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RESPONSE OF PACIFIC NORTHWEST IRRIGATED AGRICULTURE
TO RISING ENERGY COSTS

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INTRODUCTION

Throughout western irrigated agriculture a large amount of energy is used for pumping and applying irrigation water. This paper examines how the Pacific Northwest (PNW) irrigated sector would respond in the short run (3-4 years) to rising electricity prices. In this region all irrigation pumping is accomplished with electricity. The analysis provides estimates of the elasticity of short-run demand for electricity in irrigated agriculture and examines the effects of electricity cost increases on factor use and farm income.

METHODS AND BACKGROUND

Scope

The study area contains all pump irrigated agricultural land in Washington, Oregon, Idaho and Western Montana. Lands that depend upon gravity flow water supplies and application methods are obviously excluded. Also excluded is a small portion of total regional pumping energy that is within USBR projects and totally insulated from energy price changes due to long-term power supply arrangements. The analysis is based on the assumption that no changes in technology can occur in the short run. However, all managerial adjustments within the limits of current technologies are considered.

More than 8 million acres of the PNW are under irrigation. Some 3.6 million acres (44 percent) are irrigated using gravity systems. Of the 4.6 million acres irrigated with sprinkler methods, almost two thirds (63 percent) are irrigated using a combination of side roll, wheel lines and hand move sprinklers, followed by center pivot (32 percent) and solid set (5 percent). In terms of total acres irrigated, side roll and its related systems provide water to 35 percent of the region's irrigated land, while center pivot and solid set systems supply 18 percent and 3 percent, respectively. The region was divided into 13 agricultural production areas (APA's) for this analysis as shown in Figure 1. APA's are groupings of counties with similar agricultural production characteristics.

Procedure

The response to changing electricity prices was examined using mathematical programming. Estimates of electricity demand were based on the behavioral assumption that farmers seek to maximize profits and will respond to changes in relative factor prices by adjusting farm input combinations. A linear programming model was used to determine the profit maximizing input combination for farm types representative of farming practices and conditions in the various APA's. The model maximized the net return to land, management and investment in existing irrigation systems. The fixed costs of irrigation systems were not deducted from crop net revenue.

A scaled-down version of the SPAW-IRRIG simulator model developed by Bernardo and Whittlesey was employed. The actual model configuration was initially developed by Whittlesey, Hamilton, and Halverson. In summary, the farm model considered the following options for each crop. Limited water application was permitted down to about 65 percent of full net irrigation requirements (NIR). Within each of five NIR levels, at least five levels of irrigation efficiency were possible by changing the inputs of irrigation labor and management. Crop yields and production costs were varied according to the

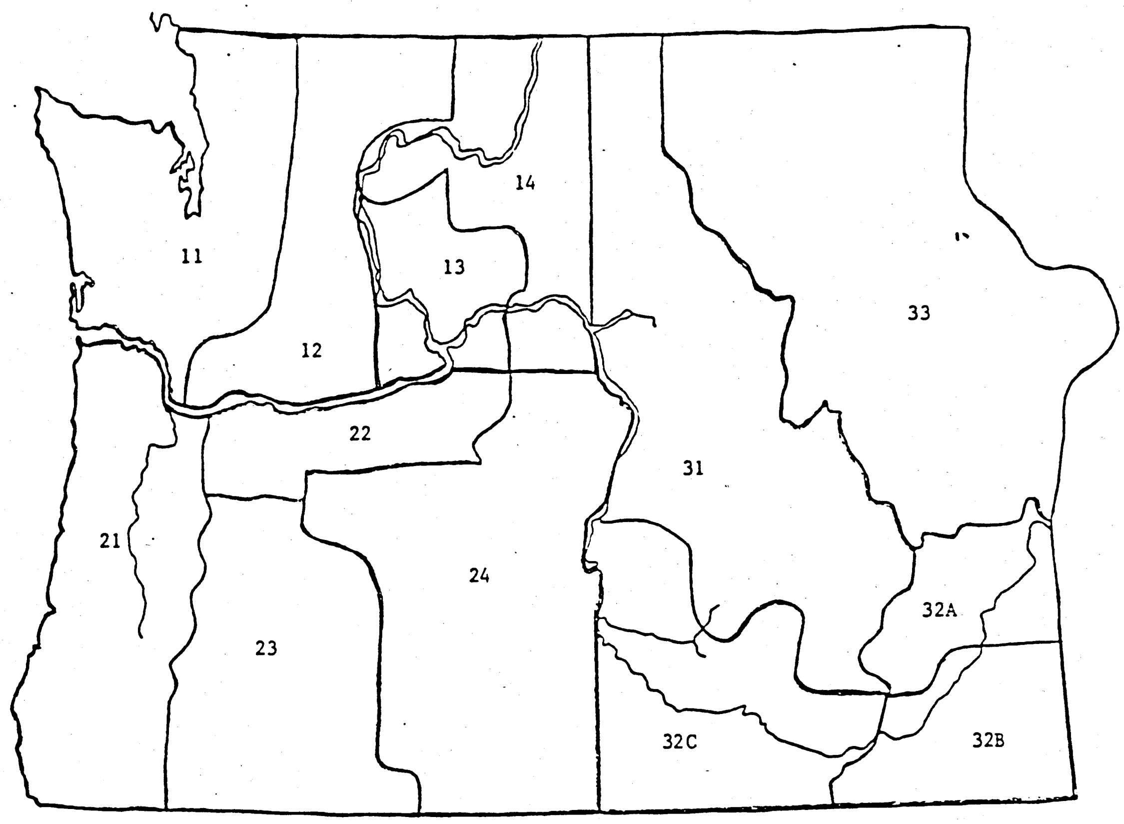

FIGURE 1. Pacific Northwest Agricultural Production Areas

NIR and other input usage. This model formulation allowed for a simultaneous consideration of trade-offs among irrigation efficiency, labor input, water application level, and the cost of electricity. A necessary assumption of the model was that the farmer could distribute the available water optimally over the irrigation season to achieve maximum attainable yield for the specified production conditions.

Several farm models were developed for each APA to represent the existing variety of production characteristics. The criteria for delineating farms within the APA's were crop mix, method of irrigation, pump lift for water supply, and, in the case of center pivot systems, whether high or low pressure application was used. In this manner, as many as 12 farm models were developed for each APA.

Prices for electricity vary widely throughout the region. A production area is commonly served by both public and investor-owned utilities, frequently charging different electricity rates and following different rate structures. The baseline rates used in the analysis were a weighted average of the existing rates within an APA. The rate a utility charges for selling electricity is made up of two components. The first is an energy charge based strictly on the amount of electricity the irrigator uses. The irrigator can influence this component of his power cost by choosing the amount of water that is pumped each season. The other component is a demand charge that is based on the horsepower requirements of the existing irrigation system, a factor difficult to alter in the short run. Table 1 shows the base line values of energy charges used for each APA in the region. Farmers can respond to all of the energy charge in the short run by adjusting water use.

TABLE 1. Average Electricity Rates, Breakdown by Energy and Demand Charges and Modified Base Electricity Rates

APA	1986 Average Electricity Rates (mills/kWh)	Percent Energy Charge	Percent Demand Charge	Model Base[1] Rates (mills/kWh)
11	40.75	70.00	30.00	34.60
12	30.75	73.62	26.38	26.69
13	23.40	63.77	36.23	19.16
14	25.51	77.20	22.80	22.34
21	36.02	92.10	7.90	34.60
22	31.09	66.83	33.17	25.93
23	38.47	76.65	23.35	33.98
24	34.16	57.70	42.30	26.94
31	44.12	73.06	26.94	38.18
32	36.77	59.36	40.64	29.30
33	46.00	72.12	27.88	39.59

SOURCE: Northwest Economic Associates, 1988.

[1]Model base rate = energy charge + 0.5 (demand charge).

However, they can respond to changes in demand charges in most cases only by changing pump horsepower requirements, which normally involves a change in technology or crops produced. In this study, it was assumed that farmers can affect up to 50 percent of any change in the demand charge in the short run by adjustments in the timing of pump use, a generous assumption.

The programming analysis considered electricity price increases of up to 50 mills/kWh above model base rates, though elasticities were calculated only for price increases up to 100 percent. Electricity price increases were assumed to be real rather than nominal, that is, inflation was not a factor considered in the study. Crop prices and production costs other than electricity prices were held constant at 1988 levels.

The crops selected for the programming model reflect the actual distribution of crops within an APA, the compatibility of crops and irrigation systems, and the agronomic requirements of crop rotations. The potential for adjusting cropping patterns in response to energy price changes had to be limited to that which was consistent with the agronomic requirements of crops and the bounds of market conditions that would reflect the fixity of short-run crop prices. Acreages of crops were allowed to vary within the limits of upper and lower bounds to meet the above criteria. Clearly these bounds were different for each major crop category.

In the short run, a farmer using sprinkler irrigation can respond in several ways when faced with rising energy costs. The crop mix can be changed, water application levels adjusted, irrigation efficiency increased with better management, and land can be taken out of production. The range of possible adjustments depends on the cropping pattern typical for the farm, the existing irrigation system, and the level of irrigation management and efficiency already in place. The farm models used were sensitive to this array of options available to the farmer.

RESULTS

Elasticities

A major objective of this study was to estimate the short-run price elasticity of demand for electricity in irrigated agriculture in the Pacific Northwest. These values were estimated using the arc elasticity formula:

$$E = \frac{\dfrac{Q_2-Q_1}{\frac{Q_2+Q_1}{2}}}{\dfrac{P_2-P_1}{\frac{P_2+P_1}{2}}}$$

where the subscripts on the price variable (P_i) and the quantity variable (Q_j) denote the end points for the price change, or arc. Elasticities were calculated for three ranges of percentage price increases: zero to 33 percent, 34 to 67 percent, and 68 to 100 percent. Table 2 presents the short run price elasticities of demand for electricity use in irrigated agriculture for each APA, state and the region. The elasticities are quite small with no elasticity having an absolute value greater than one. These values indicate that the demand for energy by irrigators is inelastic, implying that a change in the price of electricity has little effect on the quantity of energy

TABLE 2. Price Elasticities of Demand for Electricity by Irrigated Agriculture

Production Area	Energy Price Change		
	0-33%	34-67%	68-100%
11	-0.04	0.00	0.00
12	-0.07	-0.16	-0.20
13	-0.08	-0.34	-0.06
14	-0.16	-0.02	-0.02
WASHINGTON	-0.08	-0.23	-0.13
21	-0.001	-0.05	-0.05
22	-0.44	-0.23	-0.15
23	-0.05	-0.14	-0.40
24	-0.17	-0.18	-0.24
OREGON	-0.14	-0.14	-0.14
31	-0.01	-0.65	-0.08
32A	-0.05	-0.04	-0.21
32B	-0.16	-0.43	-0.05
32C	-0.14	-0.26	-0.08
IDAHO	-0.13	-0.32	-0.09
MONTANA	-0.33	-0.62	-0.06
PNW	-0.14	-0.27	-0.15

demanded. In general, the arc elasticities for small price increases, 0 to 33 percent, are lower than for the next increment of price increase. The regional elasticity at the lowest price increase is -.14 while comparable state values range from -.08 for Washington to -.33 for Montana.

The estimated elasticities shown in Table 2 are a measure of the response to energy price changes that would likely occur within 3-4 years following a price change. In most cases, the adjustment could occur within a single production period following a rise in energy costs. They reflect the changes in energy use that could be accomplished with managerial changes in water use under current technology. Such changes include increases in irrigation efficiency accomplished by substituting labor and management for water, imposed moisture stress through deficit irrigation, and modifications in crop mix. Within the range of energy price changes considered in this analysis, it was never desirable to retire land from production. It must be noted, however, that in this analysis only variable costs of production had to be recovered in order for production to continue. Adjustments to energy price changes do not include the potential changes in technology, crop mix, land use, or management that could occur in the long run. In most cases, the long-run elasticities would not differ greatly from those in Table 2. The major divergence would occur in areas dependent upon high pump lifts where land would return to non-irrigated use with large energy cost increases.

Farm Adjustments to Rising Energy Prices

The adjustments in irrigated agriculture that can follow an energy price change are varied. Different farms may respond in different ways. If current irrigation efficiency is relatively low, more options are available for adjusting irrigation management than if an irrigator has already made adjustments to proportionally higher electricity costs. The responses to energy price changes are described here for one model farm, a sideroll irrigated farm with a 400 foot pump lift.

To observe managerial responses to rising energy costs for the farm represented in Table 3, it is most instructive to move from left to right across the table. As energy prices climb, the farm makes adjustments to alfalfa, wheat, and dry bean production. When energy prices have risen by 26 percent the NIR of water for dry beans is reduced from 21 to 17 inches per acre and irrigation efficiency increases from 61 to 65 percent. A larger price increase (78 percent) stimulates a similar change in wheat production, dropping NIR from 21 to 18 inches per acre and increasing irrigation efficiency on wheat to 71 percent. Energy price increases to 182 percent above baseline levels call forth increased irrigation efficiency and lower NIR for alfalfa. The higher levels of irrigation efficiency for these three crops are typically obtained by smaller, more frequent water applications, and substituting irrigation labor and management for water and energy.

For the whole farm, the average NIR of water declines from about 25 inches per acre down to 19 inches per acre when energy prices have risen by 200 percent. Overall farm irrigation efficiency is increased from 69 to nearly 73 percent over this same price range, again indicating a substitution of labor for energy and water. Other effects of energy price changes can be noted in Table 3. Net returns to fixed assets are reduced about 50 percent by a 182 percent increase in energy cost. Gross farm income is affected much less. It will be noted from Table 2 that elasticities were calculated only for the first 100 percent increase in energy costs above baseline levels.

TABLE 3. Washington Side-Roll Irrigated Farm, 400-Foot Pump Lift, APA 13

	Unit	Base-line	29.55 (26)	35.65 (52)	41.76 (78)	47.86 (104)	53.97 (130)	60.07 (156)	66.18 (182)	72.28 (208)
			Energy Price in mills/kWh (percent price increase)							
Net Revenue	$/A	182.72	169.31	156.20	143.45	131.52	119.59	107.82	96.18	85.26
Gross Value	$/A	504.62	498.44	498.44	487.45	487.45	487.45	485.16	485.16	466.68
Alfalfa	%	31	31	31	31	31	31	31	31	31
	NIR	27	27	27	27	27	27	27	20	20
	IE	71	71	71	71	71	71	75	80	80
Pasture	%	10	10	10	10	10	10	10	10	10
	NIR	18	18	18	18	18	18	18	18	18
	IE	81	81	81	81	81	81	81	81	81
Wheat	%	48	48	48	48	48	48	48	48	48
	NIR	21	21	21	18	18	18	18	18	18
	IE	66	66	66	71	71	71	71	71	71
Beans	%	3	3	3	3	3	3	3	3	3
	NIR	21	17	17	17	17	17	17	17	17
	IE	61	65	65	65	65	65	65	65	65
Potatoes	%	7	7	7	7	7	7	7	7	7
	NIR	29	29	29	29	29	29	29	29	29
	IE	62	62	62	62	62	62	62	62	62
Avg. NIR	AI/A	24.89	23.02	23.02	21.57	21.57	21.57	21.57	21.57	19.40
Avg. Water Use	AI/A	36.01	33.85	33.85	30.81	30.81	30.81	30.06	30.06	26.68
Avg. IE		69.11	68.01	68.01	70.02	70.02	70.02	71.76	71.76	72.70
Energy Use	KWH/A	2788.25	2620.64	2620.64	2385.40	2385.40	2385.40	2327.46	2327.46	2065.88
Labor Use	HR/A	3.12	2.92	2.92	2.99	2.99	2.99	3.13	3.13	3.11
Labor Use	HR/AF/A	1.038	1.036	1.036	1.164	1.164	1.164	1.250	1.250	1.400

NIR = Net Irrigation Requirement
IE = Irrigation Efficiency

Changes in Aggregate Input Use

One impact of energy price changes is the change imposed on the use of other inputs as farmers adjust to lower energy use levels. Changes in the aggregate use of energy, water, irrigation labor, and land are discussed here. Entries in Table 4 are based on midpoint values of the price increase ranges

TABLE 4. Aggregate Input Use and Farm Income as Affected by Energy Price Changes

	Baseline	Energy Price Increase (percent) 16	50	84
Energy (GWH)	4,597	4,537	4,367	4,160
(percent Δ)	0	-1.3	-5.0	-9.5
Water (1,000 AF)	10,816	10,696	10,409	10,040
(percent Δ)	0	-1.1	-3.8	-7.2
Irrigation Labor (1,000 kWh)	10,785	10,784	10,824	10,849
(percent Δ)	0	0	0.5	0.6
Net Farm Income (million $)	1,280	1,264	1,234	1,201
(percent Δ)	0	-1.2	-3.2	-6.2
Gross Farm Income (million $)	2,887	2,884	2,875	2,863
(percent Δ)	0	-0.1	-0.4	-0.8

GWH = gigawatt hours

shown. For example, the 0-33 percent range is represented by a change of 16 percent.

Clearly, the use of energy is affected more than other inputs as the price of energy is increased. Throughout the range of energy price changes, the amount of aggregate energy use is adjusted about 1.0 percent for each 10 percent change in energy price. This is confirmed by the demand elasticities shown in Table 2.

The amount of water applied for irrigation is adjusted at a lower rate than is energy consumption as the energy prices change. In this case the rate of adjustment is about a .75 percent change in water use for each 10 percent change in energy price. Of course, the rates of adjustment are not uniform across farms or APA's within the region. Those areas currently operating with low energy costs and low pump lifts have relatively lower efficiencies of farm irrigation and the highest levels of water application. As the cost of energy is increased, these areas can more easily make adjustments in irrigation efficiency and input use than an area already operating near the permissible limit of the prevailing technology.

Irrigation labor is increased in response to the increased cost of energy. Labor is substituted for water to increase irrigation efficiency and reduce energy consumption. While the total amount of labor is not rapidly increased over the range of energy cost changes, the ratio of labor use to energy or water use is increased at a much faster rate. This is consistent with the expected managerial responses to shifts in relative factor prices.

In no case was land retired from irrigation in response to the considered energy cost changes. Also shown in Table 4 is the imposed change in net returns to fixed assets as energy prices increase. Short-run net farm income is reduced at a rate of about .65 percent for each 10 percent increase in the cost of pumping energy. Since cropping patterns and land use are not significantly altered, gross farm income is affected very little by the changes in energy cost.

CONCLUSIONS

It is important to note that all of the adjustments in input use and farm income described herein as a response to energy cost changes are strictly short run in nature. The elasticity of demand to energy price changes for irrigation pumping is quite low, generally below -.25 in the short run. Regional policy makers should not be seriously concerned about effects on irrigated agriculture by planned increases in nominal energy rates that range from 0 to 10 percent at the wholesale level. While this analysis has no specific reference to irrigated areas outside the Pacific Northwest, it is expected that similar results would be found elsewhere.

In the long run it is expected that the magnitude of response in each category would increase. There are additional adjustments in technology, crop mix, and particularly in land use that could further reduce the amount of energy used by agriculture. The entire amount of change in energy demand charge could be affected by changing the horsepower of irrigation pumps where that is compatible with other aspects of the prevailing irrigation technology and crop mix. Some high-pump-lift farms would possibly return to dryland agriculture in the long run, though this analysis gave no consideration to when that might occur.

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