THE ECONOMIC IMPACT OF IRRIGATION DEVELOPMENT IN IDAHO
AN APPLICATION OF MARGINAL INPUT-OUTPUT METHODS

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Abstract

Impacts of expanded irrigation in Idaho are estimated using marginal input-output. This allows input use for output increases to differ from the average input mix of existing sectors and allows new firms to use different technologies from existing firms. This captures effects of expanding energy intensive irrigation on limited hydropower supplies.

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I. Introduction

Input-output analysis is commonly used as a tool for economic impact analysis -- to measure the impact on regional production caused by some exogenous event (eg: Miernyk et.al. 1970; Powell et.al. 1981). The model is represented as (I-A)X=Y, where X are sector output levels, Y are final demands, and A are technical production coefficients. The coefficients a_{ij} are usually computed as the ratio of purchases of input i by sector j, divided by the total output of sector j, and thus represent the average production technology for existing firms in the sector. Impacts are usually computed using the deviation form of the inverted model $(I-A)^{-1} \Delta Y = \Delta X$. Impacts on sector output ΔX are given by the inverse matrix $(I-A)^{-1}$ times the change in final demand ΔY. In the algebraically equivalent form $(I-A)^{-1}A \Delta Y + \Delta Y = \Delta X$, ΔY represents the direct effect of changes in final demand impacting the economy, $A \Delta Y$ are the resulting changes in intermediate input use, and $(I-A)^{-1}A \Delta Y$ is thus a measure of the indirect and induced impacts.

Using average technical coefficients as outlined above may be acceptable if industries identical or similar to the impacting industry already exist in the economy. However many impacting industries, and many output level changes by existing industries can be expected to use production inputs in proportions different from the average of existing firms in the sector before the exogenous impact. This paper will use irrigation development in Idaho to demonstrate how marginal production relationships, as contrasted with the average relationships normally used, can be inserted into the input-output framework.

Marginal input-output attempts to model only marginal changes. Output levels are $X = X_0 + \Delta X$ where the base output X_0 is adequately described by $X_0 = (I-A)^{-1}Y$. In modeling marginal changes in output levels ΔX, one is not constrained to use the average coefficients A, but is free to use any more appropriate coefficient matrix B which incorporates available evidence of how marginal changes in sector output will effect input usage. Where sufficient evidence exists to justify making $B \neq A$, the resulting output levels are $X = (I-A)^{-1}Y + (I-B)^{-1}\ \Delta Y$.

The common procedure of adding a row and column to A to represent industries with technologies different from their respective sectors can be viewed as a marginal methodology. The procedure works well when the new industry produces a product distinguishable from existing industries in the sector. However if the same product is being produced already, then adding a new row and column fails to recognize consumers' indifference between the same product produced by two alternative technologies, and the model results may be badly biased.

A third way to incorporate marginal change information is in the expression $\Delta X = (I-A)^{-1}C\ \Delta Y + \Delta Y$, where the pattern of input usage by the impacting firms, matrix C, can be different from the coefficients of existing firms in A.

Thus there are three ways to incorporate marginal production information into input-output models: a) by defining a marginal technical coefficient matrix to describe the input use of all firms at the margin; b) this marginal matrix may involve the addition of rows and columns to represent alternative technologies, and; c) the impacting firms themselves may be assumed to use a different input mix from existing firms. Note that this implies three possible representations of technology: 1) the average technology used by existing firms in a sector; 2) the marginal technology for output changes by existing firms, and; 3) the technology of new firms entering the sector.

II. Characteristics of Idaho Irrigation Development

Irrigated agriculture is very important to Idaho's economy. Over 3.8 million acres are currently irrigated. At least that many more have soils and climate making them suitable for irrigation development. Early developers irrigated lowlands by streams using gravity diversion and application methods. Most remaining developable land is distant from and on high benchland above the rivers that would serve as water sources. Thus new irrigation uses large amounts of electricity for high lift pumping and for pressurizing the sprinklers needed to make efficient use of water. Clearly the technology of new irrigation is different from the technology used by most existing Idaho agriculture.

Because new irrigation is energy intensive, it will have large impacts on the energy producing sectors. Southern Idaho, until recently, was almost totally dependent on hydro-power for generating electricity. The low cost of hydro-power was the basis for growth of energy intensive agriculture and industry in the region. Now most of the good dam sites have already been developed and many of the remaining feasible sites are undevelopable because of environmental legislation. If new electric loads for new industry or irrigation are developed in Idaho, that load growth can only be served by building new thermal (coal) powerplants. Here again, marginal changes in energy production use a technology different from existing production of that sector.

New irrigation not only uses large amounts of electricity for pumping, it also diverts and consumes a large volume of water that is then unavailable for electricity generation. There are 21 existing hydroelectric structures downstream from American Falls Reservoir in southern Idaho with a total developed head of 2094 feet. Each acre-foot of water removed from American Falls Reservoir and consumed by new irrigation results in a loss of 1827 kilowatt-hours of potential downstream generation. For typical new irrigation in southern Idaho, the electricity used for pumping plus the power lost from water diversion is about 6000 kilowatt-hours per acre per year(equal to about one-third of the total annual use by a typical electrically heated house) which must be replaced by new thermal generation.

Growth of irrigated acreage would be accompanied by growth of the food processing sector. Potatoes and sugar beets are among the crops likely to be grown. Being bulky items, part of the potatoes and all of the sugar beets are likely to undergo processing before being shipped to markets outside the region.

Clearly there is reason to expect the marginal responses to development of large blocks of new irrigated land in southern Idaho to differ from average production relationships characterizing the existing economy.

III. Marginal Input-Output Analysis of New Irrigation

In this section a highly aggregated input-output model, adapted from Pongtanakorn (1981) is used to demonstrate how marginal input-output methods can be used to estimate the economic impacts caused by expansion of irrigation and food processing activities in southern Idaho.

The five sector transactions data shown in Table 1 represents the economy of a five county southwestern Idaho region in 1977. All sectors purchase their electricity needs from existing hydropower sources, and new thermal generation is assumed to be insignificant. Conventional input-output analysis would proceed by converting this base transactions table to a base technical coefficient table by dividing each cell by its column sum. The resulting matrix would then be inverted and used to compute multipliers and impacts.

However the conventional approach has implications which are inconsistent with what we know about how new irrigation would impact the regional economy. Most troubling is the implication that increases in the electricity needs of the various sectors would continue to be supplied from old hydropower sources, which we know are actually near capacity and can't be expanded. To reflect this knowledge, a marginal technical coefficient table (Table 2) is formed to show that changes in electricity use will be supplied by new thermal powerplants. The technical coefficients for such a thermal plant form the new thermal electricity column of Table 2. The addition of a new row and column to represent thermal electricity in the marginal matrix is a valid step in this case because of the absolute unavailability of increased hydropower. Users are forced to cut back their use of hydropower as new irrigation is developed, because water diversion makes less of it available. They will increase their use of thermal electricity to compensate for the lost hydropower.

To find the impact of new irrigation and related food processing it is necessary to have information on the expected direct changes in input

Table 1. Base Transactions Table.

	Agric.	Food P.	Elect.	Other	House.	Other F.D.	Total
Agric.	59.4	75.3	0.0	78.8	9.0	105.7	328.2
Food P.	.4	186.3	0.0	9.8	9.7	347.9	554.1
Elect.	.3	.6	1.9	28.7	17.8	4.9	54.2
Other	36.6	80.1	3.7	975.3	2548.5	1209.5	4853.7
House.	135.9	117.4	37.6	2914.9	49.4	386.8	3642.0
Import	95.6	94.4	11.0	846.2	3194.1	569.3	4810.6
Total	328.2	554.1	54.2	4853.7	5828.5	2624.1	14242.8

Table 2. Marginal Technical Coefficients

	Agric.	Food P.	Hydro E.	Thermal E.	Other	House.
Agric.	.181	.136	.000	.000	.016	.002
Food P.	.001	.336	.000	.000	.002	.002
Hydro E.	.000	.000	.000	.000	.000	.000
Thermal E.	.001	.001	.035	.065	.006	.003
Other	.112	.145	.068	.056	.201	.437
House.	.414	.212	.694	.150	.601	.008
Import	.291	.170	.203	.729	.174	.548
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table 3. Direct Effects of Irrigation Development on Transactions.

	Agric.	Food P.	Hydro E.	Thermal E.	Other	House.	Other F.D.	Net Use
Agric.	.800	21.200	.000	.000	.000	.000	29.300	.800
Food P.	.000	1.000	.000	.000	.000	.000	44.900	1.000
Hydro E.	-.017	-.032	-.105	.000	-1.588	-.986	-.272	-3.000
Thermal E.	6.717	.132	.105	.000	1.588	.986	.272	9.800
Other	7.300	6.500	.000	.000	.000	.000	.000	13.800
House.	21.800	9.500	.000	.000	.000	.000	.000	31.300
Import	13.900	6.600	.000	.000	.000	.000	.000	20.500
Total	50.500	44.900	.000	.000	.000	.000	74.200	74.200

Table 4. Computation of Indirect and Induced Effects.

Impact on:	Impacts from Changes in Usage of: Agric.	Food P.	Hydro E.	Thermal E.	Other	House.	Total Impact
Agric.	.990	.269	-.054	.058	.574	.670	2.507
Food P.	.005	1.512	-.017	.017	.128	.225	1.870
Hydro E.	.000	.000	-3.000	.000	.000	.000	-3.000
Thermal E.	.007	.010	.137	10.507	.221	.322	10.930
Other	.550	.825	-2.167	2.440	26.255	26.351	54.254
House.	.748	.937	-3.458	3.095	16.207	47.895	65.424

usage that result from such a change. The development example used in this paper is the 111,000 acre proposal for southwest Idaho studied in a recent environmental impact statement by the Bureau of Land Management (BLM,1979) and also used as an example in Pongtonakorn (1981). Table 3 shows estimates of the input usage to produce the $50.5 million in crops expected from the tract. Of this, $21.2 million would be processed and $29.3 million would be exported directly from the region. The entire food processing output of $44.9 million would be exported.

Table 3 also accounts for the loss of hydropower from increased irrigation water use. BLM computed the hydropower loss to the Idaho Power Company which serves the study region, as about 150,000 megawatt-hours per year. This loss would have a value of about $3.0 million. Table 3 distributes this loss across all sectors in proportion to their base use of electricity, and shows the loss being replaced by an equivalent amount of thermal power.

In Table 3, the other final demand column (exports) can be viewed as ΔY of the expression $\Delta X = (I-B)^{-1}C\ \Delta Y + \Delta Y$. The net use column of the table corresponds to $C\ \Delta Y$. Note that this defines three levels of technology. The average technology A describes the base output levels X_0. The marginal technology B describes how existing sectors react to new irrigation. And the impacting technology C characterizes the energy intensive nature of new irrigation, the particular characteristics of new food processing, and the distribution of the hydropower losses.

These net direct changes in intermediate input use must be supplied by existing sectors of the economy. Supplying these new demands will cause further increases in demand for goods -- both as inputs to production activities and as consumption goods demanded by households in response to increased income. These indirect and induced effects attributable to new irrigation are calculated according to the expression $(I-B)^{-1}C \Delta Y$ -- as the inverse of the marginal coefficient matrix times the net direct use of intermediate inputs. This calculation is shown in Table 4, with the last column being the total indirect and induced impact of new irrigation.

For some uses it would be sufficient simply to add the direct effects ΔY from Table 3 to the indirect and induced effects $(I-B)^{-1}C\Delta Y$ from Table 4 to give the total effects of new irrigation on sector output levels. In many cases however, it would be useful to have greater detail in the results -- showing all of the changes in transactions caused by new irrigation. Table 5 distributes the total indirect and induced impacts (the total row) back into the input providing sectors using the marginal technology matrix B. The direct change in transactions (Table 3) can be added to the indirect and induced transactions changes (Table 5) to give Table 6, the total change in transactions attributable to the new irrigation development. Adding the base transactions to the change in transactions gives Table 7 which shows the resulting pattern of transactions after the development of the 111,000 acres of new irrigation.

The detail in Tables 3 and 5 allow examination of the effects of development on household income. The \$50.5 million increase in crop output results in a \$65.4 million increase in household income. Of the total income increase nearly half accrues to other, about one-third to new irrigation, and most of the remainder to new food processing. The income impacts for most of the rest of the households are quite small, although

Table 5. Indirect and Induced Effects of Irrigation Development on Transactions.

	Agric.	Food P.	Hydro E.	Thermal E.	Other	House.	Total
Agric.	.454	.254	.000	.000	.868	.131	1.707
Food P.	.003	.628	.000	.000	.109	.131	.871
Hydro E.	.000	.000	.000	.000	.000	.000	.000
Thermal E.	.003	.002	-.105	.710	.326	.196	1.132
Other	.281	.271	-.204	.612	10.905	28.590	40.455
House.	1.038	.396	-2.082	1.640	32.607	.523	34.122
Import	.730	.318	-.609	7.968	9.440	35.852	53.699
Total	2.507	1.870	-3.000	10.930	54.254	65.424	131.986

Table 6. Total Marginal Transactions Change from Irrigation Development.

	Agric.	Food P.	Hydro E.	Thermal E.	Other	House.	Other F.D.	Total
Agric.	1.254	21.454	.000	.000	.868	.131	29.300	53.007
Food P.	.003	1.628	.000	.000	.109	.131	44.900	46.770
Hydro E.	-.017	-.032	-.105	.000	-1.588	-.986	-.272	-3.000
Thermal E.	6.722	.134	.000	.710	1.914	1.182	.272	10.930
Other	7.581	6.771	-.204	.612	10.905	28.590	.000	54.254
House.	22.838	9.896	-2.082	1.640	32.607	.523	.000	65.422
Import	14.630	6.918	-.609	7.968	9.440	35.852	.000	74.200
Total	53.007	46.770	-3.000	10.930	54.254	65.424	74.200	301.646

Table 7. Transactions Table with Irrigation Development

	Agric.	Food P.	Hydro E.	Thermal E.	Other	House	Other F.D.	Total
Agric.	60.654	96.754	.000	.000	79.668	9.131	135.000	381.207
Food P.	.403	187.928	.000	.000	9.909	9.831	392.800	600.870
Hydro E.	.283	.568	1.795	.000	27.112	16.814	4.628	51.200
Thermal E.	6.720	.134	.000	.710	1.914	1.182	.272	10.930
Other	44.181	86.871	3.496	.612	986.205	2577.090	1209.500	4907.954
House.	158.738	127.296	35.518	1.640	2947.507	49.923	386.800	5893.924
Import	110.230	101.318	10.391	7.968	855.640	3229.952	569.300	2698.300
Total	381.207	600.870	51.200	10.930	4907.954	5893.924	2698.300	14544.446

it is interesting to note that the electricity sector actually shows a small income loss as depreciated hydro plants are replaced with externally financed thermal plants.

IV. Conclusions

The use of input-output procedures for economic impact analysis is occasionally criticized because such studies usually contain the embedded assumption that marginal changes in sectoral output will be accomplished using the average input mix observed in industries currently in the sectors. This paper has shown, using an example based on development of 111,000 acres of new energy intensive irrigation in Idaho, that these implicit assumptions can profitably be relaxed. Rather than basing the input-output technical coefficient table on the average technology of existing firms, if superior information exists about how firms will react for marginal changes from current output levels this superior data can be incorporated into a marginal technical coefficient table. This marginal table can then be inverted and used to describe the marginal changes in an economy caused by an external impact. This more flexible approach to input-output impact analysis expands the range of problems to which the input-output methodology can usefully be applied and should increase both the validity and credibility of the results obtained.

Regarding the empirical results in this paper, several cautions are in order. The input-output tables taken from Pongtanakorn (1981) and used as the basis for this paper are provisional and would benefit from more work. More credible basic Idaho input-output tables must be completed before definitive results are possible.

The electricity sector impacts are of particular concern since hydropower lost to irrigation water use is a very cheap power source -- costing only a fraction of what it costs to generate replacement power using coal fired plants. The paper shows that new irrigation directly consumes $6.7 million of electricity, causes the loss of $3.0 million of hydropower, and is indirectly linked to $1.1 million of increased electricity use by other sectors. If these results are confirmed by empirical work based on a better basic input-output table with more accurate estimates of the electricity coefficients, then new irrigation in Idaho can be expected to have a large electricity price impact as the average cost utility pricing mechanism averages together a shrinking amount of cheap hydropower with a rapidly growing and expensive thermal share. These price increases could threaten Idaho's comparative advantage in some industries, including agriculture, that have grown up during an era of cheap hydropower. Such price effects are of course beyond the scope of the methodology discussed in this paper, although an attempt is being made to incorporate price effects in our continuing empirical work using procedures proposed by Lee, Blakeslee, and Butcher (1976).

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