts on Growers, Processors, and Consumers from Mechanical Strawberry Harvesting

by

Chong S. Kim

A THESIS

submitted to

Oregon State University

on partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Commencement June 1981

APPROVED:

Redacted for privacy

Professor of Agricultural and Resource Economics
in charge of major

Redacted for privacy

Head of Agricultural and Resource Economics

Redacted for privacy

Dean of Graduate School

Date thesis is presented July 23, 1980

Typed by Cheryl A. Graham for Chong S. Kim

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PROJECTED IMPACTS ON GROWERS, PROCESSORS, AND CONSUMERS FROM MECHANICAL STRAWBERRY HARVESTING

INTRODUCTION

Strawberries have been grown commercially in Oregon since the early 1900's. The climate and soils are well accomodated to growing high quality strawberries, for which processors often pay premiums above processing price for California berries.

Approximately 90 percent of strawberries produced in Oregon during the 1978 season were processed as frozen pack, jam, and juice stock, while only 28 percent of total strawberries produced in the United States were processed during the same year. Over 96 percent of the commercially produced strawberries for processing in the U.S. during the 1978 season were grown in three far western states, Oregon, Washington and California. During the 1960-72 period, strawberry production in Oregon for processing accounted for between 30 and 45 percent of the total processed strawberries in the U.S., while they only accounted for between 13 and 27 percent of the total processed strawberries in the U.S. during 1973-78 period (Figure 1). Strawberry production for processing in California during the 1978 season accounted for nearly 72 percent of the U.S. total strawberry production for processing, while Oregon accounted for only 16.6 percent.

The demand for processed strawberries has been increasing in the U.S. as consumers' income and population increase. However, in all producing states (with the exception of California and Florida) the trend of strawberry production for processing has been declining. Mexico has also been steadily increasing its export to the U.S. even though it has

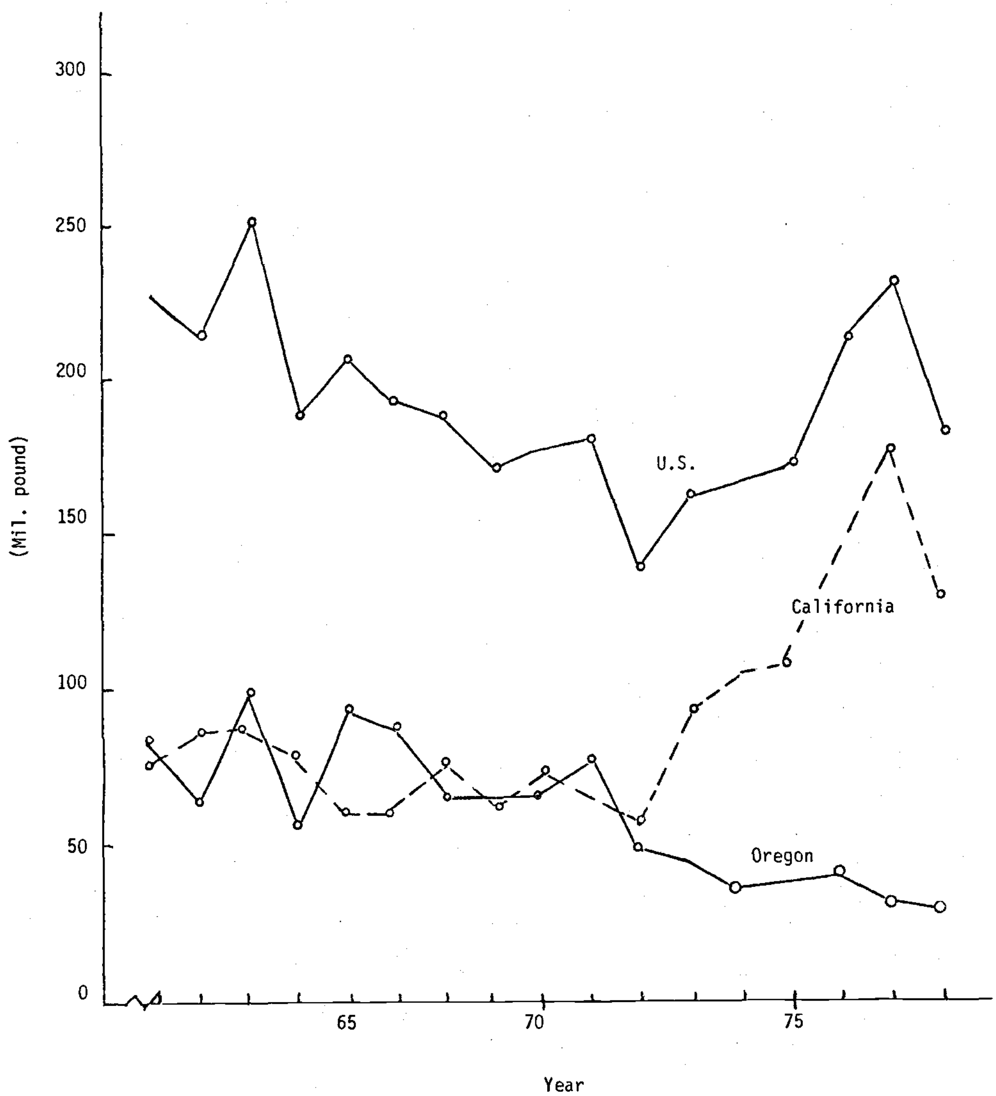

Figure 1. Strawberry Production Utilized to Processing for Oregon, California, and the United States, 1960-1978.

a relatively low yield per acre and high transportation costs to the U.S. markets. A low labor cost may contribute to its increasing acreage for strawberry production. High California strawberry production results from a longer harvesting season and intensive production practices, such as annual planting, high plant densities, and plastic mulch. California has been increasing both strawberry acreage and yield. Yield per acre has also been increasing in Oregon.

Acreage for strawberry production has declined in Oregon since 1965, even though yield per acre has increased and net profits per acre are supposedly greater than for some other crops, such as snap beans or sweet corn. In 1975, for example, the net profit to growers was estimated to be \$130 per acre for producing strawberries in Oregon compared to net profits of about \$34 per acre for sweet corn or \$48 per acre for snap beans (Kim, Brown, and Langmo, 1980). Oregon strawberry acreage reached its lowest level, 5,000 acres, in 1978 as compared to 14,000 acres in 1967. Part of this decline may have resulted from increased production of strawberries in California and increasing imports from Mexico. However, Hussen (1978) hypothesized in his thesis that increased picking costs without an off-setting increase in the farm price of strawberries was the main cause for the continuing decline of the strawberry industry in Oregon. Even though picking and handling costs have increased, another important factor in the decline of Oregon strawberry acreage has been the difficulty in obtaining enough pickers. In 1978, the picker shortage was made worse by hot weather that hastened ripening, contributing to the estimated 25 percent of the strawberries that rotted in the field. In summary, rising production costs and lack of labor to pick strawberries (with the associated uncertainty in procuring pickers) are thought to be the main reasons for the declining acreage for strawberry production in Oregon

To find a satisfactory solution to the problems of declining strawberry acreage, since 1967 Oregon has put time and money into mechanical strawberry harvesting. If mechanization in strawberry harvesting is profitable, it will alleviate not only harvesting costs, but also the difficulties in procuring labor and its accompanying uncertainty, and therefore may induce growers to increase acreages in strawberry production. The purpose of this thesis is to assess the profitability to the Oregon growers of mechanical strawberry harvesting and net benefits which are expected from mechanization in strawberry harvesting.

Problem Statement

Even though strawberry yields have increased and net profits per acre may be greater than for some other crops, such as snap beans and sweet corn, acreage for strawberry production in Oregon has been declining. Since most strawberries produced in Oregon are processed in Oregon and consumed in all parts of the U.S., the loss of the strawberry industry in Oregon not only has negative impacts on growers and processors, but also on the related industries and consumers throughout the nation. Also, the very short harvest season (four to six weeks) and the short shelf life of Oregon strawberries precludes any appreciable expansion of the fresh market.

Besides the increase in production costs, the difficulty in procuring enough hand-pickers and accompanying uncertainty are important factors in the declining Oregon strawberry acreage. Traditionally, strawberry harvesting has been dependent on elementary school-aged youngsters. In 1973, the U.S. Congress passed child labor legislation which banned children under 12 years old from picking fruit in the field.

Also, even though wages have been increasing, the wage level remains too low to attract adult laborers to pick strawberries. Therefore, it might be possible to obtain sufficient labor to pick strawberries, without increasing production costs, by relaxing labor laws. However, increasing labor availability by relaxing labor laws is not a perfect solution to the decreasing acreage and resulting decline in strawberry production. In 1979, for example, the harvesting season in Oregon came early and youngsters were still in school. Growers found it difficult to procure pickers on the appropriate date for picking.

The farm prices of strawberries fluctuate from year to year. When farm prices are relatively low, growers may be faced with net losses due to the higher unit production costs. The unit production costs may be reduced by increasing yield per acre. Oregon has been putting great effort into plant breeding, and it has been shown that the possibility exists for large increments in yield per acre. For example, during the 1978 and 1979 seasons, more than 11 tons of strawberries were harvested per acre on experiment plots, while present yields are less than four tons per acre, on the average, in Oregon. However, increased yield could make the current labor shortage situation even worse. Therefore, the problem of declining strawberry production cannot be solved by increasing yield without solving the current difficulty in procuring pickers. To solve the problems faced in the Oregon strawberry industry, the ideal alternative would decrease unit harvesting costs and simultaneously solve the difficulty in procuring hand-pickers.

To solve the problems of declining strawberry acreage and total strawberry production, since 1967 Oregon has put great effort into the mechanization of strawberry harvesting. If mechanization in strawberry harvesting is feasible in a technical sense, it could ease not only harvesting costs, but also the difficulty in procuring pickers and its accompanying uncertainty, and therefore might induce growers to assess the profitability of mechanical strawberry harvesting. Furthermore, a reduction in the harvesting costs and an increase in acreage could strengthen the Oregon strawberry industry in the nationwide competitive strawberry industry, and lead to an increase in the total supply of strawberries in Oregon and cheaper strawberries for consumers. (Note that successful mechanized strawberry harvest would benefit Oregon and Washington much more than California where mechanized harvest would be inappropriate because of the long California harvest season involving many pickings.)

The mechanical strawberry harvesting would cause a labor shift from hand-pickers to hand-sorters. This involuntary labor displacement from introducing the mechanical strawberry harvester would generate costs, not only to hand-pickers, but also to society. Therefore, even if mechanization in strawberry harvesting is economically feasible, it is desirable to estimate the benefits and costs to society before deciding upon the desirability of the adoption of the mechanical strawberry harvester.

Objectives of This Study

1. To evaluate the economic feasibility to Oregon growers of mechanically harvested strawberries.

2. To estimate the social benefits and costs that can be expected from adopting mechanization in strawberry harvesting.

To accomplish these objectives, the performance of the mechanical strawberry harvesters and the capper-stemmer will be evaluated, based upon the primary data collected during the 1978 and 1979 seasons at experimental plots and a cooperating processing company. Based upon the results obtained, the economic feasibility to Oregon growers of mechanically harvested strawberries will be evaluated in Chapter II. The unit production costs and net profits will be compared between hand-picking and mechanical harvesting under certain assumed conditions. In Chapter III, the demand and supply analyses for strawberries will be conducted. Since less than 10 processors purchase more than 90 percent of the total strawberries for processing in Oregon, an oligopsonistic market structure will be assumed in the demand-supply analysis. Because of the nature of important endogenous variables, such as price and quantity of strawberries for processing, a simultaneous equations model will be employed in estimating the demand-supply relationships for strawberries at the farm level. Since data covering the 1962-78 period are available, time series and cross-sectional data will be pooled in the estimation process. The problems arising from employing pooled data will be properly solved so as to obtain efficient estimators.

If demand-supply relationships can be accurately estimated, it is then possible to measure the benefits and costs which can be expected from mechanical strawberry harvesting. In Chapter IV, the net social benefits (or costs) will be computed by applying the different formulas used by Lindner and Jarrett, Peterson, and Griliches, respectively. Since the adoption of technology requires a transition period, a linear trend model will be employed to estimate the adoption rate. It will also be assumed that acreage will be increased according to an exponential growth model.

ECONOMIC FEASIBILITY OF MECHANICALLY HARVESTED STRAWBERRIES FOR OREGON GROWERS

Performance of Mechanical Harvesters and Processing Equipment

Two types of harvesters, the OSU and SKH&S machines, were tested on experimental plots during the 1978 season in Oregon. Seventeen field experiments with mechanical harvesting were conducted. Among these, eight experiments were on plots with no previous hand-pickings, six had one previous hand-picking, and three had two previous hand-pickings. Three strawberry varieties (Benton, Olympus, and Linn) were used in the experiments.

Even though many people believe that the mechanical harvester can be used as a clean-up operation after one or two hand-picks, the analysis of the 1978 data indicated that net profit to the grower from mechanical harvesting was decreased when the number of previous hand-picks was increased, and that losses might even be incurred. The reason for this result was because growers must incur the costs of mechanization regardless of the amount of fruit harvested, and the amount of mechanically harvested fruit decreases as the number of previous hand-picks increases.

Forty-eight among 56 field experiments were conducted on plots without previous hand-picking during the 1979 season. Three harvesters, including two SKH&S machines and the OSU harvester, were tested with five strawberry varieties: Benton, Olympus, Linn, Totem, and 70-17-12. Three replications for each variety were provided for testing at each experimental site. Data on harvest rate, percent fruit recovery, quality of harvested fruit, and time studies for each harvester were collected during the 1978 and 1979 seasons.

The stemming and capping machine developed by Oregon State University for use in processing lines for mechanically harvested strawberries was also evaluated. The processing rate and effectiveness of the OSU Capper-Stemmer in removing leaves and stems, and in separating undersized strawberries were observed. Finally, the quality of processed strawberries was evaluated to compare with hand-picked strawberries.

The two SKH&S harvesters were nearly the same, except that one machine had its own engine as a power source. To find whether those two SKH&S harvesters operated essentially the same, relevant hypotheses were tested by factorial experimental design as shown in Tables 1 and 2. Statistical tests indicated no significant difference in operation of the two SKH&S harvesters.

Estimated Mechanical Harvesting and Processing Costs

Machinery costs which are first estimated in this section are based upon the following assumptions:

(1) The owner of the mechanical harvester has 20 acres of strawberries on his 200-acre farm. (Farm size affects production costs.)

(2) The expected useful mechanical life of the harvester is around 1,500 hours, and the annual use of the mechanical harvester is 214 hours, which is needed to harvest the owner's 20 acres plus 37 acres of custom harvest at a field speed of 0.63 mph based upon actual running time and a 20 percent allowance for nonoperating needs.

(3) The list price of the harvester is $15,000.

Machinery costs include both variable and fixed costs. Variable (operating) costs include fuel, lubrication, repair, and labor costs, while fixed costs are those costs which are not affected much by the

TABLE 1. TOTAL FRUIT (LBS./RUNNING MINUTE[a/]) HARVESTED BY SKH&S HARVESTERS.

Harvester	Variety		
	Benton	Olympus	Linn
	44.74	76.20	36.17
SKH&S (I)	33.55	77.24	45.12
	--	79.35	54.34
	40.85	74.48	37.88
SKH&S (II)	48.13	65.58	46.05
	36.37	--	72.69

a/ The same ANOVA results (Table 2) would be obtained even though Table 1 is constructed with pounds per acre.

TABLE 2. ANALYSIS OF VARIANCE

Source of Variation	S.S.	D.F.	M.S.	F
Harvester	4.28	1	4.28	3.84
Variety	37.68	2	18.84	16.89
Harvester X Variety	3.85	2	1.92	1.72
Experimental Error	11.16	10	1.12	--

H_0: Main effects of harvesters are zero.
$F_{0.95}(1,10) = 4.96$, and therefore the null hypothesis is accepted.

H_0: Zero interaction among harvesters and varieties.
$F_{0.95}(2,10) = 4.10$, and therefore the null hypothesis is accepted.

amount of annual use. Fixed costs include depreciation, taxes, housing, interest, and insurance.

The OSU and SKH&S harvesters are very similar in operation, size and estimated price. Therefore, the cost figures obtained in this section are based on the OSU harvester.

Variable Costs for the Mechanical Harvester

Fuel. The amount of fuel used per hour depends upon the horsepower of the harvester and the type of fuel it uses. The OSU harvester with two 18 horsepower gasoline engines was estimated to consume 2.4 gallons of gasoline per hour. The gasoline was assumed to be delivered to the farm at 85.4¢ per gallon. (All cost figures were computed on an August 1979 basis.) An 11¢ per gallon tax refund, which includes state and federal taxes, should be deducted. Therefore, fuel cost for the OSU harvester was computed to be $1.79 per hour, i.e., 2.4 gallons per hour x $(0.854 - 0.11) per gallon = $1.79 per hour.

Lubrication. The lubrication costs, including oil, grease, and oil filters are commonly estimated by multiplying 15 percent of the fuel costs, giving $0.27 per hour for lubrication.

Repair Costs. Repair costs generally increase as a machine gets older (since the amount of wear, and therefore the amount spent for repairs, is proportional to use). Therefore, it was assumed that repair costs reach an early high level, and then slowly and continuously increase. The following formula is used to estimate repair costs (Bowers):

$$TAR = C \times RC1 \times RC2 \times L^{RC3}$$

where TAR = Total accumulated repair costs as measured at "L".

L = Percent of the designated lifetime hours of the machine

TABLE 3. EFFICIENCY OF THE MECHANICAL HARVESTERS[a/]: 1978 SEASON.

Harvesters	Varieties			Average
	Benton	Olympus	Linn	
OSU	65.2	78.0	81.3	74.8
SKH&S	59.5	76.8	--	68.2

a/ Efficiency = $\frac{\text{Total Fruit}}{\text{Gross Raw Product}}$ x 100.

TABLE 4. EFFICIENCY OF THE MECHANICAL HARVESTERS: 1979 SEASON[a/].

Harvester	Varieties					Average
	Benton	Olympus[b/]	Linn	Totem	70-17-12	
OSU	53.78	80.55	71.78	75.82	66.56	69.70
SKH&S	74.63	76.22	71.89	81.25	76.24	76.05

a/ Efficiency = $\frac{\text{Total Fruit}}{\text{Gross Raw Product}}$ x 100.

b/ Excludes experiments on Kuedell's lots.

TABLE 5. EFFICIENCY OF THE OSU CAPPER-STEMMER: 1978 SEASON.

Variety	Percent Undersize[a/] (5/8")	Percent[b/] Hand-sort-Out	Grade #1[c/] (Percent of Total Fruit)
Benton	29.54	4.52	64.64
Olympus	23.67	3.67	71.36
Average	26.61	4.10	68.00

a/ (Undersize/Total Fruit) x 100.

b/ (Hand-sort-out/Total Fruit) x 100. (Most of this fruit is used for juice, jam, and puree.)

c/ Grade #1 is defined as "Standard" quality and computed by subtracting an average spillage of 1.3 percent.

TABLE 6. EFFICIENCY OF THE OSU CAPPER-STEMMER: 1979 SEASON.

Variety	Percent Undersize[a/] (5/8")	Percent Hand-Sort	Spillage	Grade #1 (Percent of Total Fruit[c/]
Benton	24.01	22.54	2.81	50.64
Olympus	20.97	29.63	2.10	47.30
Linn	12.00	43.16	2.36	42.48
Totem	14.18	32.11	1.90	51.81
70-17-12	11.50	39.91	2.35	46.24
Average	17.80	33.47	2.30	47.70

a/ (Undersize/Total Fruit) x 100.

b/ (Hand-sort-Out/Total Fruit) x 100. (Most of this fruit is used for juice, jam, and puree.

c/ Grade #1 is defined as "Standard" quality and is composed of large, ripe berries.

TABLE 7. PERCENT MOULDED STRAWBERRIES IN TOTAL FRUIT[a/]: 1979 SEASON.

Varieties: Harvester	Benton (%)	Olympus (%)	Linn (%)	Totem (%)	70-17-12 (%)	Average (%)
OSU	6.13	5.42	3.79	9.60	4.45	5.88
SKH&S	5.34	8.38	10.55	18.98	10.38	10.73

a/ This table is based upon "five pound samples".

TABLE 8. PERCENT GRADE #1[a/] AND GRADE #5[b/] IN TOTAL FRUIT: 1978 SEASON.

Variety	GRADE:	Grade #1 (%)	Grade #5 (%)
Benton		64.64	33.22
Olympus		71.36	26.66
Average		68.00	29.94

a/ Grade #1 is defined as "Standard" quality and is componsed of large, ripe berries.

b/ Grade #5 is defined as berries for juice, jam, and puree, and is composed of undersized, misshapen, or underripe berries. All mouldy or rotten berries are discarded. Grade #2 is also defined as hand-picked berries for juice, jam, and puree. However, there is a price differentiation between grade #2 and grade #5 as noted in a later section.

TABLE 9. PERCENT GRADE #1[a/] and GRADE #5[b/] IN TOTAL FRUIT: 1979 SEASON.

Variety	Grade:	Grade #1	Grade #5
Benton		50.64	41.59
Olympus		47.30	44.16
Linn		42.48	48.36
Totem		51.81	32.80
70-17-12		46.24	43.30

a/ Grade #1 is defined as "Standard" quality and is composed of large, ripe berries.

b/ Grade #5 is defined as berries for juice, jam, and puree, and is composed of undersized, misshapen, or underripe berries.

TABLE 10. PERCENT OF USABLE FRUIT[a/] IN TOTAL RAW PRODUCT: 1978 SEASON.

Harvester / Grade:	Grade #1 (%)	Grade #5 (%)
OSU	50.86	22.40
SKH&S	46.38	20.42
Average	48.62	21.41

a/ Usable fruit is defined as the sum of grade #1 and grade #5.

b/ Grade #5 is defined as berries for juice, jam, and puree, and is composed of undersized, misshapen, or underripe berries.

TABLE 11. PERCENT USABLE FRUIT[a/] IN TOTAL RAW PRODUCT: 1979 SEASON.

Harvester:	OSU		SKH&S	
Variety / Grade:	Grade #1	Grade #5	Grade #1	Grade #5
	(%)	(%)	(%)	(%)
Benton	27.23	22.37	37.79	31.04
Olympus	38.10	35.57	36.05	33.66
Linn	30.49	34.71	30.54	34.77
Totem	38.69	24.87	41.46	26.65
70-17-12	30.78	31.42	35.25	33.01
Average	33.06	29.79	36.22	31.83

a/ Usable fruit is defined as the sum of grade #1 and grade #5.

TABLE 12. REPAIR COSTS PER HOUR FOR THE OSU HARVESTER

Age	First Year	Second Year	Third Year	Fourth Year	Fifth Year	Sixth Year	Seventh Year	Average
Repair cost per hour	$5.54	$8.21	$9.54	$10.56	$11.39	$12.10	$12.72	$10.01

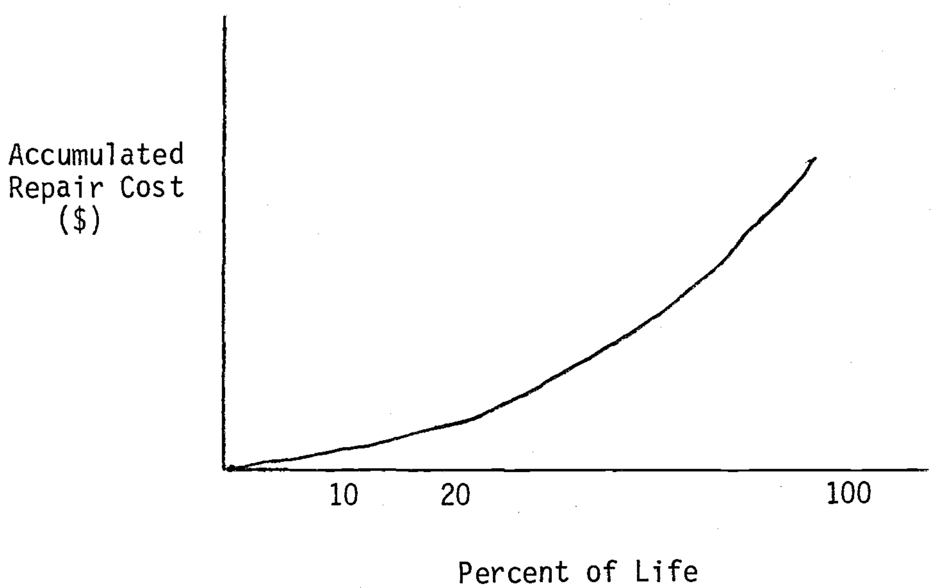

Figure 2. The accumulated repair cost curve.

that have been used up at point where accumulated repairs are to be measured.

C = Initial list price.

RC1 = A constant that is actually a ratio of TAR to C as measured at 200 percent of life, and assuming no inflation.

RC2 and RC3 are repair costs constants that go together to indicate the general shape of the accumulated repair cost curve which is assumed to be shown in Figure 2.

For the OSU harvester, 1, 0.00251, and 1.3 are used in this study for RC1, RC2, and RC3, respectively. After estimating repair costs for the machine's expected lifetime, an average repair cost of $10.01 per hour is used in this study. The results are shown in Table 12.

Labor. The OSU and SKH&S harvesters are pulled by tractors with approximately 35 horsepower. A crew of three workers is necessary for operating the OSU or SKH&S harvester, one operating the tractor and the other two assisting on the harvester.

To estimate labor costs, $8.00 per hour for the tractor operator and $5.00 per hour for the harvester assistants are assumed. Therefore, $18.00 per hour is used as the labor cost.

Total variable costs per hour, including fuel, lubrication, repair, and labor costs, was estimated to be $30.07 per hour.

Fixed Costs for the Mechanical Harvester

Fixed costs include depreciation, taxes, housing, insurance, and interest on investment.

Depreciation. The declining balance method is employed to estimate depreciation for the harvester. This method depreciates at a constant percentage of the remaining value each year and gives approximately ten percent of list price as a salvage value. The declining balance is represented by the following formula (Bowers);

$$V = C \times (1. - R/L)^{y}$$

where V = Remaining value

C = Initial list price

R = Ratio of depreciation rate used to straight-line rate (R = 2 is used in this study)

L = Estimated service life in years (L = 7 is used in this study, and the expected life is 1,498 hours with an annual use of 214 hours)

y = An exponent that is equal to the year in question

Results are shown in Table 13.

Taxes, Housing and Insurance. Taxes and housing costs are each assumed to be 1.5 percent of the remaining value, and insurance is assumed to be 0.3 percent of remaining value. (In Oregon, property tax on farm machinery is being eliminated after 1979.)

Interest on Investment. Interest payment is estimated at 11.0 percent of the remaining value of the machine. Estimated interest and other fixed costs are shown in Table 13, and total fixed costs are $13.30 per hour, on the average.

The OSU harvester can be pulled by a diesel tractor greater than 20 horsepower. Since most farmers have 35 horsepower tractors rather than 20 hoursepower tractors, it is assumed that the OSU harvester is pulled by a 35 hoursepower diesel tractor, which consumes 1.7 gallons of diesel fuel per hour. To compute fuel consumption, $0.75 per gallon is used as the cost per gallon. The cost of lubrication is assumed to be 15 percent of fuel cost. This figure gives a fuel and lubrication cost for the

TABLE 13. FIXED COSTS FOR MECHANICAL HARVESTER.

Age	Depreciation Per Hour ($)	Tax & Housing Per Hour ($)	Insurance Per Hour ($)	Interest Per Hour ($)	Total Fixed Cost/Hour ($)
1	20.03	1.50	0.15	7.71	29.39
2	14.30	1.07	0.11	5.51	20.99
3	10.22	0.77	0.08	3.93	15.00
4	7.30	0.55	0.06	2.81	10.72
5	5.21	0.39	0.04	2.01	7.65
6	3.72	0.28	0.03	1.43	5.46
7	2.66	0.20	0.02	1.02	3.90
Average	9.06	0.68	0.07	3.49	13.30

tractor of $1.47 per hour.

The list price of a 35 horsepower diesel tractor is assumed to be $9,000.00 with expected life of 12 years and usage of 500 hours per year. Using a published table (Bowers), the repair cost was computed to be $0.74 per hour. Therefore, the total variable cost of using the tractor was $2.21 per hour.

The total harvesting cost, including the variable cost for the tractor and variable cost plus fixed cost for the harvester, was computed to be $45.58 per hour.

<u>Additional Costs for Operating the Capper-Stemmer for Processing</u>

The strawberries from 52 among 56 field experiments were processed by the OSU Capper-Stemmer because the undersized berries are separated through the process. It is assumed that all raw product harvested is processed through the OSU Capper-Stemmer. Additional assumptions on cost estimation are as follows:

(1) The expected life is ten years.

(2) Annual use is 260 hours. This figure varies, depending upon the amount of raw product harvested (this figure was estimated as follows: processing machine-picked strawberries at the plant could run 3 to 3.5 weeks. Therefore, 3.25 weeks x 5 days per week x 16 hours per day = 260 hours). However, different amounts of raw product will vary the number of Capper-Stemmers needed.

(3) List price is estimated to be $8,000 for one four-foot long Capper-Stemmer. (In previous experimental use, only the one-foot long Capper-Stemmer was available. However, for large-scale use, it would be extended in size to operate efficiently at the four-foot length.

Electricity. The four-foot long OSU Capper-Stemmer would be equipped with a 7.5 horsepower motor which would consume six Kilowatts of electricity per hour. Each processing line at the processing company is equipped with two conveyor belts each with a 0.5 horsepower motor. It is estimated that the two conveyor belts consume one Kilowatt per hour. A charge for electricity of 1.716¢ per Kilowatt was used (Pacific Power and Light Company).

Repair Cost. In estimating repair cost, 0.000251 and 1.8 are used for RC2 and RC3.

Labor Cost. For each Capper-Stemmer, a dumper, a feeder, and sorters are required for processing. However, no feeder is required for processing of hand-picked strawberries. The number of sorters varies, depending upon the amount of fruit. The total fruit per acre from mechanical harvesting is less than the fruit per acre by hand-picking and, therefore, some savings in cost of sorting would occur. This is explained in detail in a later section.

To simplify estimation, only additional costs are computed. For example, one dumper is needed for the Capper-Stemmer, but a dumper is also required for processing of hand-picked berries. Therefore, it is not counted. The results for additional variable costs and fixed costs are as follows:

Additional variable costs[a/]

Electricity:	$0.12/hr.
Lubrication:	0.02/hr.
Repair cost:	3.07/hr.
Labor (feeder) cost:	4.72/hr.
Total:	$7.93/hr.

Additional fixed costs

Depreciation:	$2.75/hr.
Tax, insurance, housing:	0.20/hr.
Interest (11%):	1.51/hr.
Total:	$4.46/hr.
Additional total cost:[a/]	$12.39/hr.

[a/] Does not include the savings in sorting costs.

Operational Characteristics Affecting Variable Costs

The speed of the harvester affects operating costs and the amount of fruit harvested. In the field during the 1978 season, speeds ranged from 0.31 mph to 0.56 mph for the OSU harvester and from 0.45 mph to 0.64 mph for the SKH&S harvester. Simple regression equations were estimated to find the relationships between the amount of fruit harvested per acre and the speed of harvester. Even though statistical results failed to show a significant effect of speed upon amount of fruit, the analysis indicated a slight positive relation between speed and amount of fruit harvested per acre. (More berries tend to roll forward off the cutter bar and are lost at lower speeds.)

In the field during the 1979 season, speeds ranged between 0.52 mph and 1.02 mph for the OSU harvester and between 0.52 mph and 1.13 mph for the SKH&S harvester. Statistical results for the 1979 experiments indicated that speed of harvester and total amount of fruit harvested per acre were inversely related. According to Professor Booster, Department of Agricultural Engineering at OSU, total fruit per acre harvested with the OSU harvester is positvely related to speeds up to 0.75 mph under current technology. Therefore, a speed of 0.75 mph is chosen for the OSU and SKH&S harvesters. This figure is based on running time only. Therefore, this is readjusted by including an allowance of 20 percent for non-operating needs.

Machinery Cost Per Acre for Mechanically Harvesting Strawberries

The field capacity is estimated to determine the hours necessary to harvest one acre of strawberries.

$$\text{Field Capacity} = \frac{\text{Area Covered}}{\text{Time Required (Hours)}} = \text{Acres/Hour}$$

where time required (hours) includes both running time and an allowance of 20 percent for non-operating needs.

Using the estimated field capacity, hours necessary to harvest the strawberries on one acre can be derived, and the result is that 3.77 hours are required to harvest one acre with 0.63 adjusted mph. With this result, machinery cost per acre for harvester was computed to be $171.84. That is, $45.58 per hour x 3.77 hours per acre = $171.84 per acre.

Machinery cost for havesting is not affected by the amount of raw product. The growers must bear the machinery cost of the harvester regardless of yield. However, the amount of raw product harvested affects processing cost. It will be studied in the next section.

Estimation of Number of Capper-Stemmers for Processing

The greatest difficulty lies in determining how many Capper-Stemmers the processing company would need. The processing rates[1/] were estimated to range from 2,200 pounds to 5,200 pounds per hour to average 3,400 pounds per hour.

The following assumptions were made to determine the number of Capper-Stemmers required to process mechanically-harvested strawberries.

(1) Eighteen thousand crates (15 pounds per crate) or 135 tons of hand-picked strawberries are processed per day by the processing company. (This quantity was an average amount of hand-picked strawberries processed daily at the participating processing company.)

(2) All growers harvest berries with mechanical harvesters.

(3) A yield of four tons by hand-picking would be averaged per acre.

(4) All of the raw product harvested is processed by the OSU Capper-Stemmer.

(5) The processing capacity of the OSU Capper-Stemmer is 3,500 pounds per hour.

It is assumed that 18,000 crates of hand-picked strawberries are processed per day at a participating processing company during the season of six to seven weeks. These 18,000 crates would require 33.75 acres if four tons of strawberries were produced per acre. That is,

$$\frac{18{,}000 \text{ crates} \times 15 \text{ lbs./crate}}{4 \text{ t/a} \times 2{,}000 \text{ lbs.}} = 33.75 \text{ acres.}$$

The weight of mechanically-harvested raw product is about equal to the weight of hand-picked strawberries, as shown in Table 15. However,

1/ Processing rate is defined as an amount of raw product processed per hour.

the data collected during the 1978 season showed that the amount of raw product harvested accounted for around 90 percent of the amount of hand-picked strawberries, as shown in Table 14. Therefore, both situations will be considered.

Case A: The amount of raw product harvested is equivalent to the amount of hand-picked strawberries. Since the weight of mechanically-harvested raw product is assumed to be equal to the weight of hand-picked strawberries, the company should be able to process 135 tons of product per eight-hour day (i.e., 33.75 acres x 4 tons/acre = 135 tons/day). However, the processing hours can be extended to 16 hours per day during the harvesting season. Therefore, the company should be able to process the raw product from 67.5 acres per day.

The capacity of the OSU Capper-Stemmer is 3,500 pounds per hour, and, therefore, nine lines of the Capper-Stemmer are needed to process the raw product which is harvested by the mechanical harvester from 67.5 acres. That is,

$$\frac{270 \text{ tons/day} \times 2{,}000 \text{ lbs./ton}}{3{,}500 \text{ lbs./hr.} \times 16 \text{ hrs./day}} = 9.6.$$

(To make it more realistic, it is assumed that the processing company is equipped with nine Capper-Stemmers, by truncating the decimal point.)

Case B: The amount of raw product harvested accounts for 90 percent of the hand-picked. The company should now be able to process 243 tons of raw product per 16 hour day, (i.e., 67.5 acres x 4 tons/acre x 90% = 243 tons/day) and eight Capper-Stemmers are required to process the raw product harvested from 67.5 acres. That is,

TABLE 14. GROSS RAW PRODUCT HARVESTED (T/A) AND AMOUNT OF HAND-PICKED STRAWBERRIES (T/A): 1978 SEASON.

Harvester / Variety:	Benton (N. Willamette Exp. Sta.)	Olympus Kuedell Farm
OSU	9.12	4.57
SKH&S	9.92	6.08
Hand-pick[a/]	10.57	6.13

a/ Based on commercial picking.

TABLE 15. GROSS RAW PRODUCT HARVESTED (T/A) AT THE NORTH WILLAMETTE EXPERIMENT STATION AND AMOUNT OF HAND-PICKED STRAWBERRIES (T/A): 1979 SEASON.

Harvester / Variety:	Benton	Olympus	Linn	Totem	70-17-12
OSU	5.10	8.89	8.22	4.75	6.41
SKH&S	6.20	9.30	7.87	4.18	6.91
Hand-pick[a/]	7.41	11.98	7.13	4.68	4.31

a/ Based on commercial picking.

TABLE 16. PERCENT GRADE #1 AND GRADE #5, ON AVERAGE FOR ALL VARIETIES, OF MACHINE-HARVESTED GROSS RAW PRODUCT.

Harvester / Grade:	Grade #1 (%)	Grade #5 (%)
OSU (1978 season)	50.86	22.40
SKH&S (1979 season)	36.22	31.83

$$\frac{243 \text{ tons/day} \times 2{,}000 \text{ lbs./ton}}{3{,}500 \text{ lbs./hr.} \times 16 \text{ hrs./day}} = 8.6.$$

(It is assumed that the processing company is equipped with eight Capper-Stemmers, by truncating the decimal point.)

Estimated Number of Sorters Needed

The participating processing company is presently equipped with seven processing lines for hand-picked strawberries. According to company information, seven sorters would be needed in each line for strawberries of the qualities shown in Tables 17 and 18.

Also, it is assumed that 18,000 crates (15 lbs. per crate) of hand-picked strawberries are processed per day. Therefore, about 4,821 pounds of hand-picked strawberries could be processed per hour per line. That is,

$$\frac{18{,}000 \text{ crates} \times 15 \text{ lbs./crate}}{8 \text{ hrs./day} \times 7 \text{ lines}} = 4{,}821.43 \text{ lbs./hr./line.}$$

These 4,821.43 pounds of strawberries are the amount that seven sorters could handle. Therefore, each sorter is assumed to handle 688.78 pounds of hand-picked strawberries per hour.

However, the number of sorters needed varies, depending not only on quantity, but also quality of strawberries. According to company information, nine sorters would be required in each line for an equivalent quantity of mechanically-harvested strawberries. Therefore, each sorter is assumed to handle 535.71 pounds of machinery-harvested strawberries per hour. That is,

$$\frac{4{,}821.43 \text{ lbs./hr./line}}{9 \text{ sorters/line}} = 535.71 \text{ lbs./hr./sorter.}$$

The amount of fruit accounts for 76.05 percent of gross raw product harvested by SKH&S harvester (Table 4). Undersized strawberries and

TABLE 17. CLASSIFICATION OF HAND-PICKED STRAWBERRIES[a/]: 1979 SEASON.

Grade / Variety:	Benton (%)	Olympus (%)	Hood (%)	Average (%)
Grade #1	90	90	91	90.3
Grade #2	7	5	6	6.0
Culls	3	5	3	3.7

[a/] Obtained from participating processing company.

TABLE 18. CLASSIFICATION OF HAND-PICKED STRAWBERRIES[a/]: 1978 SEASON.

Grade / Variety:	Olympus (%)	Linn (%)
Grade #1	92.4	91.4
Grade #2	3.0	4.6
Culls	4.6	4.0

[a/] Obtained from participating processing company.

TABLE 19. COMPARISONS OF UNIT COSTS.

	Tons/Acre:	3	4	5	6
Hand-picks ($/lb.)		0.3335	0.2891	0.2624	0.2446
Case A:	SKH&S ($/lb.)	0.3113	0.2379	0.1939	0.1645
	OSU ($/lb.)	0.2892	0.2210	0.1801	0.1528
Case B:	SKH&S ($/lb.)	0.3428	0.2613	0.2124	0.1797
	OSU ($/lb.)	0.3185	0.2427	0.1973	0.1670

spillage account for 17.80 and 2.30 percent, on the average, of the total fruit, respectively (Table 6). Therefore, only 60.8 percent of the gross raw product would be handled by hand-sorters. That is, 76.05% x (100 - 17.80 - 2.30)% = 60.8%.

The capacity of the OSU Capper-Stemmer is assumed to be 3,500 pounds per hour. Therefore, only 2,128 pounds of strawberries would be handled by hand-sorters. That is, 3,500 lbs. per hour x 60.8% = 2,128 lbs. per hour. Also, it was estimated in the above that each sorter could handle 535.71 pounds of mechanically-harvested strawberries per hour. Therefore, these 2,128 pounds of strawberries could be handled by four sorters in one hour. That is,

$$\frac{2{,}128 \text{ lbs./hr.}}{535.71 \text{ lbs./hr.}} = 3.97 \text{ sorters (4 sorters).}$$

Estimation of the Net Processing Cost

The additional cost for operating the Capper-Stemmer is \$12.39 per hour.[2/] It is estimated that 4.74 hours are required to process hand-picked strawberries from 20 acres. That is,

$$\frac{4 \text{ t/a} \times 2{,}000 \text{ lbs./t} \times 20 \text{ acres} \times 8 \text{ hrs./day}}{18{,}000 \text{ crates/day} \times 15 \text{ lbs./crate}} = 4.74 \text{ hours.}$$

Therefore, the amount paid to sorters would be \$1,096.27 for hand-picked strawberries from 20 acres. That is, 4.74 hrs. x 7 lines x 7 sorters per line x \$4.72 per hour = \$1,096.27.[3/]

As explained in the preceding section, the number of Capper-Stemmers needed varies, depending upon the amount of raw product harvested.

2/ Does not include the savings in sorting cost.

3/ This figure was obtained from a participating processing company, and it includes all fringe benefits.

Therefore, the number of sorters needed to process raw products harvested will also vary.

Case A: The amount of mechanically-harvested raw product is equal to the amount of hand-picked strawberries. Since there is an equivalent weight of mechanically-harvested raw products to hand-picked berries, it is estimated that 5.08 hours are required to process the raw product harvested from 20 acres of strawberries. That is,

$$\frac{4\ \text{t/a} \times 20\ \text{acres} \times 2{,}000\ \text{lbs./t}}{3{,}500\ \text{lbs./line} \times 9\ \text{lines}} = 5.08\ \text{hrs.}$$

Therefore, the amount paid to sorters is estimated to be $863.19 for mechanically-harvested strawberries from 20 acres (5.08 hrs. x 9 lines x 4 sorters per line x $4.72 per hour = $863.19), and the saving in cost of sorting is $233.08 for 20 acres or $11.65 per acre ($1,096.27 - $863.19 = $233.08 or $233.08 per 20 acres = $11.65 per acre). To process raw products harvested from an acre, 0.25 hour is needed, and therefore, the additional cost for operating the Capper-Stemmer would be $27.88 per acre. That is,

$$\frac{4\ \text{t/a} \times 2{,}000\ \text{lbs./t}}{3{,}500\ \text{lbs./line} \times 9\ \text{lines}} = 0.25\ \text{hrs. per acre and } \$12.39\ \text{per}$$

hr. x 0.25 hr. x 9 lines = $27.88. Therefore, there is a net additional processing cost of $16.23 per acre in processing the mechanically-harvested raw product ($27.88 - $11.65 per acre = $16.23 per acre).

Case B: The amount of mechanically-harvested raw product accounts for 90 percent of the amount of hand-picked strawberries. Since less raw product is harvested, it will reduce processing time and the number of processing lines needed. It is estimated that 5.14 hours are required to process the raw products harvested from

20 acres of strawberries with eight Capper-Stemmers. That is,

$$\frac{4 \text{ t/a} \times 0.9 \times 20 \text{ acres} \times 2{,}000 \text{ lbs./t}}{3{,}500 \text{ lbs./line} \times 8 \text{ lines}} = 5.14 \text{ hrs.}$$

The total amount paid to sorters would be $776.35 for raw product harvested from 20 acres, and the saving in cost of sorting is $319.91 per 20 acres or $16.00 per acre. That is, 5.14 hrs. x 8 lines x 4 sorters per line x $4.72 per hour = $776.35, and $1,096.27 - $776.35 = $319.92 per 20 acres or $319.92/20 = $16.00 per acre. To process raw products harvested from an acre, 0.26 hour is needed, and therefore, the additional cost for operating the Capper-Stemmer would be $25.77 per acre, that is,

$\left(\frac{4 \text{ t/a} \times 0.9 \times 2{,}000 \text{ lbs./t}}{3{,}500 \text{ lbs./line} \times 8 \text{ lines}} = 0.26 \text{ hrs.}\right.$, and $12.39 per hour x 0.26 hour per acre x 8 lines = $25.77 per acre). Therefore, there is a net additional processing cost of $9.77 per acre in processing the mechanically-harvested raw product, i.e., $25.77 - $16.00 = $9.77 per acre.

Net Additional Processing Cost ($/Acre)	
Case A:	$16.23
Case B:	$ 9.77

Estimation of Total Usable Fruit[4/] of Mechanically-Harvested Berries

The date of harvest affects not only the amount of usable fruit, but also the proportion of Grade #1 and Grade #5 in total usable fruit. In 1979, the harvesting season in Oregon came earlier, and berries were over-ripe when mechanical harvesting was conducted. Missing the appropriate dates for mechanical harvesting resulted in an increased

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4/ Usable fruit is defined as the sum of Grade #1 and Grade #5.

proportion of Grade #5 relative to Grade #1 in total usable fruit harvested.

Statistical results from estimated regression equations showed a significant negative effect from late mechanical harvesting on June 27 and 28 upon total fruit harvested, and even though the regressions failed to show a significant effect of mechanical harvesting between June 11 and 19, there was an indication of a slight negative impact on the amount of fruit harvested.

Economic analyses are based on the data for SKH&S during the 1979 season and for the OSU harvester during the 1978 season, as shown in Table 16.

Case A: The amount of gross mechanically-harvested raw product is equal to the amount of hand-picked strawberries

SKH&S	Grade #1:	4 t/a x 36.22% =	2,897.6 lbs./a
	Grade #5:	4 t/a x 31.83% =	2,546.4 lbs./a
	Usable fruit:		5,444.0 lbs./a
OSU	Grade #1:	4 t/a x 50.86% =	4,068.8 lbs./a
	Grade #5:	4 t/a x 22.40% =	1,792.0 lbs./a
	Usable fruit:		5,860.8 lbs./a

Case B: The amount of gross product harvested accounts for 90 percent of the amount of hand-picked strawberries

SKH&S	Grade #1:	4 t/a x 90% x 36.22% =	2,607.8 lbs./a
	Grade #5:	4 t/a x 90% x 31.83% =	2,291.8 lbs./a
	Usable fruit:		4,899.6 lbs./a
OSU	Grade #1:	4 t/a x 90% x 50.86% =	3,661.9 lbs./a
	Grade #5:	4 t/a x 90% x 22.40% =	1,612.8 lbs./a
	Usable fruit:		5,274.7 lbs./a

Estimation of Usable Fruit of Hand-Picked Strawberries

For hand-picked strawberries with more than 95 percent of Grade #1, the growers are paid in full. Culls account for 3.7 percent on average and six percent for Grade #2 (Table 17). Therefore, the usable fruit of hand-picked strawberries is classified as follows:

Grade #1:	4 t/a x 90.3%	=	7,224 lbs./a
Grade #2:	4 t/a x 6.0%	=	480 lbs./a
Usable fruit:			7,704 lbs./a

Comparison of Total Costs, Unit Costs, and Net Revenue

Total Costs. For hand-picking, the total costs increase as yield per acre increases, due to the increase in picking and handling costs, as well as hauling costs. There is little change in harvesting costs as yield per acre increases for mechanical harvesting. However, the hauling and net processing costs change, and so will total cost. Total costs include production, harvesting, and processing costs and are computed for hand-picking and mechanical harvesting as follows:

Total Cost for Hand-Picking

Standard production cost[5/]	$1,026.90/acre
Picking and handling (14¢ per pound)	$1,120.00/acre
Hauling (1¢ per pound)	$ 80.00/acre
Total cost	$2,226.90/acre

[5/] Standard production cost is the total production cost excluding harvesting and hauling costs as shown by the production cost sheet, given in Appendix, Table A-1.

Total Cost for Mechanical Harvesting

	Case A[a]	Case B[b]
Standard production cost	$1,026.90/acre	$1,026.90/acre
Cost for harvesting	$ 171.84/acre	$ 171.84/acre
Cost for hauling (1¢ per pound)	$ 80.00/acre	$ 72.00/acre
Net processing cost	$ 16.23/acre	$ 9.77/acre
Total cost	$1,294.97/acre	$1,280.51/acre

a/ It is assumed for Case A that the weight of gross raw product harvested is equal to the weight of the hand-picked strawberries.

b/ For Case B it is assumed that the weight of gross raw product harvested equals 90 percent of the weight of hand-picked strawberries.

Unit Cost. The unit costs are computed for 3.77 hours per acre harvesting time and a 3,500 pounds per hour processing rate, and the results are shown in Table 19.

Net Revenue. It is anticipated that $0.33 per pound for Grade #1 and $0.275 per pound for Grade #2 will be paid to growers by a participating processing company for hand-picking strawberries during the 1979 season, while $0.2725 per pound for Grade #1 and $0.2365 per pound for Grade #2 were paid to growers during the 1978 season.

Net revenues were computed for 3.77 hours per acre required for mechanical harvesting and a 3,500 pounds per hour processing rate, and the results are shown in Tables 20 and 21. The results indicate that in some cases the mechanical harvesting may be more profitable for

TABLE 20. NET REVENUE COMPARISONS WITH 1979 FARM PRICES OF $0.33 PER POUND FOR GRADE #1, $0.275 PER POUND FOR GRADE #2, AND $0.177 PER POUND FOR GRADE #5. 6/

	Tons/Acre:	3	4	5	6
Hand-pick ($/a)		- 39.96	289.02	618.0	946.98
Case A:	SKH&S ($/a)	-216.04	111.53	439.10	766.67
	OSU ($/a)	- 26.31	364.50	755.31	1,146.12
Case B:	SKH&S ($/a)	-310.19	- 14.01	282.17	578.35
	OSU ($/a)	-139.44	213.66	566.76	919.85

TABLE 21. NET REVENUE COMPARISONS: 1978 FARM PRICES OF $0.275 PER POUND FOR GRADE #1, $0.2365 PER POUND FOR GRADE #2, AND $0.148 PER POUND FOR GRADE #5. 6/

	Tons/Acre:	3	4	5	6
Hand-pick ($/a)		-365.35	-144.84	75.67	296.19
Case A:	SKH&S ($/a)	-396.38	-128.93	138.53	405.98
	OSU ($/a)	-240.75	78.58	397.90	717.23
Case B:	SKH&S ($/a)	-472.50	-230.42	11.65	253.73
	OSU ($/a)	-332.44	- 43.67	245.09	533.86

6/ No official quality grade has yet been established for grade #5, the mechanically-harvested strawberries that fall below grade #1. Based upon the available information, a conservative estimate of the probable price of grade #5 was $0.177 per pound for 1979 and $0.148 per pound for 1978.

than hand-picking if harvesting takes place on the appropriate dates. Also, mechanical harvesting is more favorable to growers for relatively lower farm prices. From 1974 to 1978, the highest farm price was $0.276 per pound and average farm price was $0.2558 per pound.

The comparisons in unit costs and net revenues in Tables 19, 20, and 21 are based upon the assumption that there are no difficulties in procuring labor for hand-picking. In fact, growers in some areas estimated that their unpicked berries ran as high as 20 to 30 percent of the total yield in past years. A labor shortage has always existed in the Oregon strawberry industry, even before the U.S. Congress labor legislation had passed. In some years, hot weather after raining hastened ripening and created a need for a great number of hand-pickers at once. Also, not all the berries can be picked as the season progresses with resulting smaller berries and lighter yields. Since pickers are paid by weight, pickers are not willing to pick after the second or third picking due to the decreasing amount of fruit available to pick. These factors contribute to the estimated ten percent of the strawberries that rotted in the field even before the strict child labor rulings were made in 1973. Therefore, it is more reasonable to compare unit production costs and net revenues between the mechanical harvesting and hand-picking with the assumption that approximately ten percent of the fruit is always left in the field. Comparisons are also made under the assumption that unpicked strawberries run as high as 20 percent of the total yield. The results are shown in Tables 22, 23, and 24.

Implications and Limitations

Production costs and net revenues are compared for hand-picked versus mechanically-harvested strawberries for two types of harvesters and one Capper-Stemmer. Results indicate that mechanical harvesting may be profitable to growers, if harvesting takes place on the appropriate dates. Also, mechanical harvesting compared more favorable to hand-picking for the cases of high yields per acre and relatively lower farm strawberry prices. Considering the improving efficiency of mechanical harvesters and Capper-Stemmers, mechanical harvesting may be helpful in solving the problems facing the Oregon strawberry industry.

It should be noted that the net revenue figures in Tables 22, 23, and 24 are based on several assumed conditions, and growers operating under different conditions would have worse results from using the mechanical strawberry harvester. For example, it was assumed in this thesis that the mechanical harvester would be used on 57 acres per year (on 20 acres of berries owned by the grower and on 37 acres to be custom harvested). If the harvester were used on fewer acres, much higher costs per acre and lower net revenue from machine harvest would result. Another limitation is that the harvesting and efficiency estimates were based on only two years' data. Also, specific prices for some grades of mechanically-harvested strawberries have not yet been firmly established, which adds uncertainty to the economic comparisons between mechanical harvesting versus hand-picking.

TABLE 22. UNIT COST COMPARISONS WITH LABOR SHORTAGE.

	Tons/Acre:	3	4	5	6
Hand-pick ($/a)					
Unpicked berries:	10%	0.3532	0.3039	0.2742	0.2545
	20%	0.3779	0.3224	0.2891	0.2668
Case A:	SKH&S ($/a)	0.3113	0.2379	0.1939	0.1645
	OSU ($/a)	0.2892	0.2210	0.1801	0.1528
Case B:	SKH&S ($/a)	0.3428	0.2613	0.2124	0.1797
	OSU ($/a)	0.3185	0.2427	0.1973	0.1670

TABLE 23. NET REVENUE COMPARISONS WITH LABOR SHORTAGE: 1979 FARM PRICES OF $0.33 PER POUND FOR GRADE #1, $0.275 PER POUND FOR GRADE #2, AND $0.177 PER POUND FOR GRADE #5.

	Tons/Acre:	3	4	5	6
Hand-pick ($/a)					
Unpicked berries:	10%	-138.65	157.43	453.51	749.59
	20%	-237.35	25.84	289.02	552.20
Case A:	SKH&S ($/a)	-216.04	111.53	439.10	766.67
	OSU ($/a)	- 26.31	364.50	755.31	1,146.12
Case B:	SKH&S ($/a)	-310.19	- 14.01	282.17	578.35
	OSU ($/a)	-139.44	213.66	566.76	919.85

TABLE 24. NET REVENUE COMPARISONS WITH LABOR SHORTAGE: 1978 FARM PRICES OF $0.275 PER POUND FOR GRADE #1, $0.2365 PER POUND FOR GRADE #2, AND $0.148 PER POUND FOR GRADE #5.

	Tons/Acre:	3	4	5	6
Hand-pick ($/a)					
Unpicked berries:	10%	-431.51	-233.05	- 34.58	163.88
	20%	-497.66	-321.25	-144.84	31.57
Case A:	SKH&S ($/a)	-396.38	-128.93	138.53	405.98
	OSU ($/a)	-240.75	78.58	397.90	717.23
Case B:	SKH&S ($/a)	-472.50	-230.42	11.65	253.73
	OSU ($/a)	-332.44	- 43.67	245.09	533.86

TABLE 25. YIELD OF PROCESSING STRAWBERRIES IN POUNDS PER ACRE FOR EIGHT MAJOR STRAWBERRY PRODUCING COUNTIES IN OREGON, 1962 - 1978.

	County							
Year	Clackamas	Linn	Marion	Mult.	Polk	Wash.	Yamhill	Columbia
	(lbs./acre)							
1962	6,100	5,600	6,500	4,700	4,900	6,400	6,800	6,000
1963	5,000	4,400	4,830	3,500	4,000	5,200	5,400	6,200
1964	6,900	5,410	7,710	6,000	5,300	7,760	7,500	7,300
1965	4,700	4,300	5,200	3,700	3,900	5,850	5,300	4,800
1966	8,000	5,500	8,200	6,500	6,500	7,990	7,500	8,000
1967	6,800	6,300	7,080	6,500	6,000	7,200	7,000	7,500
1968	5,100	5,500	6,200	4,600	4,600	6,410	6,300	6,700
1969	5,900	5,700	5,810	5,000	5,000	5,990	6,100	7,300
1970	6,170	6,280	6,690	6,380	6,170	6,550	6,480	6,690
1971	7,500	7,290	8,750	8,120	8,750	8,400	8,330	7,810
1972	6,360	6,160	6,980	6,570	6,180	6,690	6,360	7,700
1973	5,660	5,560	6,880	5,150	6,180	6,690	6,880	7,200
1974	6,610	6,870	6,130	5,820	6,130	6,030	6,130	6,340
1975	6,670	7,190	7,700	7,800	7,700	6,670	7,700	7,520
1976	9,000	9,000	9,200	9,400	9,200	9,380	9,200	9,000
1977	6,960	6,460	6,460	6,470	6,960	6,960	6,460	5,770
1978	5,750	6,710	7,190	5,750	7,190	7,670	6,710	3,790

TABLE 26. HARVESTED ACREAGE OF PROCESSING STRAWBERRIES FOR THE EIGHT MAJOR STRAWBERRY PRODUCING COUNTIES IN OREGON, 1962 - 1978.

	County							
Year	Clackamas	Linn	Marion	Mult.	Polk	Wash.	Yamhill	Columbia
	(acres)							
1962	2,400	500	3,800	900	500	3,300	1,150	700
1963	2,300	460	3,700	800	520	3,800	1,200	500
1964	2,000	500	4,100	1,000	500	3,700	1,000	400
1965	1,500	400	3,300	600	350	3,550	800	350
1966	1,500	400	3,600	600	400	3,800	1,000	400
1967	1,500	450	3,800	675	450	3,800	1,100	410
1968	1,400	425	3,300	650	450	3,200	1,100	410
1969	1,300	475	3,350	650	450	3,200	1,000	425
1970	1,050	450	3,300	450	350	3,275	900	400
1971	850	400	3,150	400	200	3,200	750	375
1972	600	300	2,585	350	150	2,800	600	350
1973	530	250	2,190	350	120	2,600	600	350
1974	580	220	1,900	300	70	2,450	525	340
1975	475	200	1,675	200	80	2,100	350	450
1976	450	200	1,660	225	70	1,500	300	550
1977	450	180	1,700	225	70	1,550	300	550
1978	300	160	1,700	300	90	1,600	120	420

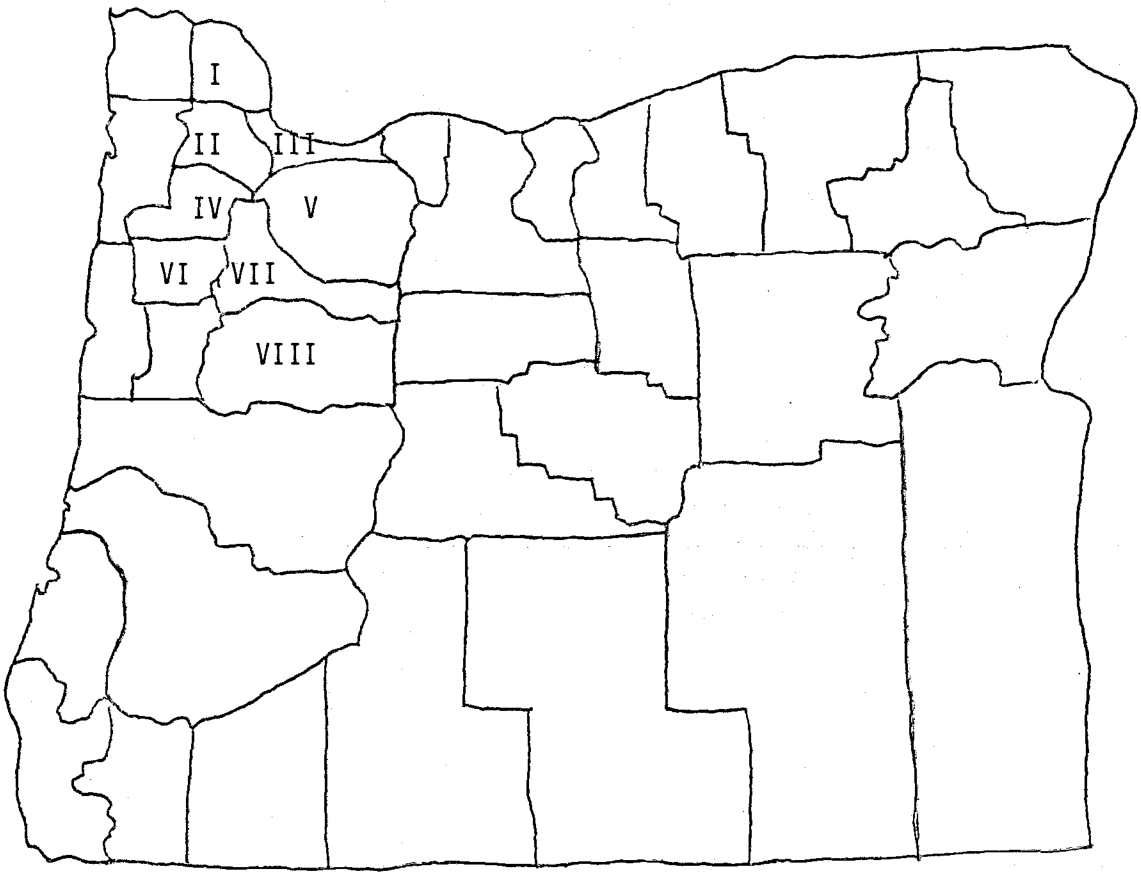
ECONOMETRIC DEMAND AND SUPPLY ANALYSES OF STRAWBERRIES FOR PROCESSING IN OREGON

Production of strawberries for processing in Oregon has been concentrated in the northern Willamette Valley. Strawberry production from eight major counties, including Columbia, Multnomah, Washington, Yamhill, Clackamas, Polk, Linn, and Marion, accounts for more than 90 percent of the total strawberry production in Oregon. The strawberries produced from the rest of counties are mainly delivered to local fresh markets.

Yield per acre and acreage for strawberry production have fluctuated from year to year in every county as shown in Tables 25 and 26. An increasing trend in yield and a decreasing trend in acreage seems to have occurred in all counties. A good understanding of the Oregon strawberry industry is necessary to develop an appropriate demand and supply analysis of strawberries for processing in Oregon. Therefore, the marketing and utilization of Oregon strawberries is discussed in the next section.

Marketing and Utilization of Oregon Strawberries

Strawberries harvested in Oregon are delivered to either the fresh market or processors. The demand for Oregon strawberries in the fresh market has been stable during the last three decades. On the average, strawberries delivered to the fresh market in Oregon from 1974 to 1978 accounted for approximately ten percent of the total harvested strawberries. The range before 1974 was between three and six percent. The reasons for increased percentages are due to the fact that the demand for strawberries in the fresh market has been stable, and the total production of strawberries has declined. For instance, growers



I	Columbia	V	Clackamas
II	Washington	VI	Polk
III	Multnomah	VII	Marion
IV	Yamhill	VIII	Linn

Figure 3. Eight major strawberry producing counties in Oregon.

delivered 96.6 million pounds of strawberries to processors and 4.2 million pounds of strawberries to the fresh market in 1964. In contrast, 30.4 million pounds of strawberries went to processors, and 3.6 million pounds went to the fresh market in 1978.

Due to the wide differences in prices between the fresh market and processors, growers prefer to move to the fresh market as much as possible and deliver the remainder to processors. However, the very short harvest season (four to six weeks), and the fragile nature and short shelf-life of Oregon strawberries force growers to deliver most of their strawberries to processors. In 1979, approximately 90 percent of the strawberries for processing in Oregon were delivered to 11 processors, including the top four processors. This indicates that processors purchase strawberries from growers under an oligopsonistic market structure. Most of growers sell their strawberries to nearby local processors at a specified price. The way in which price is set under an oligopsonistic strawberry market will be discussed in a later section.

Most of the strawberries delivered to processors are processed as frozen pack, canned product, or to provide stock for jam, juice, yogurt, and puree. In general, different qualities of strawberries are required to make each of these strawberry products. For instance, higher quality strawberries (grade #1) are required to produce the frozen pack and canned product, and juice or yogurt stock can be produced with lower quality strawberries (grade #2). However, grade #2 strawberries account for only six percent, on the average , of the total hand-picked strawberries in Oregon; therefore, Oregon processors also produce juice stock or yogurt with high quality strawberries or use strawberries from California or Washington state, depending upon the market prices of these strawberry products. Strawberries for processing are imported freely from California and Washington state. Although the amount imported is unknown, it is known to be relatively small.

Since more than 90 percent of the commercial strawberries for processing are either frozen or canned, and frozen strawberries are also used for canned strawberry products, the demand and supply functions of strawberries will be estimated on the basis of the higher quality strawberries (grade #1) which are used mainly for the frozen pack.

Relation Between Grower and Processor

Verbal contracts exist between growers and processors. Contracting is a means of reducing uncertainties regarding strawberry prices for growers and the strawberry supply for processors. However, most of the verbal contracts in the Oregon strawberry industry specify acreages for processors but do not specify strawberry prices in advance for growers, and both growers and processors do not have any legal obligations under this kind of verbal contract. The main reason for adopting this kind of ineffective verbal contract for reducing uncertainties is that the Oregon strawberry growers have no other choice except delivering to processors. This is due to a stable demand for strawberries in the fresh market (due to the short harvest season) and the short shelf-life of Oregon strawberries. The other reason is that processors want to set strawberry prices after observing not only strawberry production in Oregon but also strawberry production in California, since California strawberry production controls the nationwide strawberry supply. California strawberry growers begin to harvest strawberries for processing in mid-April and usually complete harvesting before Oregon growers begin to harvest.

One major concern in the transactions between growers and processors is the price of strawberries at the farm level. Conventionally, one powerful processor, what Stigler calls a barometric price leader, announces the prices for grade #1 and grade #2 strawberries before the harvest begins, and these announced prices are usually followed by the other processors in the industry. After prices are announced, they are fixed for the harvesting season, and growers deliver their strawberries to processors at these specified prices. By this practice, prices of strawberries are exogenously given not only for growers but also all of the processors in the industry except for the barometric price leading processor. Demand for strawberries for processing will be studied based upon prices to processors as exogenously established, and it will be further explained for the barometric price leading processor in a later section.

Econometric Supply and Demand Models

Profit maximization is assumed for growers in deriving the supply function. The supply function under profit maximization can be derived by applying Hotelling's lemma (Hotelling, 1932). This lemma is very useful in constructing an econometric model, since demand and supply functions can be derived simply by choosing a functional form for profit which meets certain conditions and differentiating it with respect to input and output prices.

Conditions on the profit function $\pi(P;C)$, where P is a vector of output prices and C is a vector of input prices

1. $\pi(P;C)$ is a real valued function defined for $p_i > 0$ and $c_j > 0$, $i=1, 2,\ldots,m$, $j=1, 2,\ldots,n$ and $\pi(P;C) \geq P'a-C'b$ for a fixed vector $(a;b) \geq (0_m;0_n)$.
2. π is nondecreasing in the components of P.

3. π is nonincreasing in the components of C.

4. π is a proper convex fucntion.

5. π is homogeneous of degree one in every output and input price.

Hotelling's Lemma

According to Diewert, if a profit function satisfies "conditions on the profit function" and is differentiable with respect to output and input prices at the point $(P^*; C^*) \geq (0;0)$, then we have

$$\frac{\partial\pi(P^*;C^*)}{\partial P_i} = Q_i\ (P^*;\ C^*) \quad \text{for } i=1,\ 2,\ldots,m$$

and

$$\frac{\partial\pi(P^*;C^*)}{\partial c_j} = -X_j(P^*;C^*) \text{ for } j=1,\ 2,\ldots,n$$

where $Q_i(P^*;C^*)$ is the profit maximizing supply of output given positive output prices P^* and input prices C^* and $X_j(P^*;C^*)$ is the profit maximizing demand for input j given prices $(P^*;C^*)$.

Supply of Strawberries for Processing

For strawberries, it takes a year for the plants to bear fruit after being set out, and the harvest can be extended to several years. However, yield declines gradually as the plants get older, and therefore, growers usually remove the plants after harvesting three consecutive seasons.

The change in the amount of acreage for strawberry production, $A_t - A_{t-1}$, is equal to newly planted acreage in year t-1, N_{t-1}, minus removed acreage in year t-1, R_{t-1}. That is, $A_t - A_{t-1} = N_{t-1} - R_{t-1}$, and

$$A_t = A_{t-1} + N_{t-1} - R_{t-1} \tag{1}$$

Equation (1) indicates that the acreage of harvested strawberries in year t is determined during year t-1.

Quite different criteria are relevant in allocating the amount of acreage for new planting (N_t), maintaining (A_t - R_t), and removal (R_t). The planting decision is based on the cost of planting, the expected stream of profits during the following years, and opportunity costs, and the maintaining decision depends on the annual costs of maintenance and harvesting and the expected profits. Since the establishment of a new stand of strawberries or re-establishing an old one is very expensive, most growers do not remove the plants before harvesting over a three-year period on an annual basis. However, a few growers remove the plants after harvesting two consecutive seasons, if the plants have disease problems. The removal decision is quite different from the planting decision or maintaining decision. Since yield declines as the plants get old, the removal decision depends on how the expected profits on an existing plant compare to the expected profits on other alternative crops. This may imply that the removal decision is mainly based upon the opportunity costs of maintaining the existing plants for strawberry production.

Suppose the grower's expected profit function is defined as follows:

$$E(\pi_t) = P_t^* Q_t - \sum_{i=1}^{5} C_{t-1,i} X_i = f(P_t^*, C_{t-1,1}, C_{t-1,2}, \ldots, C_{t-1,5}) \ldots (2)$$

where $P_t^* = \sum_{i=0}^{2} E(P_{t+i})/3$ and $E(P_t)$ is the expected price in year t

X_1 = labor for harvesting

X_2 = agricultural chemicals and fertilizers

X_3 = land

X_4 = labor for production

X_5 = capital

and C_i is the input costs for the input factor X_i.

The derived demand function for acreage can be obtained by differentiating the expected profit function (2) with respect to rent under the assumption that the expected profit function (2) satisfies the conditions of the profit function for Hotelling's lemma. That is,

$$\frac{\partial E(\pi_t)}{\partial C_{t-1,3}} = - X_{t,3}\ (P_t^*, C_{t-1,1}, \ldots, C_{t-1,5})$$

and, $$X_{t,3} = h\ (P_t^*, C_{t-1,1}, \ldots, C_{t-1,5}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The derived demand function for acreage (3) is also a supply function of acreage for strawberry production in terms of the expected price P_t^*.

Similarly, the supply function of strawberries for processing is derived by differentiating the expected profit function with respect to P_t^*. That is,

$$\frac{\partial E(\pi_t)}{\partial P_t^*} = Q_t^s\ (P_t^*, C_{t-1,1}, \ldots, C_{t-1,5})$$

and, $$Q_t^s = Q_t^s\ (P_t^*, C_{t-1,1}, \ldots, C_{t-1,5}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Neither the derived demand function for acreage (3) nor the supply function of strawberries for processing (4) includes the opportunity cost variable. Since the growers in different counties may plant different crops in rotation, it is very difficult to ascertain the grower's opportunity costs by an alternative crop price. However, red raspberry is the most suitable fruit to substitute for strawberry. Therefore, the expected red raspberry price is inserted into the supply function of strawberries for processing as follows:

$$Q_t^s = Q_t^s\ (P_t^*, B_t^*, C_{t-1,1}, \ldots, C_{t-1,5}) \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where B_t^* is the expected red raspberry price in year t.

Unfortunately, data for input factor variables are not available for the period between 1962 and 1978. However, most of the input factors used for strawberry production are also used for production of other crops, and therefore, the costs of these input factors may represent opportunity costs to growers. Since the expected red raspberry price is included in the model to absorb the grower's opportunity costs, it may not be necessary to insert all the input factor variables separately into the model. Also, growers are mainly concerned with total costs of production rather than the cost of individual input factors in the selection of the crop to be planted. Therefore, the index number of price paid by farmers for agricultural items, PI_{t-1}, (which includes interest, taxes, and wage rates) is substituted for the input factor variables in the supply function (5).

Since it was assumed that growers produce strawberries based upon their expectations of the strawberry price, growers may have risks or uncertainties associated with their price expectations. Therefore, a variable, R_t, is included in the model to represent the grower's risk or uncertainty with regard to their price expectations, and the resulting supply function can be written as follows:

$$Q_t^s = Q_t^s \; (P_t^*, B_t^*, PI_{t-1}, R_t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

<u>Difficulties in Estimating Consumers' Surplus From a Derived Demand Curve</u>

It is well known that the ordinary demand and Hick's compensated demand curve coincide if the income effect is zero for a change in the price of a commodity. A zero income effect implies that the marginal rate of substitution for money is a constant at any quantity of the commodity. Graphically, it implies that indifference curves are parallel at any amount of the commodity. With the assumption that the commodity is a normal good, the compensated demand curve lies left of the ordinary demand curve for prices lower than an initial equilibrium price. Therefore, the measured consumers' surplus from the ordinary demand curve overstates compensating variation, when price falls. Even though the income effect is not zero or close to zero, Silberberg (P353) has shown that if the commodity price changes are very small, the area below the ordinary demand curve but above the price level can be regarded as the limit of a sum of compensating variations in income for a fall in price. In summary, the area below the ordinary demand curve approximates the compensating variation, if price changes are very small or the income elasticity of a given commodity is near zero. Even so, there are other difficulties in estimating the consumers' surplus from a derived demand curve. Since a derived demand curve is derived from the profit maximization rather than the utility maximization, the area below a derived demand curve may be defined as a "middleman's surplus". It may be worthwhile to examine under what circumstances middleman's surplus approximates consumers' surplus. Four situations are discussed next.

Suppose that an input-factor is used for a production process. Then, the derived input-factor demand curve under profit maximization is the value of marginal product curve or the marginal revenue product curve depending upon whether the output is sold under perfect competition or under monopoly. First, suppose both the output and input markets are perfectly competitive. Then, the equilibrium price and quantity attained at P_C and Q_C, respectively, in Figure 4. In Figure 5, suppose the output demand curve D_O is downward sloping and parallel with the value of marginal product curve, D_C. Also, assume that the vertical supply curve shifts to right due to the adoption of technology. Then,

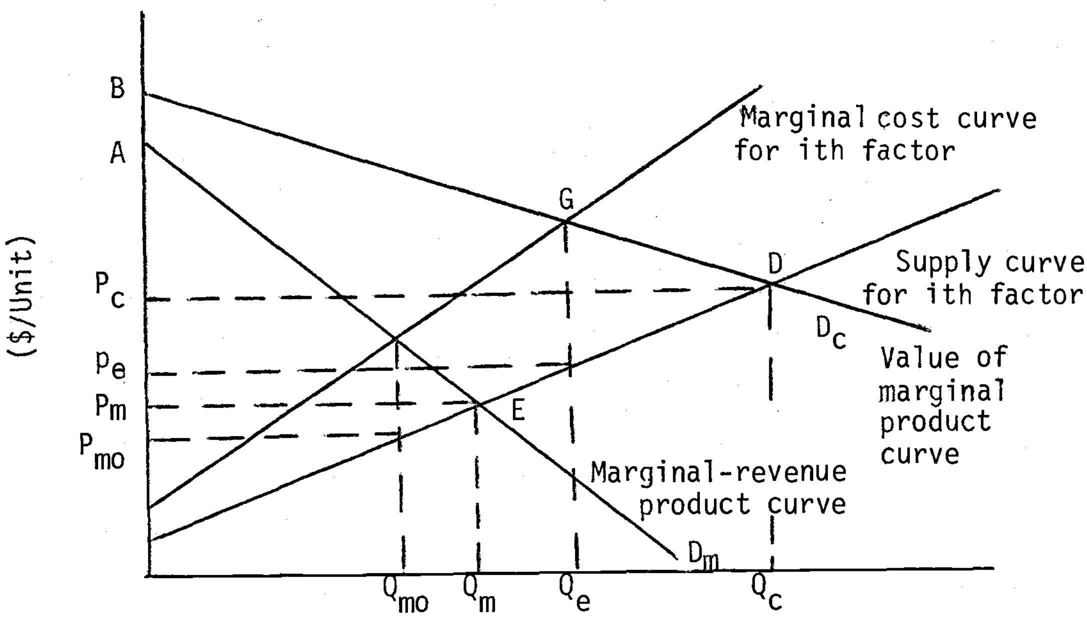


Figure 4. Factor supply and demand curves.

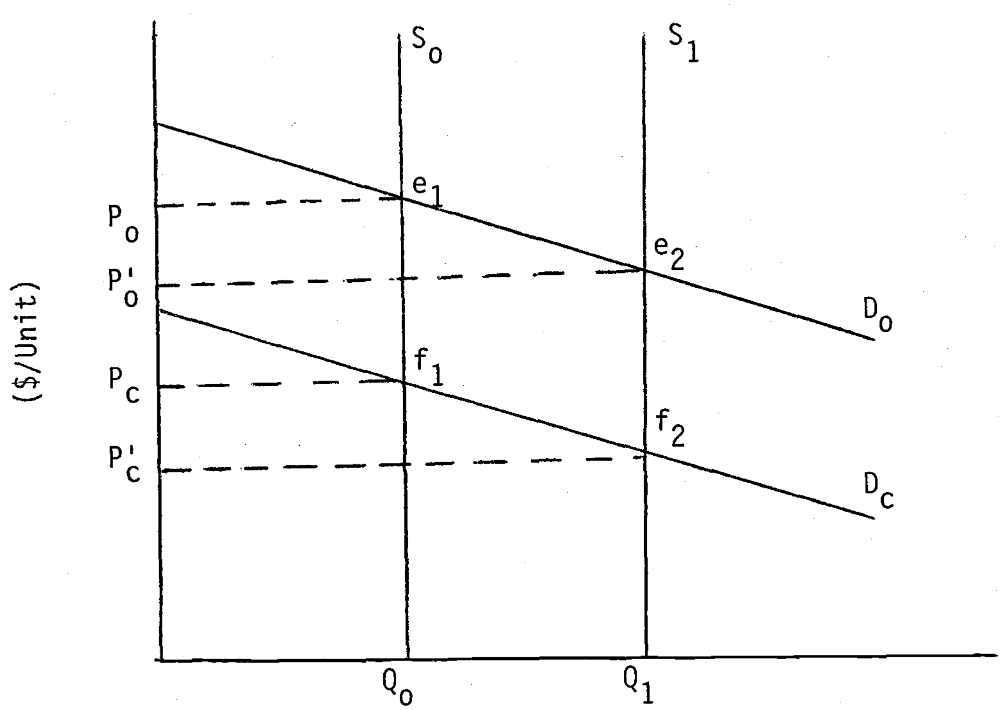


Figure 5. Factor demand and output demand and supply curve.

the consumers' surplus, $P_o e_1 e_2 P_o'$, is equal to the middleman's surplus, $P_c f_1 f_2 P_c'$. However, both the output and input-factor demand curves are parallel if the output is produced under constant cost industry. Therefore, consumers' surplus can be approximated from a derived demand curve if both output and input are sold under perfect competition, and output is produced under constant cost industry. Consumers' surplus approximated from a derived demand curve would overstate or understate the actual consumers' surplus, depending upon whether output is produced under an increasing cost industry or a decreasing cost industry, respectively.

Secondly, suppose that the output market is monopolistic, while the input market is perfectly competitive. Equilibrium price and quantity are attained at E, where the marginal revenue product curve intercepts the input-factor supply curve. If output is produced under constant cost industry, the output demand curve would be parallel with the marginal revenue product curve. Therefore, consumers' surplus can be approximated from a derived demand curve. If output is produced under a decreasing cost industry, the approximated consumers' surplus from a derived demand curve would understate the actual consumers' surplus, while it overstates the actual consumers' surplus if output is produced under an increasing cost industry.

Thirdly, suppose there is a monopoly in the output market and a monopsony in the input-factor market. Equilibrium price and quantity are attained at P_{mo} and Q_{mo}, respectively, in Figure 4. Since the monopsonist purchases input factor up to Q_{mo}, the area under the derived demand curve, D_m, but above P_m, is neither consumers' surplus nor middleman's surplus.

Finally, suppose there is a monopsony in the input-factor market and output is sold under perfect competition. Then, equilibrium is attained at G in Figure 4. Since a monopsonist purchases Q_e at a price of P_e, the area under the derived demand curve, D_c, but above P_c, BDP_c, is neither consumers' surplus nor middleman's surplus. As a result, it is concluded that consumers' surplus cannot be approximated from a derived demand curve when intput is sold under imperfect competition.

Since the processors purchase strawberries under an oligopsonistic market structure, consumers' surplus cannot be approximated from a derived factor demand curve. Therefore, the household production function which is derived from the two stage utility maximization is introduced to derive a demand curve.

Processor's Demand for Strawberries

To derive a household production function from two-stage utility maximization, certain restrictions on the utility function are necessary. One restriction on the utility function that has been widely used is the concept of separability. The main advantage of assuming separability is that the consumption decision can be viewed as occuring in two stages with a consequent reduction of the number of parameters to be estimated in regression analysis. In the first stage, the consumer allocates the budget between subsets of commodities. The second stage involves within subset allocation decisions.

Weak Separability Behavioral Assumption

A utility function U(R) is weakly separable with respect to a partition $(N_1, N_2, \ldots, N_s)$ if U(R) is of the form:

$$U(R) = U(f_1(R_{11},\ldots,R_{1N_1}),\ \ldots,\ f_s(R_{s1},\ldots,R_{sN_s})\ ) =$$

$$F(U^1(R_1),\ \ldots,\ U^s(R_s)\ )$$

where F is a function of s-variables and U^s is a function of the mutually exclusive subset $(R_{s1}, R_{s2}, \ldots, R_{sN_s})$ and if the marginal rate of substitution between two commodities i and j from the same subset M is independent of the quantities of commodities outside of M. That is,

$$\frac{\partial \dfrac{U_i}{U_j}}{\partial R_k} = 0 \quad \text{for all } i,\ j \in M, \text{ and } k \notin M$$

If the weak separability conditions are satisfied, consistent estimates, which are defined as the situation that direct and two-stage constrained maximizations of a separable utility function yield the same equilibrium solutions, can be obtained under certain conditions. According to De Janvry, two-stage maximization of a utility function under a budget constraint will be consistent in case the weak separability conditions are satisfied and each function f_i is homogeneous in the quantities of group i.

Two-Stage Anticipated Utility Maximization

It is assumed that the anticipated utility an individual processor receives from profits is weakly separable. Since there are no other alternative crops for processors to process besides strawberries during the strawberry harvesting season in Oregon, the assumption of a weakly separable utility function may be plausible. The form of the individual processor's anticipated utility function is postulated to be:

$$U^e = U\left[\pi_1^e(R_{11}, R_{12}, \ldots, R_{1N_1}),\ \ldots,\ \pi_s^e(R_{s1}, R_{s2}, \ldots, R_{sN_s})\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where U is a function of the s-variables π_i^e, for each i, and π_i^e is a function of the subset $(R_{i1}, \ldots, R_{iN_i})$. The function π_i^e in equation (7) is assumed to be homogeneous of degree one to insure consistency. It is also assumed that π_i^e is an individual processor's anticipated profits from producing strawberry products such as frozen packs, canned product, and juice stock.

In the first stage, the budget share, Y_1, is determined from

$$\max L = U\ (Y_1, Y_2, \ldots, Y_s) - \lambda(\sum_{i=1}^{s} Y_i - Y) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

where Y is the total budget, and Y_i is the budget share for subset i. By solving the Lagrangian Equation (8), one can obtain the budget share Y_1 such that:

$$Y_1 = Y_1\ (P_1, P_2, \ldots, P_s, Y) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

where P_j is the jth group price index.

In the second stage, an individual processor's utility from profit, π_1^e, is maximized subject to the budget share, Y_1. The Lagrangian can be formed as,

$$\max L^* = U(\pi_1^e\ (R_{11}, R_{12}, \ldots, R_{1N_1})) - \lambda^*(Y_1) \ldots\ldots(10)$$

which yields the household production function. This can be expressed as,

$$R_{1i} = f_i(Q_1, Q_2, \ldots, Q_n, S_{1i}; Y_{1i}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11)$$

where R_{1i} is the amount of ith strawberry product, Q_i is the ith input-factor, S_{1i} is the processing cost for the ith strawberry product, and Y_{1i} is the budget share which is allocated to produce R_{1i}.

The final stage of the process is the determination of the derived demand for strawberries from an individual processor's household production function (11). That is, maximize R_{1i} subject to Y_{1i}. This can be formed as

$$\max L^{**} = R_{1i}\ (Q_1,\ Q_2,\ \ldots,\ Q_n,\ S_{1i}) - \lambda^{**}(Y_{1i}) \ldots\ldots\ldots (12)$$

which yields the derived demand for jth input-factor

$$Q_j = g(P_1,\ P_2,,\ \ldots,\ P_n,\ s_{1i},\ EP,\ Y_{1i}) \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

where P_i is the ith input-factor price, Ep is the expected price of ith strawberry product, and s_{1i} is the unit processing costs for the ith strawberry product.

As described earlier, the processors produce frozen berries, jam, yogurt, juice stock, and puree. However, more than 90 percent of the processed strawberries in Oregon are either frozen or canned. Processors freeze berries in the form of whole or sliced berries, depending upon their utilization. The sliced frozen berries are usually used for ice-cream; therefore, flavor is the most important factor. The frozen whole berries are used for pie or topping, and good shape and bright color are emphasized. However, there are no significant differences in price.

Since frozen berries are also used for canned products, the econometric demand model will be based upon higher quality strawberries for frozen strawberry products. Therefore, the demand Equation (13) can be written as

$$Q = h(P,\ EP,\ s,\ Y_1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

where p is the farm price of strawberries for processing, Q, EP is the expected price of frozen strawberry product, and s is the processing costs, and Y_1 is the budget share for frozen strawberry production.

The demand function (14) is derived under the assumption that the strawberry price is exogenously given to the processors in industry, with the exception of a price leading processor. However, the strawberry price is determined by a barometric price leading processor. It is necessary for an econometric study to understand the nature of price determination.

According to Cohen and Cyert, barometric price leadership does not mean that a barometric price leader can set prices to get the maximum profit and force other processors to follow. Under monopsony, the input-factor is utilized up to the point where the marginal factor cost equals the value of the marginal product (since strawberry products are sold under perfect competition). Therefore, a barometric price leading processor sets a price at P_c or P_m, or somewhere between P_c and P_m, where P_c is the strawbery price under competition and P_m is the strawberry price under monopsony.

In case of an input variable, the equation (10) can be written as,

$$\max L^* = \sum_{i=1}^{m} EP_i \; R_i(Q_i) - \sum_{i=1}^{m} P \; Q_i - \sum_{i=1}^{m} s_i(Q_i) - \lambda\left(\sum_{i=1}^{m} P \; Q_i + \sum_{i=1}^{m} s_i \; (Q_i) - Y_1\right) \qquad (15)$$

where $R_i(Q_i)$ is the ith strawberry product, EP_i is the expected price of $R_i(Q_i)$, $s_i(Q_i)$ is the processing costs for ith product, λ is the Lagrangian multiplier, and Y_1 is the available budget share.

For a barometric price leading processor, the first-order condition for anticipated utility maximization with respect to Q_i is expressed as follows:

$$\frac{\partial L^*}{\partial Q_i} = \sum_{i=1}^{m} EP_i \; R_i'(Q_i) - \left[P(1 + F_i) + \sum_{i=1}^{m} s_i'(Q_i)\right] - \lambda \left[P(1 + F_i) + \sum_{i=1}^{m} s_i' \; (Q_i)\right] = 0 \qquad (16)$$

$$\text{and, } P = \frac{\sum_{i=1}^{m} EP_i \, R_i'(Q_i) - \sum_{i=1}^{m} s_i'(Q_i)(1 + \lambda)}{(1 + \lambda)(1 + F_i)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(17)$$

where F_i is the price flexibility of supply function. Since the price flexibility of supply function is nonnegative, equation (17) shows that a barometric price leading processor discounts the strawberry price under perfect competition by $1/(1 + F_i)$ and, therefore, it implies that the strawberry price is determined simultaneously through the supply-demand relation, even though it is exogenously given to the rest of the processors in the Oregon strawberry processing industry.

In the demand equation (14), the unit processing cost, s, is included as an explanatory variable. However, as shown in equation (17), a barometric price leading processor takes the marginal processing cost into account when he makes a price determination. Therefore, the unit processing cost variable, s, is omitted from the econometric supply function.

Since the amount of strawberries demanded by processors depends upon their price expectation for strawberry products, processors may also have risks or uncertainties on their price expectation. Therefore, a risk or uncertainty variable, H, is included in the demand model to account for processors' risk or uncertainty in their price expectation.

Other variable included in the model is the amount of cold-storage holdings on May 31 in the Pacific region. The result can be written as follows:

$$Q_t^d = Q_t^d \, (EP_t, P_t, H_t, CS_t, Y_1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots(18)$$

where CS is the cold-storage by May 31 in the Pacific region.

Measurement of Unobservable Variables

In supply function (6) and demand function (18), there are unobservable variables, such as expected strawberry and red raspberry prices and risk or uncertainty for growers. It is not known how growers predict the prices of strawberries and red raspberries, or how processors predict the price of strawberry products. Therefore, it is assumed that growers and processors behave with regard to the expected prices as follows:

1. Growers' expectation of strawberry price

It is assumed that growers adjust their expectation of strawberry price by the following simple reaction model.

$$P_t^* - P_{t-1} = \lambda(P_t - P_{t-1}) \qquad 0 < \lambda \leq 1 \text{ ....} (19)$$

and,
$$P_t^* = \lambda P_t + (1 - \lambda)\, P_{t-1} \qquad 0 < \lambda \leq 1 \text{ ....} (20)$$

The reaction model (19) has a quite different implication from Nerlove's adjustment model in econometric study. For Nerlove's adjustment model:

$$P_t - P_{t-1} = \alpha(P_t^* - P_{t-1}) \qquad 0 < \alpha \leq 1 \text{ ....} (21)$$

which implies
$$P_t^* = \frac{1}{\alpha} P_t - (\frac{1}{\alpha} - P)P_{t-1} \qquad 0 < \alpha \leq 1 \text{ ....} (22)$$

Equation (22) implies that the estimate of the parameter with regard to P_{t-1} should have a negative sign in an econometric model, while a positive sign is implied by equation (20).

2. Growers' expectation of the red raspberry price and processors' expectation of product price

If Nerlove's adaptive expectation model or adjustment model is employed, the disturbance term would be complicated. To simplify this matter, a simple deterministic time-series model is employed to measure the expected red raspberry and strawberry product prices. The model introduced in this section is deterministic in that no reference is made to the nature of the underlying randomness in the series. The simple extrapolation model which is adopted in this study is as follows:

The exponential growth model. If it is anticipated that P_t will grow with constant percentage increase rather than constant absolute increases, the simple trend model is the exponential growth curve such that,

$$P_t = f(t) = A\, e^{rt} \quad \text{.................................} (23)$$

$$\text{or} \quad \ln P_t = c_1 + c_2\, t \quad \text{where } c_1 = \ln A$$

$$c_2 = r$$

t = time. "t" is chosen to equal 0 in the base year and to increase by 1 during each successive year.

3. Risk or uncertainty variables, R_t and H_t

As described earlier, it was assumed that growers and processors attempt to maximize their expected profits, and therefore, risks or uncertainties may exist with regard to their expectations of prices. Profit maximization in classical economic theory assumes that the producer is risk neutral. However, the producer's risk-taking or risk-averting behavior actually influences him in his decision process, and therefore, it is desirable to reflect the producer's risk attitude in the model.

Expected utility maximization has been widely employed to determine producer's attitude on risk (Baron, Dhrymes, Hymans, Leland, Sandmo). However, methods explaining the effect of risk attitude for aggregated data has not been well defined. the variance or standard deviation has been widely employed in aggregated supply-demand analyses to explain risk attitude in group. Therefore, the variance of prices for the preceding three years is introduced to reflect risk attitude.

Data

Time-series data for the dependent and explanatory variables in the model cover the period between 1962 and 1978, as shown in Appendix B.

Strawberry Prices and the Expected Prices of Red Raspberries

The strawberry prices are deflated by the index of fruit price. The expected red raspberry prices are estimated by the simple exponential growth model (equation 23), then deflated by the index of fruit price.

Processor's Expected Prices for Frozen Strawberry Product

Since the data for actual cost of individual input-factors or total costs for strawberry production is not available, the index number of prices paid by farmers for agricultural items, interest, taxes, and wage rates is used in place of individual input-factor prices, as discussed earlier.

Cold-storage Holdings

Processors purchase strawberries through June and early July for processing, depending upon weather conditions in each year. Therefore, the cold-storage holdings by May 31 of each year in Pacific region are used.

Budget Share

Unfortunately, information on processors' budget share for frozen strawberry product is not available. However, the processors' budget share may represent opportunity costs for producing strawberry products. Since there are no alternative fruits or crops for processors to process during the strawberry harvesting season in Oregon, it is hoped that the impacts on estimation of omitting the budget-share variable from the demand model would be minimal.

By inserting equation (2) into equation (6), supply and demand functions to be estimated are as follows:

$$Q_t^s = Q_t^s\ (P_t,\ P_{t-1},\ B_t^*,\ PI_{t-1},\ R_t) \ldots\ldots\ldots\ldots\ldots\ldots (24)$$

$$Q_t^d = Q_t^d\ (EP_t,\ P_t,\ H_t,\ CS_t) \ldots\ldots\ldots\ldots\ldots\ldots (25)$$

Analysis of the Strawberry Market

As described earlier, a barometric price leading processor determines strawberry prices at the farm level and the processors' demand for strawberries is based upon the expected prices of their strawberry products. The processors' expectations of strawberry product prices have very significant roles in the strawberry market analysis.

Processors' demand curve for strawberries, D_F, is derived by subtracting the processing cost curve, s(Q), from the expected demand curve for strawberry product, D_p^e, in Figure 6. Then, an equilibrium price is determined at a point where the demand function, D_F, and supply function, S_F, cross each other. In year t, strawberries equivalent to OQ_1 are exchanged at price P_1 in the strawberry market.

Suppose the realized demand for strawberry product, D_p', is greater than the expected demand for strawberry product, D_p^e, in year t as shown in

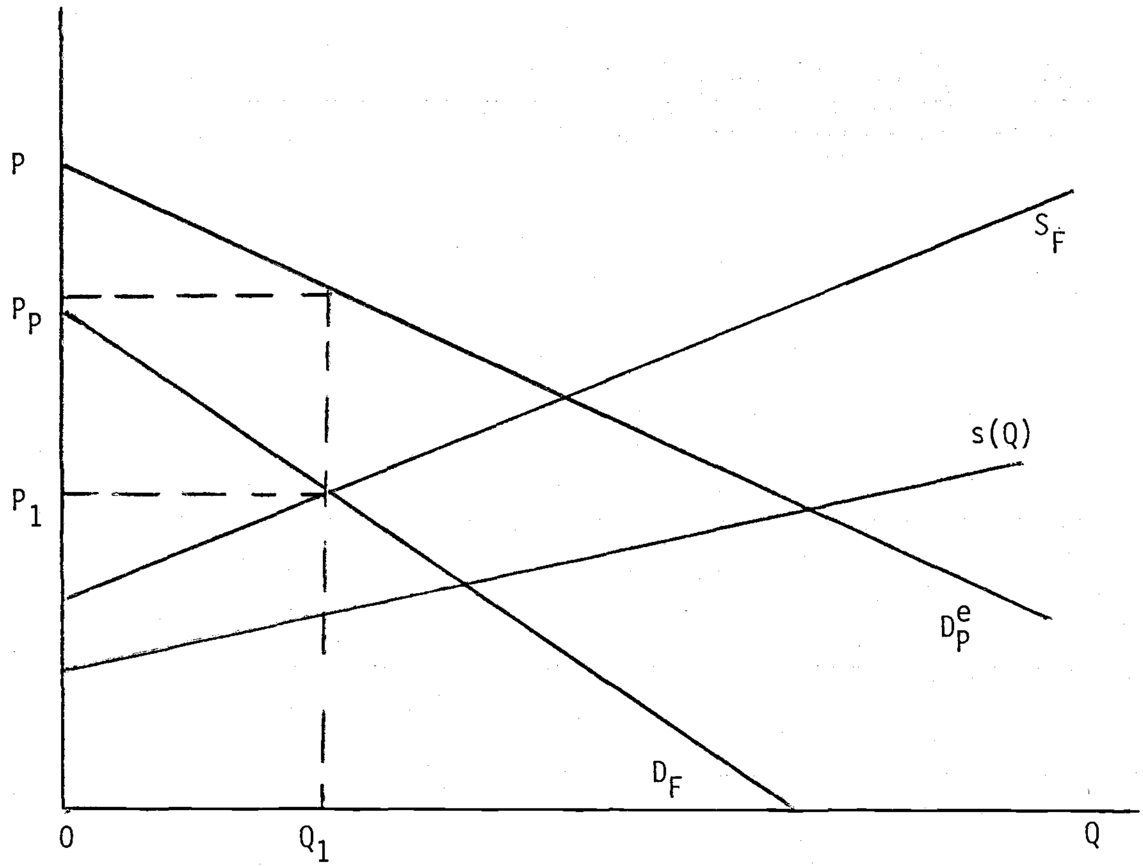


Figure 6. Strawberry market equilibrium.

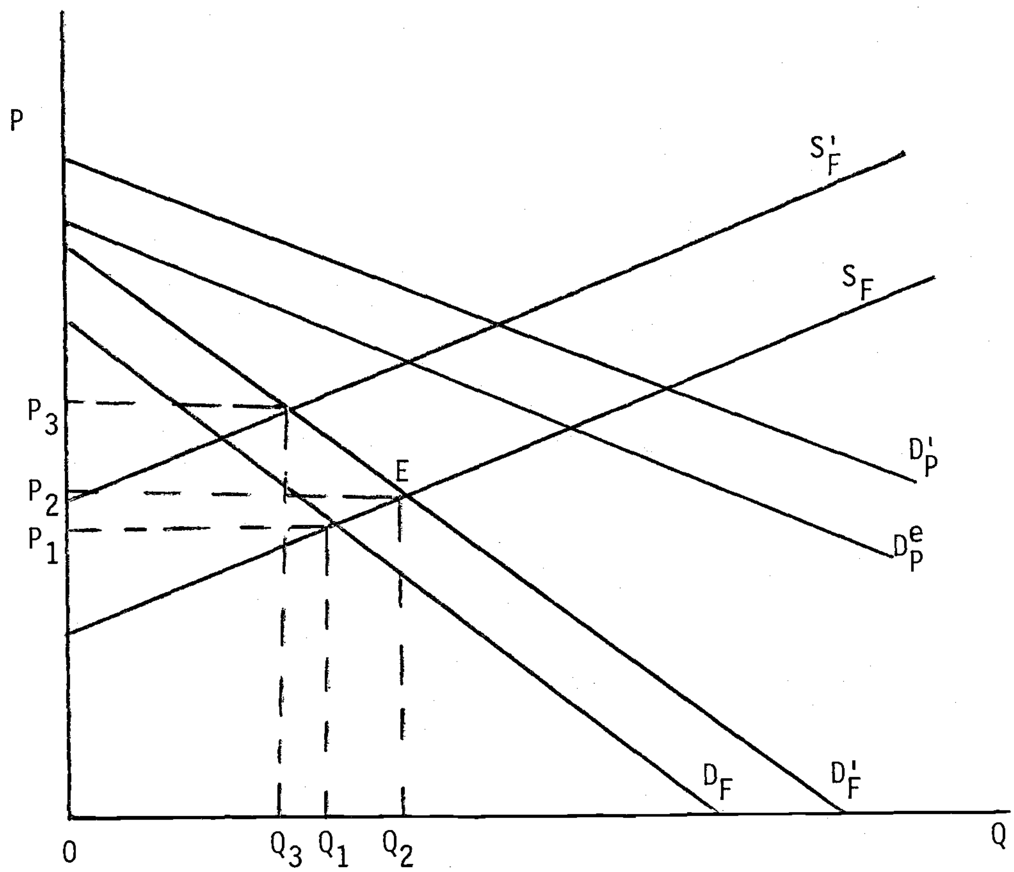


Figure 7. Changes in market equilibrium.

Figure 7. Since the demand for strawberry products is stronger than expected, demand for strawberries for processing, D_F, will shift to right to D_F'. Consequently, growers will realize the strong demand for strawberries for processing and will increase acreage for strawberry production. Therefore, a new equilibrium will be attained at E in Figure 7.

The above market analysis is based upon the assumption that there are no constraints, such as the difficulties in procuring hand-pickers. However, the acreage for strawberry production has been declining due to the shortage of hand-pickers. This labor constraint induces the supply curve, S_F, to shift to left, S_F', in Figure 7. By introducing the labor constraint, a higher equilibrium price, P_3, and a smaller quantity, Q_3, will result in Figure 7.

Econometric Supply and Demand Analyses of Strawberries for Processing

It was explained theoretically in the previous section that strawberry prices are determined simultaneously by the supply and demand relations. Since data only for the period between 1962 and 1978 are available, the statistical estimation of parameters in simultaneous equations with aggregated time-series data will generate biased and also inconsistent estimators due to the small number of observations. To increase the sample size, it is common to use a pooling procedure which combines time-series and cross-sectional data. The pooling procedure is not appropriate if the cross-section parameters shift over time. However, pooling is an acceptable procedure when all parameters across counties (excluding the intercept) are the same, and the intercept is allowed to vary across counties.

Since the disturbance term is assumed to result in part from the effects of omitted variables, such as weather, management, and government policy, these omitted variables may lead to changing cross-sectional intercepts. Therefore, a covariance model, which includes binary dummy variables to permit a model with changing cross-sectional intercepts, is used in this study. The binary dummy variables associated with the counties are as follows:

C_1 = Clackamas	C_5 = Polk
C_2 = Linn	C_6 = Washington
C_3 = Marion	C_7 = Yamhill
C_4 = Multnomah	C_8 = Columbia

When dealing with pooled time-series and cross-sectional data, it is reasonable to assume that the disturbances are autoregressive and heteroskedastic. Also, if no endogenous variables are included among the explanatory variables, the disturbances can be assumed to have contemporaneous covariances. Contemporaneous covariances concern disturbances of the sets of equations corresponding to the same year. These assumptions about the disturbance term can be written as:

$$Y_{it} = \beta_o + \beta_1 X_{it,1} + \beta_2 X_{it,2} + \cdots + \beta_k X_{it,k} + u_{it} \qquad \text{.................(26)}$$

and the set of combined m-equations are

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_m \end{bmatrix} = \begin{bmatrix} X_1 & 0 & 0 & \cdots & 0 \\ 0 & X_2 & 0 & \cdots & 0 \\ \vdots & & \ddots & & \vdots \\ 0 & 0 & 0 & \cdots & X_m \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_m \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_m \end{bmatrix} \qquad \text{........(27)}$$

where Y_i is a (T x 1) subvector, X_i is a (T x k) submatrix, B_i is a (k x 1) vector, and u_i is a (T x 1) vector.

$u_{it} = \rho_i u_{i,t-1} + \varepsilon_{it}$ Autoregression

$E(u_{it}^2) = \sigma_i^2$ Heteroskedasticity

$E(U_{it}, U_{jt}) = \sigma_{ij} \quad i \neq j$ Contemporaneous covariance

where i = 1, 2, ..., m (the number of counties)

t = 1, 2, ..., T (the number of time-series observations)

Serial correlation occurs in time-series data when the disturbance terms associated with observations in a given time period carry over into future time periods. For a single equation, the presence of serial correlation will not affect the unbiasedness or consistency of the ordinary least-squares regression (OLS) estimators, but it does affect their efficiency. For the system of simultaneous equations, two-stage least-squares (2SLS) estimators are still biased although consistent, but not efficient when the disturbances are serially correlated.

With the assumption of first-order serial correlation, the serial correlation coefficient, ρ, measures the correlation coefficient between disturbances in time period t and disturbances in time period t-1.

Efficient parameter estimates can be obtained by estimating each ρ_i and then by using the estimated $\hat{\rho}_i$ as a basis for the generalized least-squares regression. Since the parameter estimates by two-stage least-squares (2SLS) are consistent, each ρ_i can be estimated consistently from the two-stage least-squares residuals $\hat{u}_{ij}$ as

$$\hat{\rho}_i = \frac{\sum_{t=2}^{T} \hat{u}_{it}\hat{u}_{i\ t-1}}{\sum_{i=2}^{T} \hat{u}_{i\ t-1}^2} \quad \text{for } i = 1, 2, \ldots, m \ldots\ldots\ldots\ldots\ldots\ldots (28)$$

By transforming the original variables, the generalized difference form of the original model (26) can be written as

$$Y^*_{it} = \beta^*_o + \beta_1 X^*_{it,1} + \beta_2 S^*_{it,2} + \ldots + \beta_k X^*_{it,k} + u^*_{it} \quad \ldots\ldots\ldots(29)$$

where $Y^*_{it} = Y_{it} - \hat{\rho}_i Y_{i,t-1}$

$$X^*_{it} = X_{it} - \hat{\rho}_i X_{i,t-1}$$

$$u^*_{it} = u_{it} - \hat{\rho}_i u_{i,t-1}$$

$$\beta^*_o = \beta_o(1 - \hat{\rho}_i)$$

The generalized difference form (29) is estimated from the pooled model. Since one observation from each county is dropped in the estimation process of ρ_i by equation (28), m(T - 1) observations are used in the estimation.

A very serious disadvantage with the generalized difference process is in the loss of information. Pindyck and Rubinfield state that "A better solution would take the first time period observations into account as follows:

$$Y^*_1 = \sqrt{1 - \rho^2}Y_1 , \quad X^*_{21} = \sqrt{1 - \rho^2}\, X_{21}, \ldots, X^*_{k1} = \sqrt{1 - \rho^2}\, X_{k1}$$

This transormation works because it adjusts the variance of Y and X's for the first time period, so that the corresponding error variance is equal to the error variance associated with all other time periods. By construction, $u^*_1 = \sqrt{1 - \rho^2}\, u_1$ and $Var(u^*_1) = (1 - \rho^2)var(u_1) = \sigma^2_u$." However, the generalized difference process (29) was used in this study.

Since it is assumed that heteroskedasticity is present in the model of equation (26), the residuals of the generalized difference model of equation (29) can be used to estimate the error variance of each county and then used to apply weighted least-squares in the estimation process. The weighted least-squares regression model has the following form:

$$Y^{**}_{it} = \beta^{**}_o + \beta_1 X^{**}_{it,1} + \beta_2 X^{**}_{it,2} + \ldots + \beta_k X^{**}_{it,k} + u^{**}_{it} \quad \ldots\ldots\ldots(30)$$

where $S_{u_i^*} \sqrt{\frac{1}{T - k - 1} \sum_{t=2}^{T} u_{it}^{*2}}$

$$Y_{it}^{**} = Y_{it}^{*}/S_{u_i^*}$$

$$X_{it,j}^{**} = X_{it,j}^{*}/S_{u_i^*} \quad (j = 1, 2, \ldots, k)$$

$$u_{it}^{**} = u_{it}^{*}/S_{u_i^*}$$

$$\beta_0^{**} = \beta_0^{*}/S_{u_i^*}$$

for $i = 1, 2, \ldots, m$

$t = 2, 3, \ldots, T$

The presence of contemporaneous covariance from pooling time-series and county data can be considered as the problem of Zellner's (1962) seemingly unrelated regression equations.

The sets of equations (30) can be written as follows:

$$\begin{bmatrix} Y_1^{**} \\ Y_2^{**} \\ \vdots \\ Y_m^{**} \end{bmatrix} = \begin{bmatrix} X_1^{**} & 0 & 0 & \cdots & 0 \\ 0 & X_2^{**} & 0 & \cdots & 0 \\ \vdots & & \ddots & & \vdots \\ 0 & 0 & 0 & \cdots & X_m^{**} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_m \end{bmatrix} + \begin{bmatrix} u_1^{**} \\ u_2^{**} \\ \vdots \\ u_m^{**} \end{bmatrix} \quad \ldots\ldots\ldots(31)$$

$$\text{or} \quad Y^{**} = X^{**} B + u^{**} \quad \ldots\ldots\ldots\ldots\ldots\ldots(32)$$

where Y^{**} = $(T - 1) \times 1$ subvector of the dependent variable in the ith county over $(t - 1)$ time period.

X^{**} = $(T - 1) \times k$ submatrix of the explanatory variables related with the equations of ith county.

B_i = (k x 1) subvector of parameters related with the equations of ith county.

u^{**} = (m x 1) subvector of serially independent and homoskedastic error term

Suppose $E(u_i^{**} u_j^{**'}) = \sigma_{ij} I$, where I is a (T - 1) x (T - 1) identity matrix. Then, the Zellner estimator for the regression equation (31) can be written as the Aiken's generalized least-squares estimator. That is,

$$\hat{B} = \left[X^{**'} (\Sigma^{-1} \otimes I) X^{**}\right]^{-1} \left[X^{**'} (\Sigma^{-1} \otimes I) Y^{**}\right] \qquad (32)$$

and $Var(\tilde{B}) = \left[X^{**'} (\Sigma^{-1} \otimes I) X^{**}\right]^{-1}$, where $\Sigma = \left[\sigma_{ij}\right]$

Kmenta and Johnston have shown that the gain in efficiency yielded by the Zellner estimator over the ordinary least-squares estimator increases directly with the correlation between the disturbances from the different equations in a given year and inversely with the correlation between the different sets of explanatory variables. However, the ordinary least-squares estimator and Zellner's estimator are equivalent when each of the seemingly unrelated regression equations involves exactly the same explanatory variables.

The Estimation Results

Using a double logarithmic functional form, two stage least-squares estimators were obtained for the supply and demand equations, (24) and (25), respectively. The results are as follows:

$$\log Q_t^s = \underset{(.8934)}{5.4596} + \underset{(.4765)}{.2307} \log P_t + \underset{(.2966)}{.4447} \log P_{t-1} - \underset{(.1505)}{1.1732} \log PI_{t-1}$$

$$- \underset{(.4015)}{.1562} \log B_t^* - \underset{(.0397)}{.0862} \log R_t + \underset{(.1066)}{.7348} C_1 - \underset{(.1066)}{.3636} C_2 + \underset{(.1066)}{1.8787} C_3$$

$$- \underset{(.1066)}{.0744} C_4 - \underset{(.1066)}{.7846} C_5 + \underset{(.1066)}{1.9026} C_6 + \underset{(.1066)}{.4349} C_7 \quad \ldots\ldots\ldots\ldots\ldots (33)$$

$$R^2 = .92$$

$$F = 115.39$$

$$\log Q_t^d = \underset{(.9836)}{.8715} - \underset{(.1926)}{.4533} \log P_t + \underset{(.3729)}{.9988} \log EP_t - \underset{(.0459)}{.1630} \log CS_t - \underset{(.0214)}{.0842} \log H_t$$

$$- \underset{(.1178)}{.7348} C_1 - \underset{(.1178)}{.3636} C_2 + \underset{(.1178)}{1.8787} C_3 - \underset{(.1178)}{.0744} C_4 - \underset{(.1178)}{.7846} C_5$$

$$+ \underset{(.1178)}{1.9026} C_6 + \underset{(.1178)}{.4349} C_7 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (34)$$

$$R^2 = .90$$

$$F = 100.87$$

Numbers in parentheses below coefficients are standard errors. The signs on all explanatory variables in supply equation (33) are consistent with prior expectations. The price variables P_t and B_t^* were not significant. Since two-stage parameter estimates from pooled data are biased and consistent, but inefficient, it may be dangerous to interpret the results in equations (33) and (34).

The expected red raspberry price, B_t^*, was included to represent the opporunity costs to growers. However, it is not easy to identify a single crop which adequately represents the growers' opportunity costs. This may be the reason why B_t^* was asymptotically insignificant. One binary dummy variable, C_4, was also asymptotically insignificant. The use of binary dummy variables does not directly identify the variables which might cause the regression line to shift over counties. Also, the use of binary dummy variables is an attempt to adjust for important missing variables in the model. However, it is very difficult to interpret the coefficients of binary dummy variables, since a large portion of disturbance variation may be explained without knowledge about the model. However, it is incorrect to drop those binary dummy variables whose coefficients are insignificant, because this would bias the statistical tests when the new regression is run (Pindyck and Rubinfeld).

From the demand Equation (34) the signs on all the explanatory variables are consistent with prior expectations, and the coefficients of all explanatory variables are asymtotically significant with the exception of the binary dummary variable, C_4.

Since two stage least-squares estimators are biased but consistent, the supply and demand equations, Equations (33) and (34), are used to compute the autocorrelation coefficients. The results are shown in Table 27.

For both supply and demand equations, large values of the estimated serial correlation coefficients in Clackamas, Polk, Yamhill, and Columbia counties implies the existence of first-order serial correlation.

To obtain asymtotically consistent and efficient parameter estimates, the data were transformed and the equations fitted in the generalized difference form (29). The generalized difference form (29) has an error process which is independently distributed with zero mean and variance, σ_i^2. The results of parameter estimation for the generalized difference form (29) were as follows:

TABLE 27. THE ESTIMATED FIRST-ORDER AUTOCORRELATION COEFFICIENTS FOR EACH COUNTY.

County	Supply ($\hat{\rho}$)	Demand ($\hat{\rho}$)
Clackamas	.4934	.5174
Linn	.2454	-.0730
Marion	-.1322	-.2045
Multnomah	-.3999	-.2481
Polk	.6152	.6076
Washington	.0679	.1039
Yamhill	.6251	.5239
Columbia	.6968	.5981

TABLE 28. THE ESTIMATED VARIANCE AND STANDARD DEVIATION OF DISTURBANCE FOR EACH COUNTY AFTER CORRECTING FOR SERIAL CORRELATION.

	Supply		Demand	
County	$S^2_{u^*_{it}}$	$S_{u^{**}_{it}}$	$S^2_{u^*_{it}}$	$S_{u^{**}_{it}}$
Clackamas	.4099	.6402	.4291	.6551
Linn	.3790	.6156	.2312	.4808
Marion	.1678	.4096	.1987	.4457
Multnomah	.3221	.5675	.3086	.5555
Polk	.4866	.6976	.4197	.6478
Washington	.1024	.3201	.1855	.4306
Yamhill	.3950	.6285	.4472	.6687
Columbia	.4503	.6710	.3639	.6033

$$
\begin{aligned}
Q_t^s = & \ 4.0559 + .1848 \log P_t + .5775 \log P_{t-1} - 1.1079 \log PI_{t-1} \\
& \ (.7999) \quad (.3974) \qquad\quad (.2145) \qquad\qquad (.1407) \\
& - .0082 \log B_t^* - .1196 \log R_t + .6429\, C_1 - .3418\, C_2 + 1.9046\, C_3 \\
& \ (.3413) \qquad\quad (.0298) \qquad\quad (.2471) \quad (.2220) \quad (.2220) \\
& - .0602\, C_4 - .8304\, C_5 + 1.9399\, C_6 + .2923\, C_7 \quad \ldots\ldots\ldots\ldots (35) \\
& \ (.2220) \quad (.2698) \quad (.2220) \quad (.2726)
\end{aligned}
$$

$$R^2 = .977$$

$$F = 370.23$$

$$
\begin{aligned}
Q_t^d = & \ .9764 - .1695 \log P_t + .7733 \log EP_t - .1439 \log CS_t - .0786 \log H_t \\
& \ (.7924) \ (.1697) \qquad\quad (.2952) \qquad\quad (.0396) \qquad\quad (.0204) \\
& + .6329\, C_1 - .2943\, C_2 + 1.9134\, C_3 - .0514\, C_4 - .8359\, C_5 + 1.9206\, C_6 \\
& \ (.2415) \quad (.2012) \quad (.2003) \quad (.2003) \quad (.2659) \quad (.2003) \\
& + .3410\, C_7 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (36) \\
& \ (.243)
\end{aligned}
$$

$$R^2 = .968$$

$$F = 295.35$$

The signs on all explanatory variables are still consistent with prior expectations. The price variables, P_t and B_t^*, in the supply equation (34) and P_t in the demand equation (36) are still asymptotically insignificant. However, the results from the generalized difference forms show that the standard errors of the parameter estimates have been decreased relative to the standard errors from two-stage least squares estimates, except for the dummy variables.

To correct heteroskedasticity, the residuals from the supply and demand equations (35) and (36) were used to compute the disturbance variances, and the results are shown in Table 28.

In Table 28, the disturbance variance of Polk County is nearly five times larger than the disturbance variance of Washington County on the supply side, and the disturbance variance of Yamhill County is more than twice that of the disturbance variance of Washington County on the demand side. The data were corrected to adjust heteroskedasticity, and the results of the parameter estimates for the weighted least-squares regression model (30) in both supply and demand equations were as follows:

$$\begin{aligned}
Q_t^s = & -.0089 + 1.4279 \log P_t + 1.1356 \log P_{t-1} - .5769 \log PI_{t-1} \\
& \ (.0040) \quad (.3003) \qquad\quad (.1871) \qquad\qquad (.1087) \\
& - 1.0610 \log B_t^* - .2121 \log R_t + 1.1076\, C_1 + .1317\, C_2 + 2.3773\, C_3 \\
& \quad (.2641) \qquad\quad (.0226) \qquad (.2948) \qquad (.2626) \qquad (.2566) \\
& + .4134\, C_4 - .3769\, C_5 + 2.4138\, C_6 + 1.0158\, C_7 \ \ldots\ldots\ldots\ldots (37) \\
& \quad (.2610) \quad (.3348) \quad (.2547) \qquad (.3435)
\end{aligned}$$

$$R^2 = .988$$

$$F = 745.13$$

$$\begin{aligned}
Q_t^d = & \ 1.1431 - .1834 \log P_t + .7143 \log EP_t - .1487 \log CS_t - .0786 \log H_t \\
& (.7101) \quad (.1595) \qquad\quad (.2603) \qquad\quad (.0363) \qquad\quad (.0192) \\
& + .6332\, C_1 - .2984\, C_2 + 1.9129\, C_3 - .0662\, C_4 - .8366\, C_5 + 1.9196\, C_6 \\
& \quad (.2656) \quad (.2078) \quad (.2058) \quad (.2103) \quad (.2931) \quad (.2052) \\
& + .3395\, C_7 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (38) \\
& \quad (.2698)
\end{aligned}$$

$$R^2 = .963$$

$$F = 469.32$$

The parameter estimates, excluding the binary dummy variables in the supply equation (37), are at least four times larger than the size of their standard errors. But, the estimated parameter of the strawberry price variable, P_t, in the demand equation (38) is still not asymptotically significant. However, the standard errors of parameter estimates have been reduced in both supply and demand equations with the exception of the binary dummy variables.

The estimated supply equation (37) and demand equation (38) were used to estimated the unkown variance-covariance matrix, Σ, in the Aiken's generalized least-squares estimator (32). To find consistent estimators of the variances and covariances of the residuals, Zellner (1963) has suggested the use of the residuals from ordinary least-squares estimates with pooled data. That is,

$$\hat{\Sigma} = S = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1m} \\ S_{21} & S_{22} & \cdots & S_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ S_{m1} & S_{m2} & \cdots & S_{mm} \end{bmatrix} \quad \ldots\ldots\ldots\ldots (39)$$

where $\qquad S_{ij} = \Sigma u_{it}^{**} u_{jt}^{**}/(T - k - 1) \qquad i, j = 1, 2, \ldots, m$

The results from the Aiken's generalized least-squares estimators were as follows:

$$\begin{aligned} Q_t^S = {} & \underset{(.0011)}{-.0003} + \underset{(.2826)}{1.6460} \log P_t + \underset{(.1820)}{1.2235} \log P_{t-1} - \underset{(.1055)}{.5761} \log PI_{t-1} \\ & - \underset{(.2526)}{1.2157} \log B_t^* - \underset{(.0214)}{.2240} \log R_t + \underset{(.1449)}{.6446}\, C_1 + \underset{(.0757)}{.2074}\, C_2 + \underset{(.0959)}{1.8822}\, C_3 \\ & + \underset{(.0804)}{.3360}\, C_4 - \underset{(.0897)}{.0033}\, C_5 + \underset{(.0928)}{1.9515}\, C_6 + \underset{(.1484)}{.2490}\, C_7 \quad \ldots\ldots\ldots\ldots (40) \end{aligned}$$

$$Q_t^d = .0077 - .1042 \log P_t + 1.2294 \log EP_t - .1271 \log CS_t - .0656 \log H_t$$
$$(.1061) \quad (.1368) \qquad (.1665) \qquad (.0334) \qquad (.0186)$$
$$+ .0542 C_1 - .1130 C_2 + 1.4767 C_3 - .0038 C_4 - .1556 C_5 + 1.4924 C_6$$
$$(.1040) \quad (.0335) \quad (.0677) \quad (.0314) \quad (.0799) \quad (.0668)$$
$$+ .0304 C_7 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (41)$$
$$(.0555)$$

The estimated coefficient of the strawberry price variable in demand equation (41) is not asymptotically significant, while the coefficient of the strawberry product price variable is asymptotically significant. Since the strawberry prices are assumed to be determined by a barometric price leading processor, the amount of strawberries demanded for processing may depend on the strawberry product price. An important implication of the supply equation (40) and demand equation (41) is that the equilibrium price and quantity obtained from simultaneous equations systems are unstable. The supply of strawberries is price elastic, while the demand for strawberries is price inelastic.

By comparing the results from the seemingly unrelated regression estimations and the supply and demand equations (37) and (33), there are no significant gains in reducing the standard errors of parameter estimators from adopting the Aitken's generalized least-squares estimations. As described earlier, there are two possible reasons:

(1) High multicollinearity among the explanatory variables may exist.

(2) The explanatory variables are the same.

To find out the degree of multicollinearity, the variance inflation factors (VIF) were computed from the supply equation (40) and the demand equation (41). The equation (42) is used to compute the VIF, and the results are shown in Table 29.

$$VIF = C_{ii}\Sigma X_i^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (42)$$

where ΣX_i^2 = (standard deviation of $X_i)^2$ x (n - 1)

$C_{ii} = \hat{\sigma}^2_{\hat{\beta}_i} / \hat{\sigma}^2_{u}$**

The VIF's in Table 29 indicate that there exists multicollinearity among the explanatory variables. The variance of parameter estimate corresponding to the strawberry price variable P_t in supply equation, for instance, is increased more than 307 times what it would be if there were no multicollinearity.

Since all explanatory variables (with the exception of binary dummy variables) are identical across counties, it is not known whether the existing high multicollinearity or the nearly same explanatory variables in the equations contributes most toward insignificant benefits in reducing the standard errors of parameter estimates from the seemingly unrelated regression estimation.

TABLE 29. THE VARIANCE INFLATION FACTOR OF EACH MAJOR EXPLANATORY VARIABLE IN BOTH SUPPLY AND DEMAND EQUATIONS.

Major Explanatory Variable	VIF	
	Supply	Demand
P_t	307.17	46.44
P_{t-1}	118.51	--
PI_{t-1}	127.24	--
B_t^*	308.21	--
R_t	1.92	--
EP_t	--	83.94
CS_t	--	4.87
H_t	--	4.92

MEASURES OF SOCIAL BENEFITS AND COSTS WHICH ARE EXPECTED FROM THE PROSPECTIVE STRAWBERRY HARVEST MECHANIZATION

The cost reductions resulting in advantages to growers from adopting the mechanical strawberry harvester were analyzed in Chapter II. While the successful mechanization of strawberry harvesting would expand the strawberry and other related industries, and so create new employment, it would also result in involuntary labor displacement. This involuntary labor displacement would be a cost to society. Therefore, prior to actual adoption of the mechanical strawberry harvester, it would be helpful to estimate the net social return which is defined as the difference between the social benefits and social costs.

Consumers' and producers' surplus analyses are adopted to measure the social benefits which are predicted from technological change in the strawberry harvest. Since this approach does not explain who may be affected by the mechanization and how the effects will be distributed among the different groups involved, this approach is based upon the well-known Hicks-Kaldor's compensation principle which separates efficiency from the distributional aspects of allocation evaluation.

Conceptual Framework for Measuring Social Benefits from Mechanizing the Strawberry Harvest

With the assumption that the marginal rate of substitution for Hicks-Allen money is a constant, the area under the demand curve to the left of a given quantity represents consumers' total utility for a given quantity. Also, the supply curve reflects the processors' opportunity costs for input-factors to produce each quantity.

Since the supply curve reflects a long-run average cost curve, a reduction in average costs for growers will shift the supply curve to the

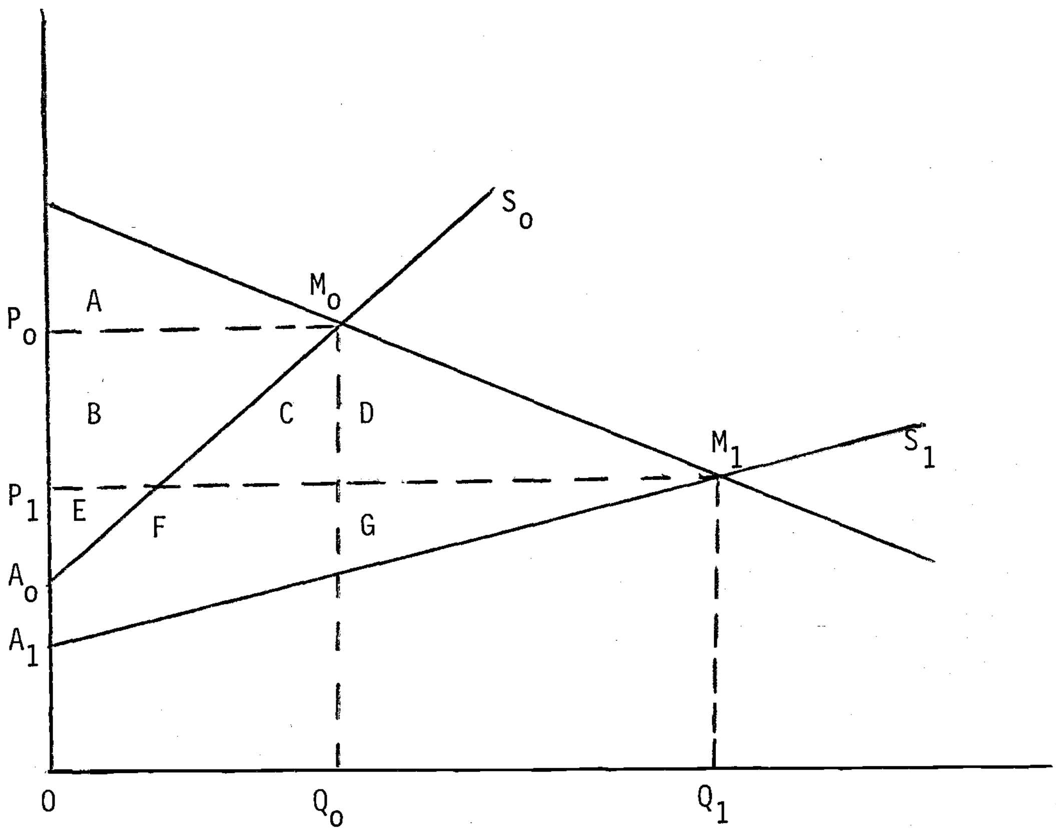


Figure 8. Changes in market equilibrium.

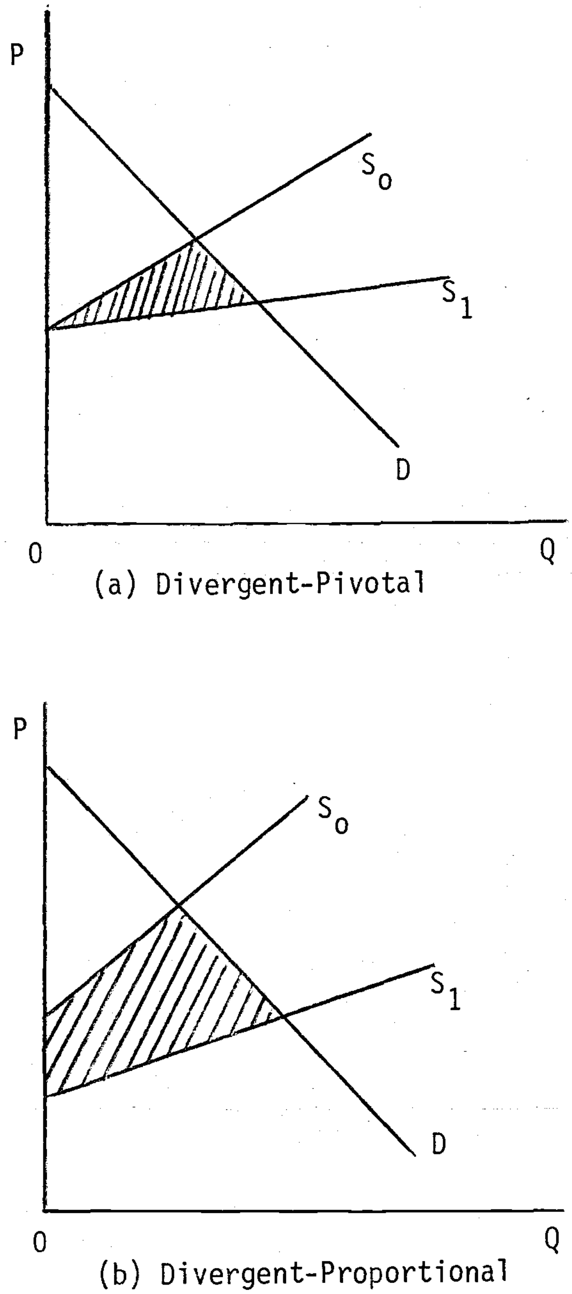
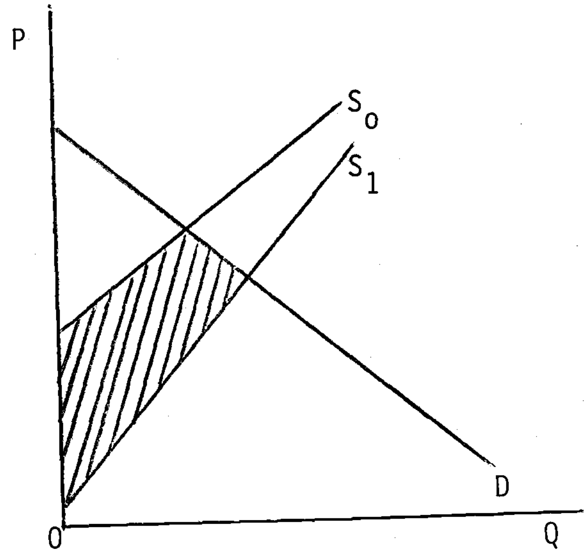
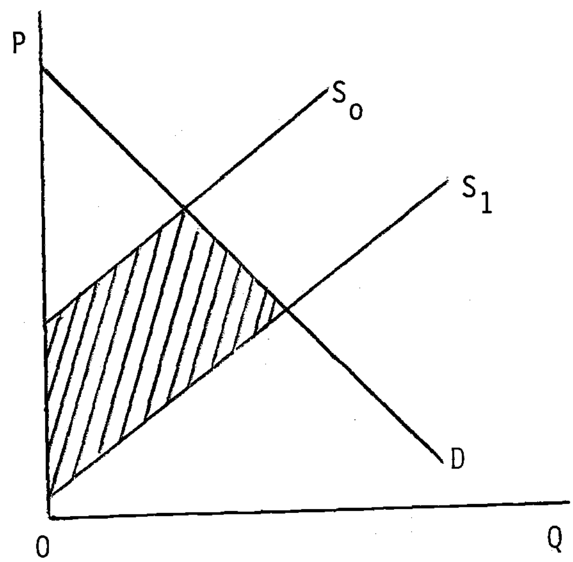


Figure 9. Types of supply shift-- the shaded area indicates the gross annual social benefits. (Parts c and d on the next page.)



(c) Convergent



(d) Parallel

Figure 9. Types of supply shift--the shaded area indicates the gross annual social benefits.

right. Suppose that the supply curve, S_o, shifts to S_1 in Figure 8, by introducing the mechanical strawberry harvester. Then, the gross annual social benefits (GASB) resulting from adoption of the mechanical strawberry harvester can be estimated by measuring the area C + D + F + G, which is the sum of gains in consumers' surplus, B + C + D, and producers' surplus, F + G -B.

The distribution of benefits between growers and processors will be determined by the nature of the supply shift. Lindner and Jarrett have shown the importance of the nature of the supply shifts by comparing the relative benefits from four different types of supply shift as shown in Figure 9.

The formulas derived by Lindner and Jarrett to estimate the GASB from Figure 8 are as follows:

$$\text{Consumer benefit} = \tfrac{1}{2}(P_oQ_1 - P_1Q_o + P_oQ_o - P_1Q_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots(43)$$

$$\text{Producer benefit} = \tfrac{1}{2}(Q_oA_o - Q_1A_1 - P_oQ_o + P_1Q_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots(44)$$

$$\text{Total benefit} = \tfrac{1}{2}(P_oQ_1 - P_1Q_o + Q_oA_o - Q_1A_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots(45)$$

Peterson's formula is based upon the assumption that the supply shift would be proportional. The formula used by Peterson in measuring the gross annual social benefits is as follows:

$$kQ_1P_1 + (\tfrac{1}{2})k^2P_1Q_1/n - (\tfrac{1}{2})Q_ok^2P_1(P_1/P_o)\left(\frac{\varepsilon n}{\varepsilon + n}\right)\left(\frac{n - 1}{n}\right)^2 \quad \ldots\ldots(46)$$

where k is the proportionate shift in the supply function, P_1 and Q_1 are the new equilibrium price and quantity, respectively; and ε and n are the price elasticity of supply and demand, respectively.

Also, Griliches measured the gross social benefits under the conditions that the supply curve was either perfectly elastic or perfectly inelastic, and he assumed that the results would represent the minimum and maximum social benefits, respectively, from the supply shift. The formulas used by Griliches are as follows:

With the perfectly elastic supply curve: $kP_1Q_1(1 - \frac{1}{2}kn)$ ....(47)

With the perfectly inelastic supply curve: $kP_1Q_1\ (1 + \frac{1}{2}kn)$ ....(48)

Since the mechanical strawberry harvester is in an experimental stage, it is not known what type of supply shift would occur if and when it is adopted. Therefore, the gross annual social benefits (GASB) will be measured by employing the formulas used by Lindner and Jarrett, Griliches, and Peterson, and the results will be compared.

Measurement of Unobservable Variables in Using the Formulas

The formulas used by Lindner and Jarrett, Peterson, and Griliches require a knowledge of the new equilibrium price, P_1, and a knowledge of A_1 is also required for the Lindner and Jarrett formula.

The demand equation (41) was estimated from the pooled data, and therefore, it may not be appropriate to use it to predict the new equilibrium price, P_1, in an aggregate analysis. Since the amount of strawberries produced in each county was used in the estimations, the predicted new equilibrium price could even be a negative value when an aggregated amount of strawberries is inserted into the demand equation (41).

Lindner and Jarrett used the following formula to estimate the new equilibrium price. That is,

$$P_1 = P_0\ (1 - \frac{k\varepsilon}{n + \varepsilon}) \quad \text{..................(49)}$$

A difficulty in using equation (49) in this study is that the estimated new equilibrium price would be negative, when k is greater than $(\varepsilon + n)/\varepsilon$.

One possible approach in predicting the new equilibrium price after the shift in the supply and/or demand curve is Equation (50) which was used by Pinstrup-Anderson, Ruiz de Londoño, and Hoover:

$$P_1 = P_o \left[1 - \frac{k - d}{(\varepsilon + n)}\right] \quad \ldots\ldots\ldots\ldots\ldots(50)$$

where d is the horizontal shift in the demand curve.

By assuming that demand curve does not shift, Equation (50) can be written as follows:

$$P_1 = P_o \left[1 - \frac{k}{(\varepsilon + n)}\right] \quad \ldots\ldots\ldots\ldots\ldots(51)$$

Equation (51) is very similar to Equation (50). However, the formula in Equation (51) permits a greater value of k than Equation (50) used by Lindner and Jarrett.

The formula used by Lindner and Jarrett requires a knowledge of the new intercept, A_1. If a proportional shift k is postulated, A_1 can be estimated in the same way as the new equilibrium price, P_1. That is,

$$A_1 = A_o \left(1 - \frac{k}{\varepsilon + n}\right) \quad \ldots\ldots\ldots\ldots\ldots(52)$$

Since the statistically estimated supply curve does not yield a reliable estimate of the true intercept, the gross social benefits measured by using Equation (45) may be biased. However, according to Lindner and Jarrett, the estimated social benefits are relatively insensitive to the value of the intercept used. Estimated social benefits are, however, much more sensitive to the nature of the shift in the supply curve induced by adoption of the innovation.

Assumption Made for Estimating the Social Benefits

The following assumptions are made in the process of estimating the gross annual social benefits from the mechanization in strawberry harvest. (1) Since the machine has not yet been widely used, there is no basis for estimating a rate of adoption. The experience of mechanization in tomato harvesting in California may give us some intuition on the adoption rate, but there is no way to predict the adoption rate with confidence.

In California, all tomatoes were harvested by hand before 1963. After the 1964-1966 transition period, more than 95 percent of processing tomatoes, corresponding to 80 percent of the California acreage for tomatoes, have been harvested by the mechanical tomato harvester. Therefore, it is assumed that the adoption rate would be 80 percent after a four-year transition period if mechanization in strawberry harvesting is successfully implemented in Oregon. (2) With the adoption rate assumed in (1), it is assumed that Oregon is expected to harvest 14,000 acres of strawberries. This figure is identical to the acreage for strawberries in 1967. At this time, difficulties in procuring handpickers began marking the beginning of efforts to mechanize strawberry harvesting in Oregon.

The expansion of acreage for strawberries is assumed to follow the exponential growth model as shown in Figure 10.

(3) It is assumed that a yield of four tons of strawberries per acre is averaged in Oregon. (4) The weight of mechanically-harvested raw product is assumed to be equal to the weight of hand-picked strawberries, as shown in Chapter II. (5) The social benefits are estimated under the assumption that the mechanical harvester adopted will perform as the OSU harvester during the 1978 season.

It is assumed that the adoption rate follows the linear trend model, $Y_t = 5 + 25\ t$, and the expansion of acreage is assumed to follow the exponential growth model, $\log A_t = 8.6125 + .31144\ t$, where Y_t is the adoption rate in year t, A_t is the acreage for strawberries in year t,

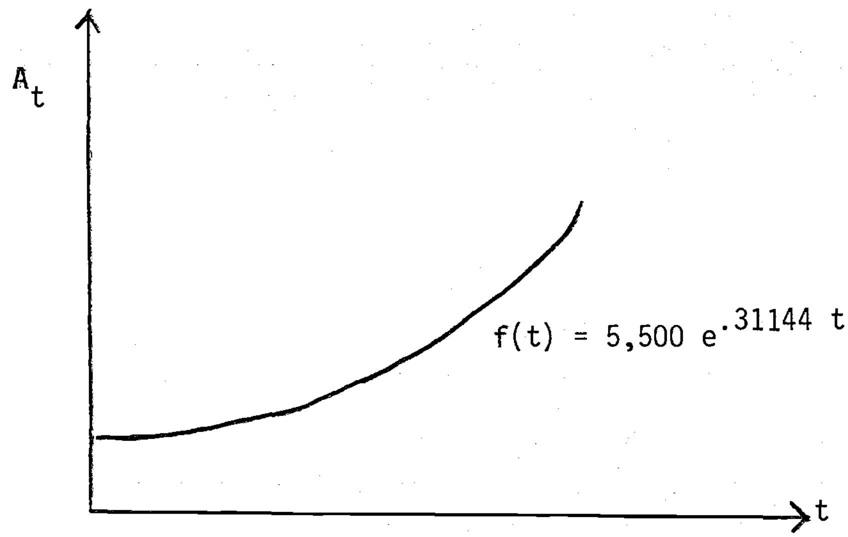


Figure 10. Exponential growth model.

and t is equal to zero for the first year. The estimated adoption rates and acreages for strawberry production are shown in Table 30.

In Table 10, grade #1 and grade #5 strawberries represented 50.86 and 22.40 percent, respectively, of the total raw product harvested by the OSU harvester. The estimated amount of strawberries corresponding to the expected acreages are also shown in Table 30.

Estimation of the Horizontal Proportionate Shift, k, in Supply Curve

According to the food scientist at Oregon State University who has worked with mechanically-harvested strawberries, the quality of grade #1 strawberries is equal to the quality of hand-picked strawberries. However, grade #5 strawberries have a lower quality compared to hand-picked strawberries, and consumers' acceptance of products made with the grade #5 strawberries is not yet known.

The gross annual social benefit estimates will be based upon two alternative assumptions: (1) only the grade #1 strawberries are accepted by consumers, and (2) both the grade #1 and grade #5 strawberries are accepted by consumers as the same quality, since plant breeding research has been undertaken to produce uniformly ripening varieties of strawberries. The results would represent the minimum and maximum social benefits, respectively, from mechanization of strawberry harvesting.

The horizontal proportionate shift, k, is estimated from Table 30, and the corresponding new equilibrium price, P_1, and the new intercept, A_1, are estimated by using Equations (51) and (52), respectively. The results are shown in Table 31.

Estimated Gross Annual Social Benefits

The estimated gross annual social benefits obtained by adopting the

TABLE 30. THE ESTIMATED RATES OF ADOPTION, ACREAGE, AND AMOUNT OF STRAWBERRIES.

Year	Expected Rate of Adoption	Expected Acreage	Expected Supply of Strawberries Grade #1	Grade #5	Total
	(%)	(acre)	(tons)	(tons)	(tons)
1979	0	5,200			
1980	5	5,500	21,459.46	246.40	21,705.86
1981	30	7,510	25,611.50	2,018.69	27,630.19
1982	55	10,254	29,930.61	5,053.17	34,983.78
1983	80	14,000	33,985.28	10,035.20	44,020.48

TABLE 31. THE ESTIMATED VALUES OF HORIZONTAL PROPORTIONATE SHIFT k,[c/] NEW EQUILIBRIUM PRICE, P_1, AND NEW EQUILIBRIUM INTERCEPT, A_1, WHEN P_0 IS \$0.33 PER POUND AND A_0 IS 8.40.

Year	Case A[a/] k	P_1	A_1	Case B[b/] k	P_1	A_1
1980	.03	32.43	8.26	.04	32.25	8.21
1981	.23	28.66	7.30	.33	26.78	6.82
1982	.44	24.70	6.29	.68	20.18	5.14
1983	.63	21.12	5.38	1.12	11.88	3.02

[a/] Case A refers to the case where only grade #1 strawberries are utilized.

[b/] Case B refers to the case where both grade #1 and grade #5 strawberries are utilized identically.

[c/] $k = (\theta_1 - \theta_0)/\theta_0$

formula used by Lindner and Jarrett are shown in Tables 32 and 33. Results in Tables 32 and 33 indicate that processors and consumers are far better off than growers, and growers may even be worse off if a pivotal shift in the supply curve is assumed to have occurred. The distribution of benefits between growers and processors (or consumers) depends upon not only the nature of the supply shift, but also the price elasticity of demand. Since the demand for strawberries for processing is very inelastic, the shift of the supply curve to the right will result in greater benefits to processors (or consumers) than to growers.

The gross annual social benefits are also estimated by using Peterson's formula and Griliches' formula with the assumption that the supply curve is perfectly elastic. The results are shown in Table 34.

Results in Tables 33 and 34 indicate that gross annual social benefits (GASB) measured by applying Peterson's formula are always greater than the GASB measured by applying Lindner-Jarrett's formula. Also, GASB measured by using Griliches' formula are generally greater than the GASB estimated by applying the Lindner-Jarrett formula.

Conceptual Framework for Measuring the Social Costs of Unemployment Caused by the Mechanical Strawberry Harvester

As described earlier, the mechanization of strawberry harvesting will result in involuntary unemployment of hand-pickers. The social costs which are caused by the mechanical strawberry harvester can be estimated by applying the concepts of producers' surplus.

Suppose that the initial equilibrium in labor market is at "a" in Figure 11. If the demand curve for pickers shifts to D_1 from D_0, then, wage and demand for labor will fall to W_1 and N_1 along the supply curve S_0. If it is hypothesized that wages are rigid in the downward direction

TABLE 32. ESTIMATED CONSUMERS', PRODUCERS' AND GROSS SOCIAL BENEFITS FOR THE CASE OF A PIVOTAL SHIFT IN SUPPLY CURVE.

Year	Case A a/			Case B b/		
	Consumers' Surplus ($)	Producers' Surplus ($)	GASB ($)	Consumers' Surplus ($)	Producers' Surplus ($)	GASB ($)
1980	240,878	39,901	280,780	318,793	60,048	378,841
1981	2,014,259	72,090	2,086,349	3,012,357	- 38,370	2,973,987
1982	4,210,640	-238,110	3,972,529	7,151,480	-995,711	6,155,769
1983	6,508,491	-793,873	5,714,618	13,690,085	-3,584,887	10,105,198

a/ Case A refers to the case where only grade #1 strawberries are utilized.

b/ Case B refers to the case where both grade #1 and grade #5 strawberries are utilized identically.

TABLE 33. ESTIMATED CONSUMERS', PRODUCERS', AND GROSS SOCIAL BENEFITS FOR THE CASE OF A PROPORTIONATE SHIFT IN SUPPLY CURVE.

Year	Case A a/			Case B b/		
	Consumers' Surplus ($)	Producers' Surplus ($)	GASB ($)	Consumers' Surplus ($)	Producers' Surplus ($)	GASB ($)
1980	240,878	69,952	310,830	318,793	101,289	420,083
1981	2,014,259	353,817	2,368,076	3,012,357	398,186	3,410,544
1982	4,210,640	393,424	4,604,065	7,151,480	144,760	7,296,240
1983	6,508,491	232,483	6,740,974	13,690,085	-1,216,585	12,473,500

a/ Case A refers to the case where only grade #1 strawberries are utilized.

b/ Case B refers to the case where both grade #1 and grade #5 strawberries are utilized identically.

TABLE 34. ESTIMATED GROSS ANNUAL SOICAL BENEFITS BY USING THE FORMULAS OF PETERSON AND GRILICHES.

Year	Case A[a/]		Case B[b/]	
	Peterson ($)	Griliches ($)	Peterson ($)	Griliches ($)
1980	471,721	416,906	657,044	558,844
1981	6,830,316	3,336,057	12,126,909	4,799,618
1982	19,501,318	6,356,579	39,752,746	9,261,075
1983	35,276,734	8,747,043	73,574,992	11,030,821

a/ Case A refers to the case where only grade #1 strawberries are utilized.

b/ Case B refers to the case where both grade #1 and grade #5 strawberries are utilized identically.

in Oregon local markets, the demand for labor will follow horizontally along the iniitial wage, W_0, line. Consequently, employment will drop to N_2 at wage rate W_0. Introduction of the wage rigidity will increase the magnitude of the unemployment which is equal to $N_1 - N_2$ in Figure 11.

With the assumption that there are no alternative employment opportunities for the involuntarily displaced hand-pickers, and with wage rigidity in Oregon labor markets, the total costs to society can be estimated by measuring the area $(N_0 - N_2)W_0$ which constitutes the loss in producers' surplus (abcd) and the loss for hand-pickers (N_0acN_2).

Since there is no information concerning the labor demand and supply in Oregon local markets, it is assumed that the supply curve of hand-pickers is perfectly wage elastic. This assumption simply implies that the wage level is not changed by an increase or decrease in demand for hand-pickers.

Estimated Net Annual Social Benefits

It was explained in Chapter II that the demand for hand-sorters is decreased for strawberries harvested by machine. However, the increase in acreage for strawberries from adopting the mechanical strawberry harvester would eventually increase the demand by processors for hand-sorters. Since the net extra processing cost computed in Chapter II includes the savings in labor costs per acre, the value of extra processing cost is simply subtracted from the gross annual social benefits.

The estimated net social benefits, which are obtained by subtracting the social costs from unemployment and the net extra processing cost from the GASB, are shown in Tables 35 through 38.

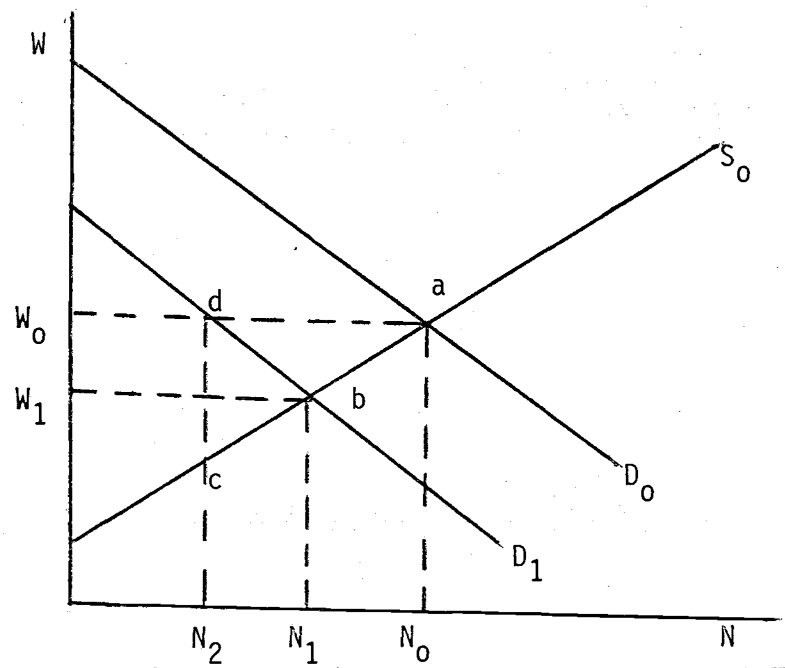


Figure 11. Labor market equilibrium with rigid wages.

TABLE 35. ESTIMATED GROSS AND NET ANNUAL SOCIAL BENEFITS: THE LINDNER-JARRETT ESTIMATE WITH A PIVOTAL SHIFT

	Year	Expected Acreage	Adoption Rate (%)	Loss (Gain) in Acreage Harvestable by Pickers	Gross Annual Social Benefit ($)	Net Extra Processing Cost ($16.23/a) ($)	Social Cost (Benefit) From Pickers ($)	Net Annual Social Benefit ($)
Case A[a/]	1980	5,500	5	25	280,780	4,463	28,000	304,317
	1981	7,510	30	57	2,086,349	36,566	63,840	2,113,623
	1982	10,254	55	- 585.7	3,972,529	91,532	- 655,984	3,225,013
	1983	14,000	80	-2,400	5,714,618	181,776	-2,688,000	2,844,842
Case B[b/]	1980	5,500	5	25	378,841	4,463	28,000	402,378
	1981	7,510	30	57	2,973,987	36,566	63,840	3,001,261
	1982	10,254	55	- 585.7	6,155,769	91,532	- 655,984	5,408,253
	1983	14,000	80	-2,400	10,105,198	181,776	-2,688,000	7,235,422

a/ Case A refers to the case where only grade #1 strawberries are utilized.

b/ Case B refers to the case where both grade #1 and grade #5 strawberries are utilized identically.

TABLE 36. ESTIMATED GROSS AND NET ANNUAL SOCIAL BENEFITS: THE LINDNER-JARRETT ESTIMATE WITH A PROPORTIONATE SHIFT.

	Year	Expected Acreage	Adoption Rate (%)	Loss (Gain) in Acreage Harvestable by Pickers	Gross Annual Social Benefit ($)	Net Extra Processing Cost ($16.23/a) ($)	Social Cost (Benefit) From Pickers ($)	Net Annual Social Benefit ($)
Case A[a/]	1980	5,500	5	25	310,830	4,463	28,000	334,367
	1981	7,510	30	57	2,368,076	36,566	63,840	2,395,350
	1982	10,254	55	- 585.7	4,604,065	91,532	- 655,984	3,856,549
	1983	14,000	80	-2,400	6,740,974	181,776	-2,688,000	3,871,198
Case B[b/]	1980	5,500	5	25	420,083	4,463	28,000	443,620
	1981	7,510	30	57	3,410,544	36,566	63,840	3,437,818
	1982	10,254	55	- 585.7	7,296,240	91,532	- 655,984	6,548,724
	1983	14,000	80	-2,400	12,473,500	181,776	-2,688,000	9,603,724

a/ Case A refers to the case where only grade #1 strawberries are utilized.

b/ Case B refers to the case where both grade #1 and grade #5 strawberries are utilized identically.

TABLE 37. ESTIMATED GROSS AND NET ANNUAL SOCIAL BENEFITS: THE PETERSON ESTIMATE.

	Year	Expected Average	Adoption Rate (%)	Loss (Gain) in Acreage Harvestable by Pickers	Gross Annual Social Benefit ($)	Net Extra Processing Cost ($16.23/a) ($)	Social Cost (Benefit) From Pickers ($)	Net Annual Social Benefit ($)
Case A[a]	1980	5,500	5	25	471,721	4,463	28,000	495,258
	1981	7,510	30	57	6,830,316	36,566	63,840	6,857,590
	1982	10,254	55	- 585.7	19,501,318	91,532	- 655,984	18,753,802
	1983	14,000	80	-2,400	35,276,734	181,776	-2,688,000	32,406,958
Case B[b]	1980	5,500	5	25	657,044	4,463	28,000	680,581
	1981	7,510	30	57	12,126,909	36,566	63,840	12,154,183
	1982	10,254	55	- 585.7	39,752,746	91,532	- 655,984	39,005,230
	1983	14,000	80	- 2,400	73,574,992	181,776	-2,688,000	70,705,216

a/ Case A refers to the case where only grade #1 strawberries are utilized.

b/ Case B refers to the case where both grade #1 and grade #5 strawberries are utilized identically.

TABLE 38. ESTIMATED GROSS AND NET ANNUAL SOCIAL BENEFITS: THE GRILICHES ESTIMATE WITH PERFECTLY ELASTIC SUPPLY CURVE.

	Year	Expected Average	Adoption Rate (%)	Loss (Gain) in Acreage Har-vestable by Pickers	Gross Annual Social Benefit ($)	Net Extra Processing Cost ($16.23/a) ($)	Social Cost (Benefit) From Pickers ($)	Net Annual Social Benefit ($)
Case A[a/]	1980	5,500	5	25	416,906	4,463	28,000	440,443
	1981	7,510	30	57	3,336,057	36,566	63,840	3,363,331
	1982	10,254	55	- 585.7	6,356,579	91,532	- 655,984	5,609,063
	1983	14,000	80	-2,400	8,747,043	181,776	-2,688,000	5,877,267
Case B[b/]	1980	5,500	5	25	558,844	4,463	28,000	582,381
	1981	7,510	30	57	4,799,618	36,566	63,840	4,826,892
	1982	10,254	55	- 585.7	9,261,075	91,532	- 655,984	8,513,559
	1983	14,000	80	-2,400	11,030,821	181,776	-2,688,000	8,161,045

a/ Case A refers to the case where only grade #1 strawberries are utilized.

b/ Case B refers to the case where both grade #1 and grade #5 strawberries are utilized identically.

Present Value of the Net Social Benefits

Since the social benefits and costs occur over time, it is assumed that society wants to maximize the present value of its net social benefits. Under this assumption, the mechanization in strawberry harvesting should be undertaken if and only if the present value of the net social benefits, when discounted at the market rate of interest, is positive.

Suppose the acreage and adoption rate are stable from 1983 and thereafter. Then, the present value of net social benefits for the period 1980 - 1982 can be computed by:

$$PV = \sum_{t=1}^{3} \frac{R_t}{(1+r)^t}$$

where R_t is the net social benefits in year t, and r is the market rate of interest

and, the present value for the year 1983 and thereafter can be computed by:

$$PV^* = \sum_{t=4}^{\infty} \frac{R_4}{(1+r)^t}$$

$$= \sum_{t=1}^{\infty} \frac{R_4(1+r)^{-3}}{(1+r)^t}$$

$$= R_4(1+r)^{-3}/r$$

The present values of net social benefits computed with an 11 percent market rate of interest are shown in Table 39.

Since Case A refers to the situation where only grade #1 strawberries are used to measure the net social benefits and Case B refers to the case where both grade #1 and grade #5 strawberries are assumed to be homogeneous in measuring the net social benefits, the results in Table 39 may indicate the minimum and maximum expected net social benefits from each prospective supply shift.

TABLE 39. COMPARISONS OF PRESENT VALUES OF SEVERAL ESTIMATED NET SOCIAL BENEFITS, WHEN THE MARKET RATE OF INTEREST IS 11 PERCENT.

Type of Shift	Present Value of the Net Social Benefits Case A[a] ($)	Case B[b] ($)
Pivotal (L-J formula)	39,717,670	96,710,929
Proportionate (L-J formula)	53,195,867	191,155,412
Peterson	422,284,090	918,076,622
Griliches (perfect elastic supply curve)	80,299,964	112,133,673

a/ Case A refers to the case where only grade #1 strawberries are utilized.

b/ Case B refers to the case where both grade #1 and grade #5 strawberries are utilized identically.

The net social benefits measured from applying Peterson's formula in case A are 7.94 times greater than those obtained from applying the Lindner-Jarrett formula for proportionate shift, and 4.8 times greater in case B. Lindner and Jarrett have shown that the differences between the net social benefits measured from applying the Lindner-Jarrett formula and Peterson's formula are positively related to the elasticity of the supply curve and inversely related to the elasticity of the demand curve.

Lindner and Jarrett have also shown that the net social benefits measured from applying Griliches' formula, when the supply curve is perfectly elastic, are overestimated at least 50 to 100 percent if a supply elasticity of unity is assumed, and by a substantially larger margin if the long-run supply is assumed to be inelastic. However, the results in Table 39 show that the net social benefits measured from applying Griliches' formula are 1.51 times greater in case A than those measured from using the Lindner-Jarrett formula with proportionate supply shift, while the Lindner-Jarret formula estimates net social benefits that are 1.7 times greater than those computed from Griliches' formula. These results imply social benefits measured from different formulas differ, not only from the supply shifts and the elasticities of demand and supply curves, but also because of the magnitude of the proportionate shift in the supply function, k.

Limitations of the Estimated Net Social Benefits

The adoption of the mechanical strawberry harvester in Oregon would generate not only new employment, but also involuntary unemployment. Net social benefits of the mechanical strawberry harvester were estimated under the assumption that new employment opportunities for hand-sorters at processing companies would not be filled by displaced hand-pickers from the field. By employing involuntarily unemployed hand-pickers for sorting machine-picked strawberries at processing companies, the social costs which arise from the displacement of pickers would be reduced, and therefore, net social benefits would be increased.

The present value of net social benefits from the mechanical strawberry harvester were estimated through the application of formulas used by Lindner and Jarrett, Griliches, and Peterson. The results in Table 39 indicate that net social benefits vary depending upon the types of supply shifts and formulas applied. Among the formulas, the formula used by Lindner and Jarrett with a proportionate shift in supply was the most sensitive to changes in the value of the proportional shift in the supply curve, k, while the formula used by Griliches was the most insensitive for changes in the value of k.

The results in Table 39 were estimated under the assumption that the adoption rate would be 80 percent after a three-year transition period, using the linear trend model, $Y_t = 5 + 25\ t$. In addition, acreage allocated for strawberry production was assumed to increase to 14,000 acres if mechanical strawberry harvesting in Oregon were successfully implemented. Furthermore, it was assumed that the increase in acreage during the transition period is specified by the exponential growth model, $A_t = 5{,}500\ e^{.31144\ t}$. If either the adoption rate or the expected acreage differ, the value of the proportionate shift in the supply curve, k, would change and therefore, the present value of net social benefits would differ from the results in Table 39.

SUMMARY AND CONCLUSIONS

Summary

The climate and soils in Oregon are suitable to growing high-quality strawberries for which processors often pay premiums above the price paid for California berries. Even though net profits per acre from growing strawberries are supposedly greater than some other crops, such as snap beans or sweet corn, and yield per acre has been increasing in Oregon, the acreage for strawberry production in Oregon has been declining since 1965, and it reached its lowest level, 5,000 acres, in 1978. The highest acreage level was 18,300 acres in 1958.

The increased harvesting costs and the difficulties in procuring hand-pickers to pick strawberries with the associated uncertainties in procuring pickers are thought to be the main reasons for declining acreage for strawberry production in Oregon. Traditionally, strawberry harvesting has been dependent upon school-aged youngsters. The enactment of child labor legislation in 1973 which banned children under 12 years of age from picking in the field created very critical impacts on the strawberry harvesting. In 1978, for instance, the picker shortage was very acute, contributing to an estimated 25 percent of the strawberries that rotted in the field (Charles Holzhauer).

To solve the problems facing the Oregon strawberry industry such as the increasing harvesting costs and the difficulties in procuring hand-pickers, since 1967 Oregon has put great efforts into the mechanization in strawberry harvesting.

The objectives of this thesis are to evaluate the economic feasibility to the Oregon strawberry growers of the mechanically harvested strawberries, and to estimate net social benefits (costs) which can be expected from the impending mechanization in strawberry harvesting in Oregon.

In Chapter II, unit costs and net profits were compared under certain conditions between hand-picking and mechanical harvesting. Mechanical strawberry harvesting reduced unit costs in each assumed case, and the differences in unit costs between mechanical harvesting and hand-picking increased as yield per acre increased.

Net revenue varied depending upon, not only yield per acre, but also the strawberry prices. The mechanical strawberry harvesting was more profitable to growers than hand-picking in cases of the relatively lower strawberry prices and high yield per acre. Oregon has put considerable efforts into plant breeding, and the results have been promising. More than 11 tons of strawberries were harvested per acre on experimental lots during the 1978 and 1979 seasons, while present yields are less than four tons per acre, on the average, in Oregon. If mechanical strawberry harvesting takes place on the appropriate date, mechanical strawberry harvesting could be a promising solution for not only reducing harvesting costs, but also in removing the difficulties in procuring hand-pickers.

Adoption of the strawberry harvester would cause a shift in labor from hand-pickers in the field to hand-sorters in processing companies. This involuntary labor displacement from introducing the mechanical strawberry harvester would generate costs not only to hand-pickers, but also to society. If the demand and supply curves of strawberries for processing can be accurately estimated, net social benefits (costs) can be estimated in terms of consumers' and producers' surpluses.

In Chapter III, the demand and supply of strawberries for processing in Oregon has been analyzed to use in estimating net social benefits (costs). The supply function has been derived by applying Hotelling's lemma from the expected growers' profit function under the assumption that growers are profit-maximizers. Since consumers' surplus cannot be measured correctly from a profit-maximizing derived demand curve if the input-factor is sold under imperfect competition, a concept of the household production function has been introduced to derive a demand function for strawberries.

Time-series and cross-sectional data were pooled in estimation of parameters. Therefore, disturbance terms are assumed to have problems, such as heteroskedasticity, serial correlation, and contemporaneous covariance, and these problems have been properly corrected to obtain efficient estimators.

In Chapter IV, net social benefits are estimated under certain assumptions by applying formulas used by Lindner and Jarrett, Griliches, and Peterson. The estimated net social benefits are affected by, not only the supply shifts, the elasticities of demand and supply curves, and the magnitude of proportionate shift in the supply curve, but also by the formulas used. In case of a proportionate supply shift, the net social benefits estimated by Peterson's formula are always greater than those measured by the formula used by Lindner and Jarrett. Also, the formula used by Griliches generates greater net social benefits compared to the formula used by Lindner and Jarrett for relatively smaller proportionate shifts in the supply curve, while Griliches' formula generates smaller net social benefits for relatively larger proportionate shifts in the supply curve than the Lindner-Jarrett formula. These results may imply that net social benefits measured by applying Griliches' formula are overstated for the relatively smaller proportionate shifts in the supply curve by assuming a perfectly elastic supply curve and understated for the relatively larger proportionate shifts in supply.

Even though the present values of net social benefits are estimated to be at least more than $39 million, for the case of pivotal shift, an adoption of the mechanical strawberry harvester would not result in Pareto optimality. If the displaced hand-pickers can be employed by the processing companies as the newly-needed hand-sorters, the present values of net social benefits would be greater than the results shown in Table 39, and also Pareto optimality might be obtained.

Since the demand for strawberries was price inelastic, the benefits to processors were greater than these to growers. However, if the pattern of the California tomato industry is repeated, the number of growers will decrease over time, while the strawberry acreage per grower will increase as a result of mechanization of strawberry harvesting. Consequently, growers might strengthen their bargaining power in determining strawberry prices.

Since a grading and pricing system has not yet been established for machine picked berries, there is increased uncertainty to growers in adopting mechanical harvesting. Therefore, a grading and pricing system needs to be firmly established to reduce growers' uncertainty about the price that they would receive for machine harvested strawberries.

Recommendation for Future Research

The ridge regression estimator has been widely used when problems of multicollinearity exist among the explanatory variables. Since the results in Table 29 indicate that multicollinearity problems exist among the explanatory variables, problems of multicollinearity may be alleviated by using the ridge regression estimator.

For the linear model $Y = X B + u$, the nonstandardized ridge regression estimator is, $B = (X'X + k\lambda)^{-1} X'Y$ where k denotes a small positive number and λ is a diagonal matrix consisting of the sum of squares, and the variance-covariance matrix for B is $\text{Var-Cov}(B) = \sigma^2 (X'X + k\lambda)^{-1} X'X (X'X + k\lambda)^{-1}$.

Even though the ridge regression estimator is biased, it has smaller mean square error (MSE) than the ordinary least-squares estimator for some positive value of k (Hoerl and Kennard, 1970).

For the Zellner estimator, Equation (32), if there is no perfect correlation between any pair of disturbance subvectors, the variance-covariance matrix Σ is symmetric and positive definite, and therefore the matrix $\Sigma \otimes I$ is also symmetric and positive definite. Then, $\Sigma^{-1} \otimes I$ can be written as follows:

$$
\begin{aligned}
\Sigma^{-1} \otimes I &= (\Sigma \otimes I)^{-1} \\
&= (P\, P')^{-1} \\
&= P^{-1'}\, P^{-1} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (53)
\end{aligned}
$$

where P is nonsingular matrix.

By substituting Equation (53) for $\Sigma^{-1} \otimes I$ in Equation (32), Equation (32) can be written as follows:

$$
\begin{aligned}
B &= \left[X^{**'} (\Sigma^{-1} \otimes I)\, X^{**}\right]^{-1} \left[X^{**'} (\Sigma^{-1} \otimes I)\; Y^{**}\right] \\
&= \left[X^{**'} (P^{-1'}\, P^{-1}) X^{**}\right]^{-1} \left[X^{**'} (P^{-1'}\, P^{-1})\; Y^{**}\right] \\
&= \left[(P^{-1}X^{**})' \;\; (P^{-1}X^{**})\right]^{-1} \left[(P^{-1}X^{**})' \;\; (P^{-1}Y^{**})\right] \\
&= (Z'Z)^{-1}(Z'W) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (54)
\end{aligned}
$$

where Z equals to $P_X^{-1}{}^{**}$, and W equals to $P^{-1}Y^{**}$.

Equation (54) indicates that the Aitken's generalized least-squares estimator is weighted least-squares estimator. For Equation (54), the seemingly unrelated ridge regression estimator can be written as follows:

$\tilde{\beta} = (Z'Z + k\lambda)^{-1} (Z'W)$ ....(55)

and the variance-covariance matrix for $\tilde{\beta}$ is

$\text{Var-Cov}(\tilde{\beta}) = \sigma^2 (Z'Z + k\lambda)^{-1} (Z'Z) (Z'Z + k\lambda)^{-1}$ ....(56)

For a single equation model, the Aitken's generalized least-squares estimator (54) is unbiased, while the seemingly unrelated ridge regression estimator (55) is biased. However, the mean square error of the seemingly unrelated ridge regression estimator should be smaller than those of the Aitken's generalized least-squares estimator, at least for a reasonable value of k, such as the computed values of k suggested by Lawless and Wang or by Hoerl, Kennard, and Baldwin.

For a simultaneous equation model, the two-stage least squares estimator is biased, but consistent. Therefore, the Aitken's generalized least squares estimator of the models used in this thesis are biased.

Since both the two-stage least squares estimator and the seemingly unrelated ridge regression estimator are biased, the relative magnitude of biasedness between the Aitken's generalized least-squares estimator and the seemingly unrelated ridge regression estimator for a simultaneous equations system is not known. Suppose that a two-stage estimator is biased upward (or downward) by α and the seemingly unrelated ridge regression estimator is biased downward (or upward) by β, where $|\alpha + \beta| < |\alpha|$. Then, the seemingly unrelated ridge regression estimator not only has a smaller mean square error (MSE), but also a smaller bias than the Aitken's generalized least-squares estimator for the simultaneous equations system.

BIBLIOGRAPHY

Adams, F.G. and J.R. Behrman. 1976. Econometric models of world agricultural markets, cocoa, coffee, tea, wool, cotton, sugar, wheat, rice. Cambridge, Massachusetts: Ballinger Publishing Co.

Anderson, J.E. 1974. "A note on welfare surpluses and gains from trade in general equilibrium," American Economic Review, 64: 758-762.

Arak, Marcelle. 1969. "Estimation of asymetric longrun supply functions," Canadian Journal of Agricultural Economics, 17: 15-22.

Bancroft, R.L. and J.K. Whittaker. 1977. "Estimation of acreage response functions using pooled time-series and cross-sectional data: corn in the midwest," Purdue University Agricultural Experiment Station Bulletin No. 165.

Baritelle, John L. and D.W. Price. 1974. "Supply response and marketing strategies for deciduous crops," American Journal of Agricultural Economics, 56: 245-253.

Baron, David P. 1971. "Demand uncertainty in imperfect competition," International Economic Review, 12: 196-208.

Bateman, J.J. 1965. "Aggregate and regional supply functions for Ghanaian cocoa, 1946-1962," Journal of Farm Economics, 47:384-401

Behrman, Jere R. 1968. "Monopolistic cocoa pricing," American Journal of Agricultural Economics, 50: 702-719.

Bowers, W. 1970. Modern concepts of farm machinery management, Champaign, Illinois: Stipes Publishing Company.

Brown, W.G. and B.R. Beattie. 1975. "Improving estimates of economic parameters by use of ridge regression with production function applications," American Journal of Agricultural Economics, 57: 21-32.

Chern, W.S. and R.E. Just. 1978. "Econometric analysis of supply response and demand for processing tomatoes in California," Giannini Foundation Monography No. 37, California Agricultural Experiment Station.

Cohen, K.L. and Richard M. Cyert. 1975. Theory of the firm: Resource allocation in a market economy, second edition, Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Currie, J.M., J.A. Murphy, and Andrew Schmitz. 1971. "The concept of economic surplus and its use in economic analysis. The Economic Journal, 81: 741-799.

De Janvry, A.E. 1966. Measurement of demand parameters under separability, Ph.D. Thesis, Department of Agricultural Economics, University of California, Berkeley: pp. 140-154.

Dhrymes, Phoebus J. 1964. "On the theory of the monopolistic multi-product firm under uncertainty," International Economic Review, 5: 239-257.

Diewert, W.E. 1973. "Functional forms for profit and transformation functions," Journal of Economic Theory, 6: 284-291.

Doll, John P. 1974. "On exact multicollinearity and the estimation of the Cobb-Douglas production function," American Journal of Agricultural Economics, August: 556-563.

French, Ben C. and J.L. Matthews. 1971. "A supply response model for perennial crops," American Journal of Agricultural Economics, 53: 478-490.

George, P.S. and G.A. King. 1971. "Consumer demand for food commodities in the United States with projections of 1980," Giannini Foundation Monography No. 26, California Agricultural Experiment Station.

Griliches, Zvi. 1958. "Research costs and social returns: Hybrid corn and related innovations," Journal of Political Economics, 66: 419-431.

Hassan, Z.A. and S.R. Johnson. 1976. "Consumer demand for major foods in Canada," Agriculture Canada, Economics Branch Publication No. 7612.

Hoerl, A.E. and R.W. Kennard. 1970. "Ridge regression: biased estimation for nonorthogonal problems," Technometrics, 12: 55-67.

Hoerl, A.E. and R.W. Kennard. 1970. "Ridge regression: applications to nonorthogonal problems," Technometrics 12: 69-82.

Hoerl, A.E., R.W. Kennard, and K.F. Baldwin. 1975. "Ridge regression: some simulations," Commun. Stat., 4: 105-123.

Holzhauer, Charles. 1979. "Machine harvest for strawberries?," Oregon Farmer-Stockman, March 11-13.

Hotelling, Harold. 1932. "Edgeworth's taxation paradox and the nature of demand and supply functions," Journal of Political Economics, 40: 590-598.

Hussen, Ahmed M. 1978. Economic feasibility of mechanical strawberry harvesting in Oregon, unpublished Ph.D. dissertation, Department of Agricultural and Resource Economics, Oregon State University.

__________. 1979. "Assessment of the economic and social impacts of agricultural technology: a case study," Western Journal of Agricultural Economics, 4: 17-31.

Hymans, Saul H. 1966. "The price-taker: uncertainty, utility, and the supply function," International Economic Review, 7: 346-356.

Johnson, S.S. and M. Zahara. 1976. "Prospective lettuce harvest mechanization: impact on labor," Journal of American Society of Horticultural Science, 101: 378-381.

Johnston, J. 1972. Econometric methods, second edition, New York: McGraw-Hill Book Company.

Just, R.E. and D.L. Hueth. 1979. "Welfare measures in a multimarket framework," The American Economic Review, 69: 947-954.

Kakwani, N.C. 1967. "The unbiasedness of Zellner's seemingly unrelated regression equations estimators," American Statistical Association Journal, 62: 141-142.

Kim, C.S., W.G. Brown, and D. Langmo. 1980. Economic feasibility to Oregon growers of mechanically harvested strawberries, Agricultural Experiment Station Technical Paper No. 5397, Oregon State University.

Kmenta, Jan. 1971. Elements of econometrics. New York: MacMillan Publishing Company, Inc.

Kmenta, Jan and Roy F. Gilbert. 1970. "Estimation of seemingly unrelated regressions with autoregressive disturbances," Journal of the American Statistical Association, Theory and Methods Section, 65: 186-197.

Lancaster, Kelvin J. 1966. "A new approach to consumer theory," Journal of Political Economics, 74: 132-157.

Lau, L.J. and P.A. Yotopoulos. 1971. "A test for relative efficiency and application to Indian agriculture," American Economic Review, March: 214-223.

________________. 1972. "Profit, supply, and factor demand functions," American Journal of Agricultural Economics, 54: 11-18.

________________. 1973. "A test for relative economic efficiency: some further results," American Economic Review, March: 214-223.

Lawless, J.F. and P. Wang. 1976. "A simulation study of ridge and other regression estimators," Commun. Stat., A5: 307-323.

Leland, Hayne E. 1972. "Theory of the firm facing uncertain demand," The American Economic Review, 112: 278-291.

Lindner, R.K. and F.G. Jarrett. 1978. "Supply shifts and the size of research benefits," American Journal of Agricultural Economics, 60: 48-58.

Moe, Debra K. and J.K. Whittaker. 1980. Wheat acreage response to changes in prices and government programs in Oregon and Washington, Agricultural Experiment Station Special Report 572, Oregon State University.

Nicholls, William H. 1941. Imperfect competition with agricultural industries, Ames, Iowa: The Iowa State College Press.

Pacific Power and Light Company. 1979. Schedule 25, General Service; Portland, Oregon.

Parks, Richard W. 1967. "Efficient estimation of a system of regression equations when disturbances are both serially and contemporaneously correlated," American Statistical Association Journal, June: 500-509.

Parsons, Philip S., M.P. Zobel, and Ray King. 1964. Costs of Harvesting tomatoes by machine: Yolo and San Joaquin counties, University of California Agricultural Extension Service.

Peterson, Willis L. 1967. "Return to poultry research in the United States," Journal of Farm Economics, 49: 656-669.

Pindyck, R.S. and D.L. Rubinfeld. 1976. Econometric models and economic forecasts, New York: McGraw-Hill Book Company, Inc.

Pinstrup-Andersen, Per, Norha Ruiz de Londoño, and Edward Hoover. 1976. "The impact of increasing food supply on human nutrition: implications for commodity priorities in agricultural research and policy," American Journal of Agricultural Economics, 58: 131-142.

Plessner, Yakir. 1971. "Computing equilibrium solutions for imperfectly competitive markets," American Journal of Agricultural Economics, 53: 192-195.

Pope, Rulon D. 1978. "The expected utility hypothesis and demand-supply restrictions," American Journal of Agricultural Economics, November: 619-627.

President's Advisory Committee on Labor-Management Policy. 1962. "The benefits and problems incident to automation and other technological advances," Washington, D.C.

Sandmo, Agnar. 1971. "On the theory of the competitive firm under price uncertainty," The American Economic Review, 111: 65-73.

Schmitz, A. and David Seckler. 1970. "Mechanized agriculture and social welfare: the case of the tomato harvester," American Journal of Agricultural Economics, 52: 569-577.

Shaw, L.H. 1967. "Alternative measures of aggregate inputs and productivity in agriculture," Journal of Farm Economics, 49:670-683

Silberberg, Eugene. 1978. The structure of economics: a mathematical analysis, New York: McGraw-Hill Book Company, Inc.

Stigler, George J. 1947. "The Kinky oligoppoly demand curve and rigid prices," Journal of Political Economy, 55: 432-449.

Theil, Henri. 1971. Principles of econometrics, John Wiley & Sons, Inc., New York.

Wallace, T.D. 1962. "Measures of social costs of agricultural programs," Journal of Farm Economics, May: 580-597.

Weaver, Robert D. 1978. "Consistent output and input choice functions for multiproduct technologies," Proceedings of a symposium at joint meetings of the American Agricultural Economic Association and Canadian Agricultural Economic Society, Blacksburg, Virgnia: Virginia Polytechnic Institute and State University, August.

______________. 1978. "Discontinuous policy and distorted choices: the case of acreage control," Staff Paper 11, Agricultural Economics and Rural Sociology Department, The Pennsylvania State University, October.

Zellner, Arnold. 1962. "An Efficient method of estimating seemingly unrelated regressions and tests for aggregation bias," American Statistical Association Journal, 57: 348-368.

______________. 1963. "Estimators for seemingly unrelated regression equations: some exact finite sample results," American Statistical Association Journal, 58: 977-992.

APPENDICES

TABLE A-1. SUMMARY DATA FOR THE PRODUCTION COSTS.[a]

Based on:

(1) 20 acres on a 200 acre farm
(2) 3 bearing years; 4 tons/acre average
(3) Operator's labor, $8/hour [b]
(4) Hired labor, $5/hour [b]

(5) Tractors:
90-100 HP $12/hour
50 HP $ 6/hour
25 HP $ 3/hour

	INPUTS PER ACRE					
	Labor			Other		Total
Producing Years	Hours	Value ($)	Machinery ($)	Item	Value ($)	Cost ($)
Pre-Harvest Cultural Operation						
Cultivate (3X)	3.00	24.00	12.00			36.00
Hoeing	8.00	40.00				40.00
Insecticide & fungicide spray or dust (3X)	1.00	8.00	20.00	mtl.	40.00	57.00
Irrigation (2X, 2" each)	2.00	10.00	20.00	elec.	3.50	33.50
Post-Harvest Operations						
Irrigation (2X, 2" each)	2.00	10.00	20.00	elec.	3.50	33.50
Clip tops	.33	2.65	4.60			7.25
Weevil control (banded)	.2	1.60	1.80		18.00	21.40
Cultivate & runner control (2X)	2.0	16.00	10.00			26.00
Subsoil	.5	4.00	6.75			10.75
Herbicide	.2	1.60	1.80	mtl.	6.00	9.40
Side dress fertilizer[c]				fert.	47.00	47.00
Other Charges						
Bookkeeping		80.00		supp.	9.00	89.00
Land chgs., incl. taxes					150.00	150.00
Operating capital interest (11%)					18.00	18.00
General overhead					15.00	15.00
Cash costs		1180.00	50.40		153.50	1383.90
Non-cash costs		177.85	75.55		156.50	409.90
TOTAL ANNUAL PRODUCTION COSTS		1357.85	125.95		310.00	1795.80
Amortized establishment cost (next page)						480.00
Credit for post-harvest practices not incurred in last year						(46.90)
Standard production cost						$1026.90

CONTINUED NEXT PAGE

TABLE A-1., CONTINUED.

Producing Years	Labor Hours	Labor Value ($)	Machinery ($)	Other Item	Other Value ($)	Total Cost ($)
			INPUTS PER ACRE			
Harvest Costs						
Picking & handling ($0.14/lb.)	1120.00					1120.00
Hauling ($0.01/lb.)	80.00					80.00
Total Cost						$2226.90
Cultural Operations						
Subsoil	.5	4.00	6.75			10.75
Plow	.4	3.20	7.20			10.40
Disc & harrow (3X)	.75	6.00	13.50			19.50
Field cultivator (2X)	.5	4.00	8.00			12.00
Fumigation c/	.5	4.00	6.00	mtl.	140.00	150.00
Cultimulcher (2X)	.33	2.65	5.96			8.60
Fertilize (broadcast)	.17	.85	1.20	fert.	15.00	17.05
Preplant insecticide	.2	1.60	1.80	mtl.	43.00	46.40
Lime (2 tons) c/				custom	50.00	50.00
Plant trimming	3.00	15.00				15.00
Planting, 11,000 plants/acre, 5 people (5 acres in 8 hours)	8.00	44.80	14.40	plants	385.00	444.20
Roll plants	.2	1.00	2.60			3.60
Fertilize d/				fert.	47.00	47.00
Herbicide	.2	1.60	1.80	mtl.	45.00	48.40
Irrigation (3X, 6" tl.)	3.0	15.00	60.00	elec.	6.00	81.00
Cultivate (3X)	3.0	24.00	12.00			36.00
Herbicide (fall)	.2	1.60	1.80	mtl.	20.00	23.40
Hand weeding, crew	8.0	40.00				40.00
Pest control	.2	1.60	1.80	metl.	14.00	17.40
Other Charges						
Land charge (cash rent basis)					150.00	150.00
Operating capital interest (11%)					45.60	45.60
General overhead					36.50	36.50
Total cash costs		103.85	58.00		816.00	977.85
Total non-cash costs		67.05	86.80		181.10	334.95
Total establishment costs		170.90	144.80		997.10	1312.80
Amortized for three years at 10%						480.00

a/ This table is based on the Enterprise Data Sheet, Extension Service, Oregon State University, 1979.

b/ Includes Social Security, Workman's Compensation, and other labor expenses.

c/ Generally done but not required in all cases.

d/ Applied during another operation and includes soil insecticide.

TABLE B. SUMMARY DATA FOR PRICES, PRICE INDEXES, AND COLD-STORAGE HOLDINGS.

Year	(a) Strawberry Price (¢/lb.)	(b) Red Raspberry Price (¢/lb.)	(c) Price of Frozen Pack ($/30 lb. tin)	(d) Index of Fruit Price (1967=100)	(e) Producer Price Index: Processed Food and Feed (1967=100)	(f) Production Items, Interest Taxes and Wage Index. PI_{t-1} (1967=100)	(g) Cold-Storage Holdings by May 31 in Pacific Regions (Million Pound)
1962	12.9	16.0	5.55	102.6	77.9	87	31.8
1963	12.1	17.4	5.70	128.2	79.9	89	22.2
1964	13.9	15.1	6.15	134.8	81.8	90	77.2
1965	15.3	17.1	7.20	108.4	86.0	90	33.8
1966	17.3	18.2	6.75	113.2	92.7	93	21.9
1967	14.1	16.5	5.85	100.0	100.0	99	25.2
1968	16.5	20.4	6.60	133.9	108.5	100	13.2
1969	17.0	26.5	7.35	100.0	119.4	102	10.6
1970	15.6	21.4	7.05	95.6	127.9	107	15.3
1971	14.7	23.5	7.50	108.4	134.5	112	27.9
1972	17.2	32.1	7.65	116.7	142.3	117	33.4
1973	23.4	45.6	10.65	137.4	155.1	125	18.9
1974	24.5	32.6	11.70	140.5	177.8	149	24.5
1975	22.0	23.7	10.50	137.9	192.1	169	28.4
1976	27.5	31.8	13.05	129.5	210.3	186	85.4
1977	27.6	51.0	13.35	163.0	226.1	198	101.5
1978	27.3	67.8	11.85	227.3	242.4	208	185.7

Source: (a) Commodity Data Sheet, Extension Economic Information Office, Oregon State University.
(b) Commodity Data Sheet, Extension Economic Information Office, Oregon State University.
(c) Conroy Packing Company, Woodburn, Oregon and the American Food Institute, New York, New York.
(d) Agricultural Prices, Economics, Statistics, and Cooperative Service, U.S.D.A., Washington, D.C.
(e) Agricultural Prices, Economics, Statistics, and Cooperative Service, U.S.D.A., Washington, D.C.
(f) Agricultural Prices, Economics, Statistics, and Cooperative Service, U.S.D.A., Washington, D.C.
(g) Cold-Storage Report, U.S.D.A., Statistical Reporting Service.

TABLE C. DATA FOR STRAWBERRY PRODUCTION IN EACH COUNTY.

Year	County							
	Clackamas	Linn	Marion	Multnomah	Polk	Washington	Yamhill	Columbia
	(Million Pound)							
1962	14.640	2.800	24.708	4.230	2.450	21.120	7.820	4.200
1963	11.500	2.024	17.866	2.800	2.080	19.760	6.480	3.100
1964	13.800	2.703	31.600	6.000	2.650	28.722	7.500	2.920
1965	7.050	1.720	17.160	2.220	1.365	20.765	4.240	1.680
1966	12.000	2.200	29.520	3.900	2.600	30.346	7.500	3.200
1967	10.200	2.835	26.892	4.388	2.700	27.360	7.700	3.075
1968	7.140	2.338	20.460	2.990	2.070	20.525	6.930	2.747
1969	7.670	2.708	19.462	3.250	2.250	19.175	6.100	3.102
1970	6.480	2.824	22.064	2.870	2.160	21.449	5.832	2.674
1971	6.373	2.916	27.556	3.249	1.750	26.885	6.248	2.928
1972	3.818	1.848	18.042	2.299	.924	18.393	3.818	2.694
1973	3.000	1.389	15.061	1.901	.741	17.392	4.127	2.521
1974	3.834	1.512	11.652	1.745	.429	14.766	3.220	2.157
1975	3.169	1.512	12.897	1.560	.616	14.012	2.695	3.384
1976	4.050	1.800	15.272	2.115	.644	14.069	2.760	4.950
1977	3.132	1.163	10.987	1.455	.487	10.788	1.939	3.172
1978	1.726	1.074	12.224	1.726	.647	12.272	.805	1.591

Source: Commodity Data Sheet, Extension Economic Information Office, Oregon State University.