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An Analysis of the Effects of the Impacts of Oil Shale Development on the Economy of the Uintah Basin

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AN ANALYSIS OF THE EFFECTS OF THE IMPACTS OF OIL SHALE DEVELOPMENT ON THE ECONOMY OF THE UINTAH BASIN

by

David Zachary Kaufman

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ABSTRACT

An Analysis of the Effects of the Impacts
of Oil Shale Development on the
Economy of the Uintah Basin

by

David Zachary Kaufman, Doctor of Philosophy

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Major Professor: Dr. John Keith
Department: Economics

The development of oil shale resources will have a significant impact on the Uintah Basin in Utah. To analyze this impact, this study used a regionalized imput-output model. The input-output table for the State of Utah was revised to fit the Uintah Basin, using the RAS technique.

The scarcity of water in the Basin may cause a shift of water use from irrigated agriculture to oil shale. This reduction in agricultural production was estimated, using demand curves for water in agriculture and an intergen programming model which generated minimum water requirements for shale developments from 25,000 barrels per day to 250,000 barrels per day.

The inclusion of agricultural decline and of the shale industry's rows and columns, based on previous studies, allowed the estimation of a type IV multiplier. The input-output table was closed, and regional gross output estimated for the various levels of shale production.

Results indicate very large changes in retail and wholesale trade, real estate and housing, and public service sectors for high levels of shale production. The loss in agricultural production appears to have almost insignificant effects in comparison. Local planners may be faced with providing significant increases in services, and a large expansion of the private sectors if shale development is substantial.

(86 pages)

CHAPTER I

INTRODUCTION

In late 1973, as a result of the OPEC[1] embargo on the United States, interest in the development of oil shale fields as a domestic source of energy increased. These fields are located in Southwestern Wyoming, Western Colorado and Eastern Utah. They comprise the total known deposits of oil shale in the United States and have been estimated to contain between 600 billion and 1.8 trillion barrels of petroleum.[2]

In 1974 the U. S. Department of the Interior auctioned off the rights to develop the oil shale resources on two tracts of land in Utah's Uintah Basin. Since then there has been considerable interest in the economic impact that oil shale development may have on the surrounding region. This interest has been particularly intense because the surrounding counties are sparsely populated and economically dependent on irrigated agricultural land.

The problem

The development of an oil shale industry will have substantial impacts on imports, exports and most of the other sectors of the region's economy. These impacts however, will be different depending on which

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[1] Organization of Petroleum Exporting Countries.

[2] United States Federal Energy Administration. Project Independence Blueprint Final Task Force Report Water Requirements, Availabilities Constraints and Recommended Federal Actions. November 1974.

combination of the two possible technologies for extracting petroleum from the shale rock is selected.

The two technologies are known as in-situ and surface retorting. In-situ retorting is a process whereby the oil is extracted from the shale below ground. The oil is then funneled above ground for collection and further processing. Surface retoring processes the shale rock above ground. Once the oil is extracted from the rock, the remaining rock must be disposed of. As may be expected from the differences is the processes, the input requirements for each are quite different. As a result, the regional impacts are different.

At present, the in-situ process is expected to develop more slowly than the surface process.[3] In fact, there are already several small, experimental, surface retorting plants in operation. There are no in-situ plants in operation at present.

Both of these two technologies for the production of crude oil from shale rock will utilize large quantities of water. However, there does not exist a sufficient amount of water in the Uintah Basin to reliably provide for both the demands of the incipient oil shale industry and the current water usage. Water used as an input to agriculture has been found to have the lowest value of the marginal product of any use in the Basin.[4] Therefore, if the oil shale industry is developed, agriculture will likely be constrained as water is transferred from low valued agricultural use to high valued use by the oil shale industry.

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[3] Ibid.

[4] M. H. Anderson, "On Economic Analysis of Demand and Supply for Irrigation Water in Utah: A Linear Programming Approach" (MS thesis, Utha State University, 1974).

The focus of this dissertation will be to project the direct and indirect effects of both the introduction of the shale industry and the changes in agriculture on the economy of the Uintah Basin.

The objective

The primary objective of the dissertation is to analyze the impact of potential oil shale development on the economy of the Uintah Basin. There are two components of this analysis: First, the change in agricultural activity resulting from the transfer of water to oil shale will be estimated for various oil shale industry sizes; and second, the direct and indirect economic impacts of both the incipient oil shale industry and the resulting changes in agricultural activity will be examined. To do this, a regional growth model which projects change in both the oil shale and agricultural sectors must be developed.

A secondary objective is to develop a methodology that can be used in analyzing any situation in which regional economic impacts result from new industrial development.

Procedure

In order to examine the effects of the transfer of water to the oil shale industry from agricultural production, the residual supply of water from agriculture must be compared to the demand for water by the oil shale industry. As water is transferred to the shale sector, the increase in value added to the shale industry and the decrease in value added to the agricultural sector may be used in a selected regional growth model so that the impact of the direct and secondary effects of shale development may be analyzed.

The flow chart below provides a step-by-step breakdown of the tasks necessary to accomplish the desired analysis.

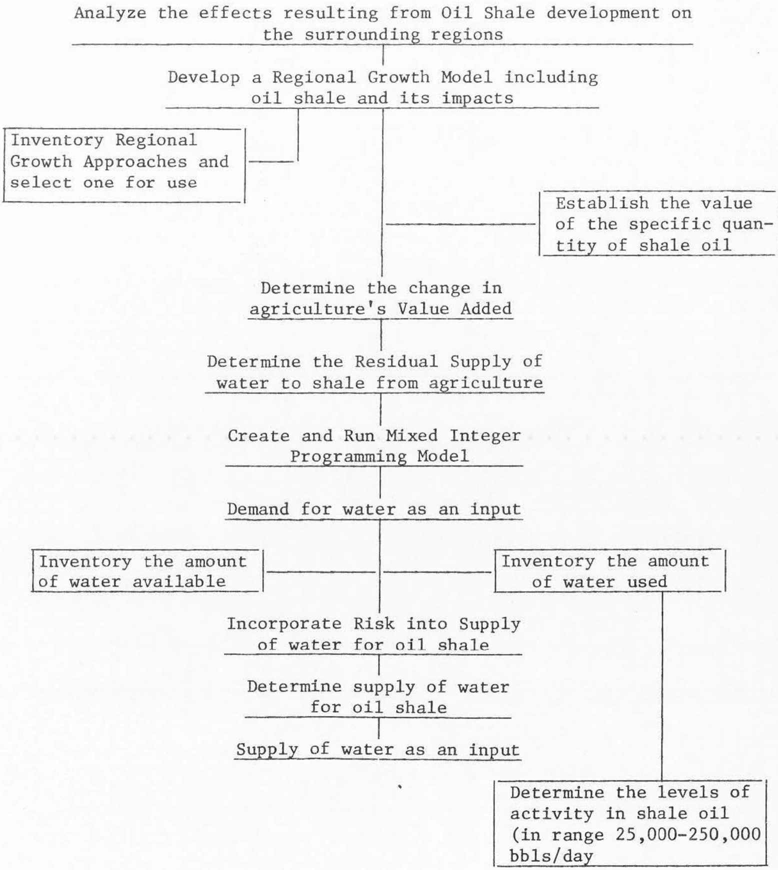

Figure 1. Procedure used to accomplish the desired analysis.

The first step, then, is to determine the most appropriate theoretical framework. This is done in the following chapter.

CHAPTER II

SURVEY OF LITERATURE ON REGIONAL GROWTH MODELS

The purpose of this survey is to identify the various approaches to studying regional growth. This is done so that the most appropriate model and methodology can be selected for use in the dissertation. As will be seen below, the most appropriate technique is Input-Output analysis. There are three other types of models available: multiplier theories, accelerator theories, and the export-base and employment multiplier theory. Each of these last theories however, has sufficient theoretical and empirical inadequacies to be rejected as the analytical approach, as is demonstrated below.

Multiplier theory

Both the multiplier and accelerator theories are based on a Keynesian model of the national economy. They are designed so that all the regions may be summed up to arrive at the national totals. A characteristic multiplier model is below:[1]

Ya = the change in GNP in region A

CA = the change in consumption in region A

Tda = the change in direct tax

Tia = the change in indirect tax payments in region A

---

[1] A. J. Brown and Associates, "Regional Multipliers," In Regional Economics: A Reader, ed. H. W. Richardson (New York: McMillan and Co. Ltd., 1970), pp. 69-71.

Ga = the change in government expenditures on value added in region A

Ma = the change in imports in region A

RA = the change in transfer payments in region A

$$Ya = Ca + Ga - Ma - Tia.$$

If

$$Ca = c(Ya - Tda + Ra)$$

$$Tda = t_d Ya$$

$$Tia = t_i Ca$$

$$Ra = -uYa$$

$$Ma = m_a Ca$$

then

$$Ya = cYa(1 - t_d - u)(1 - m_a - t_i) + Ga$$

$$= \frac{Ga}{1 - c(1 - t_d - u)(1 - m_a - t_i)}$$

The solution for Ya works out very neatly in theory. Unfortunately, when utilizing the theory there are several problems.

> Only if the marginal propensity to consume out of "home-produced" (region r) goods and services and the marginal propensity to import goods and services from region s are known will the precise level of direct impacts on region r and region s be calculable. There is no a priori reason for believing either one of these marginal propensities to be greater than the other.[2]

In addition, the model makes no provision for the possibility of changing amounts of capital (investment), labor and technology.[3]

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[2] J. I. Round, "Regional Input-Output in the U. K.: A Reappraisal of some Techniques," Regional Studies 6(1) (March 1974):3.

[3] W. Cris Lewis, Lecture of May 10, 1976.

Hartman and Seckler[4] Also contend that there are theoretical problems with the model when it is used in a dynamic situation. They contend that a region cannot generate its own growth due to the outward leakages of income, investment and imports. In addition, they demonstrate that there does not exist a clear and defined warranted rate of growth resulting from the use of the model.

Finally,

> the multiplier is an *UNDERESTIMATE* (italics the author) of the likely increase in regional income. The reason is that as income increases imports from other regions will increase. This will cause income in other regions to increase as their exports increase. As income in other regions increases, the other regions will buy more exports from the region in question with the original increase in exports and income so that exports will shift upward again.[5]

Since many of the exogenous variables in the model are either highly unreliable or unavailable for small regions, the multiplier approach appears to be unusable.

Accelerator models

Accelerator models were designed, at least in part, to deal with some of the problems models using regional multipliers faced. Characteristically, a dynamic accelerator would appear as below:[6]

---

[4] L. M. Hartman and David Seckler, "Towards the Application of Organic Growth Theory to Regions," In Regional Economics: A Reader ed. H. W. Richardson (New York: MacMillan and Co., Ltd., 1970), pp. 98-106.

[5] H. O. Nourse, Regional Economics (New York: McGraw-Hill Book Co., 1968), p. 160.

[6] A. Peaker, "Regional Growth and Economic Potential--a Dynamic Analysis," Regional Studies 5(2) (July 1971): 49-54.

$$Y_1 = AK_1^a$$

$$Y_2 = AK_2^a$$

$$\dot{K}_1 = aY_1 + b(EP_1 - EP_2)$$

$$\dot{K}_2 = cY_2 + d(EP_2 - EP_1)$$

$$EP = Y_1/p + Y_2/p+q+r$$

$$EP_2 = Y_1/p+q+r + Y_2/r$$

a,b,c,d greater than or equal to 0.

Where

$\dot{K}$ = dK = Investment

Y = output

K = regional capital stock

EP = economic potential

q = interregional cost of transport

p,r = intra-regional cost of transport of regions 1 and 2 respectively.

This model fails to consider changes in labor and technology. Furthermore, consideration must be given to autonomous as well as induced investment. Finally, the model is incomplete without a theory of structural change.[7]

Data for capital stock, investment, and transport costs are difficult to obtain in many cases and relatively unreliable. These problems tend to preclude the use of this in a study such as the one being undertaken here.

---

[7] Nourse, p. 160.

The export-base theory and the employment multiplier

The export base theory and the employment multiplier are used together so frequently that they may be considered to be virtually one theory. The theory starts by assuming 1) that regional exports are autonomous; 2) that changes in regional income are a function of regional exports; and 3) that income is a function of total employment.[8]

Total employment is used as a proxy for production and income in a region. Then, using the location quotient (or a modification of it) split total employment into employment for producing export (basic) and non-export (non-basic) goods. If it is assumed that the marginal propensity to consume is equal to the average propensity to consume:

$dY = \frac{1}{1-s} dX$. Using employment proxies,

dY is defined as the change in total employment N

dX is defined as the change in basic employment N_b

s is defined as N_b/N.

Therefore:

$$\frac{1}{1-s} = \frac{1}{N_b/N} = N/N_b.$$ [9]

There are a number of theoretical problems to this model. First, the theory ignores imports and the multiplier effects of import

[8] Steven J. Weiss and Edwin C. Gooding, "Estimation of Differential Employment Multipliers in a Small Regional Economy," In Regional Economics: A Reader, ed. H. W. Richardson (New York: MacMillan and Co., Ltd., 1970), pp. 55-68.

[9] Nourse, p. 161.

substitution.[10] Second, the theory ignores the differences among industries in the degree of interindustry linkage in production.[11] Third, the "theory fails to illuminate the key role a diversified service sector may ... play in the development of larger regions."[12] Fourth, the theory doesn't take into account regional differences in wages and productivity.[13] Fifth, there is some question as to the stability over time of the basic employment: non-basic employment ratio. Finally, the marginal propensity to consume locally increases as the income and population of the region increases. This is due to a decreasing marginal propensity to import into the region as the region grows.[14] These objections indicate that the export-base approach allows only a gross indication of economic impacts.

Input-output (I-O) analysis

Input-output analysis was originated by Wassily Leontief in the late 1930s for use in international economics. Within a short period its value in regional and interregional economic analysis was recognized. I-O analysis has two major assumptions:[15]

---

[10] Weiss and Gooding.

[11] *Ibid.*

[12] *Ibid*, p. 56.

[13] *Ibid.*

[14] Nourse, p. 163.

[15] H. W. Richardson, *Input-Output and Regional Economics* (New York: Halstead Press, 1972).

1. There exist relatively few outputs when compared with the mathematical complexity of the Walrasian system. In other words, there are a quantifiable number of outputs.

2. The supply equilibrium for labor and the demand equilibrium for final consumers are abandoned and the remaining production equilibrium is expressed in the simplest linear form. This means that regardless of the amount of labor available, only a certain amount will be used. Furthermore, the amount of labor used will be determined by the amount of capital used. In addition, regardless of the demand for final products, the ratios of the different amounts of goods produced will be constant. As a result of these two assumptions the

> Essence of Leontief's model is the technological relationship that the purchases of any sector (except final deman) from any other sector depend, *via a linear production function* (italics the author) on the level of output of the purchasing sector.[16]

Therefore, the I-O model assumes away economies of scale and factor substitutions (except under certain conditions as stated in the Samuelson Theorem[17]).[18]

Despite their rigidity, "the implausible assumptions of the production function straitjacket do not appear to have turned out too badly."[19]

---

[16] Ibid., p. 8.

[17] Samuelson's Theorem is: Assume 1) each industry has one output; 2) each industry uses only one scarce primary factor of production which is homogeneous in all industries; and 3) constant returns to scale. Then: 1) even if there are a wide number of alternative production processes it is compatible with efficiency to use only one; and 2) the same process will be used regardless of the commodity composition of the net output of all industries combined. Furthermore, this will occur regardless of the quantity of labor available.

[18] Richardson, p. 8.

[19] Ibid.

In fact, if one applies Friedman's criteria for a good model[20] "I-O models pass the critical test in that for many purposes they predict reasonably well."[21]

Each X_{ij} indicates how much the jth industry consumes from the production of each of the i^{th} industries. The F_i are the components of the Final Demand vector. The elements of the Final Demand vector express how much of each industry's production is sold to a user who does not, in turn, treat the purchased product as an input into a new production process. Final Demand is also a balancing item. Input-output theory indicates that the sum of all rows and columns must be equal. A change in, for example, Value Added, must produce a corresponding change in Final Demand so that the sum of each column equals the respective sum of each row. The Final Demand vector is composed of Investment, Exports, and Federal, State, and Local Government expenditures. The Value Added row vector is composed of Profits and Payments to Labor.

Now let a_{ij}, known as the direct coefficient, be defined as Xij/X.j where Xij is a flow in the transaction matrix. Then

$$X._1 = a_{11}X._1 + a_{12}X._2 t \ldots t a_{1N}X._N + a_{1N+1}\ H. + F,$$

$$X._2 = a_{21}X._1 + a_{22}X._2 t \ldots t a_{2N}X._N + a_{2N+1}\ H_N + F_N$$

$$\vdots$$

$$X._N = a_{N1}X._1 + a_{N2}X._2 t \ldots t a_{NN}X._N + a_{NN+1}H_N + F_N$$

---

[20]See Milton Friedman, "The Methodology of Positive Economics" in Readings in Microeconomics, ed. Briet & Hockman (New York: Holt, Rinehart and Winston, Inc., 1968), pp. 23-47.

[21]Richardson, p. 8.

		Consuming Sectors 1	2	...	N	House-hold	Final Demand
Producing sectors	1	X_{11}	X_{12}	---	X_{1n}	H_1	F_1
	2	X_{21}	X_{22}	...	X_{2n}	H_2	F_2
	.						
	.						
	.						
	N	X_{n1}	X_{n2}	...	X_{nn}	H_{n1}	F_n
Value Added		Xn+11	Xn+12	...	X_{n+1}	H_n	
Total		$X_{.1}$	$X_{.2}$	...	$X_{.n}$	H	

Figure 2. An example of an I-O model.

This can be arrayed in matrix form as

$$X = AX + F$$

$$(I - A)X = F$$

$$X = (L - A)^{-1}F$$

$$X = BF$$

where b_{ij} is the change in output of industry i when the final demand for industry j's product increases. Using the b_{ij}'s, it is possible to compute the direct, indirect and secondary effects on regional income resulting from a change in final demand.[22]

[21] Ibid, p. 32-33.

The vector X is known as the Gross Output vector. It should be noted, however, that this vector includes an Import sector. Imports are also included in the total output of each sector since each row contains an a_{ij} for imports. Thus, a certain amount of double counting is unavoidable.

I-O analysis does have its limitations. Perhaps the best critique of I-O models was made by Dr. Charles M. Tiebout in 1957:[22]

> The criticism of regional input-output analysis may well start with the whole issue of production coefficients. ... Three aspects of regional production coefficients; (1) the use of national coefficients at the regional level; (2) the use of average coefficients; and (3) the implications of the spatial component of the production coefficient.
>
> The failure to handle product mix adequately can lead to some ridiculous results in determining net exports and imports. ... The final problem relating to product mix and net exports and imports, comes in determining the regional multipliers. ... In measuring the imports and exports leakages is understated. It is impossible with the data now available to estimate this error, but it may be substantial.
>
> The final operational criticism of input-output models deals with agglomeration considerations in regional impact studies. It is argued that once the new industry is established in a region other industries will agglomerate and they, in turn, will need inputs. Just which industries will agglomerate, ..., can be decided on the basis of location theory. ... Location theory is not in a condition to predict at the fine margin this analysis requires. At best, all that can be hoped for is a rough approximation.[23]

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[22] Charles M. Tiebout, "Regional and Interregional Input-Output Models: An Appraisal," Southern Economic Journal 24(2) (October 1957): 140-147.

[23] Charles M. Tiebout, "An Empirical Regional Input-Output Projection Model: The State of Washington 1980," Review of Economics and Statistics 51 (1969): 334-340. It is interesting to note that despite his reservations, Tiebout did use I-O analysis, most notably in the study cited above.

Despite these reservations, input-output analysis is the most appropriate methodology for this study for two reasons. First, a recent input-output transaction table is available for the State of Utah and a methodology exists for creating an input-output table for a specific sub-state area from the state table. Second, and most importantly, with input-output analysis a region's economy can be examined in much more detail than any other technique permits.

CHAPTER III

THE THEORETICAL MODEL

Regionalization of a state input-output table

Given the decision to use input-output analysis, the choice as to which I-O model ought to be used is relevant. The area under study is the Uintah Basin--a four-county region in East-Central Utah.[1] Ideally, the appropriate I-O model is one which exactly reflects the economic structure of the region. Such a model does not exist. There does exist however, an I-O model for the entire State of Utah. In addition, there is a proven technique for adapting the State model to the smaller region. This process of adaptation is known as "regionalization."

Addition of the shale sectors

Once regionalization has been accomplished, additional information must be obtained before the I-O model may be used. First, the direct coefficients vector for the oil shale sector must be obtained. These coefficients must then be incorporated into the I-O model's matrix. Changes in the final demand for oil from shale may be computed by multiplying the price of oil (F.O.B. Denver, Colorado) by the specific quantity of oil because all oil is exported from the basin.

---

[1]The four counties are Carbon, Duchesne, Emery and Uintah which together form a defined hydrologic region for which data are readily available.

Different scenarios may be created by arbitrarily varying the quantity of oil produced from shale.

Water transfer and changes in the agricultural sector

Changes in the final demand for agriculture may be derived from the change in agricultural productions resulting from oil shale development. The residual supply of water as an input to the oil shale industry must be determined, and it is necessary to know the minimum amount of water required by the shale industry. It is this amount which will be transferred from agricultural use to use by the oil shale industry. This minimum amount of water is determined by the use of a mixed-integer programming model. For the mixed-integer model to operate the demand for water as an input by the oil shale industry must be known.

Water demand by the oil shale industry

The only demand for water which has been developed to date for the oil shale industry is in the form of requirements; i.e., three gallons of water are required for each gallon of crude oil extracted from shale rock. As a result, it is assumed for the purposes of this dissertation that the demand for water is infinitely price inelastic.[2] By this it is meant that no change in the price of water will have an effect on

[2] A 100,000 bbl/d oil shale plant is variously estimated as having a fixed cost of between $500,000,000 and $1 billion. On that scale, the cost of water is proportionately very small. In fact, the Federal Energy Administration, in an unpublished paper of July 1974, discovered that increasing the price of water 10 times would not affect the price of oil produced from shale by more than 0.5 percent.

the quantity of water demanded. In order to remain consistent with I-O theory, fixed coefficients of production are assumed.[3] In addition to this theoretical reason, this assumption is made because the empirical data necessary for the implementation of any other assumption is unobtainable. Furthermore, it is assumed that any oil shale plant will produce output at its maximum capacity. This assumption is designed to prevent the intrusion of substitution effects and prevent economies of scale for which no data is available. Finally, it is assumed that the stated plant output is actual, not expected, output.[4]

The next problem is to determine the minimum water requirements associated with the various levels and types of oil shale development which might reasonably be expected to occur.

The mixed-integer programming model

The objective of this programming model is to minimize the amount of water required by a shale industry of varying size. To determine this minimum water requirement, the model examines each combination of technology and plant size (25,000 bbl/d and 50,000 bbl/d for the in-situ retorting process and 50,000 bbl/d and 100,000 bbl/d for the surface retorting process). In this way, the adverse effects on the agricultural industry will also be minimized.

---

[3] Fixed coefficients of production means that to produce quantity Q of oil, the production process uses only X quantity of labor and Y quantity of capital. Excess quantities of either input will be unused.

[4] Gary M. Roodman, "The Fixed Coefficients Production Process under Productions Uncertainty," Journal of Industrial Economics 20(3) (1972): 273-286. Roodman points out that when risk and fixed coefficients of production are used, one can speak of optional levels of inputs. Empirical data is not available to permit this however. These assumptions are therefore made so that the theory and the available data are compatible.

The first step is to determine the water requirement for each combination of technology and plant size. The data were obtained from the Project Independence Blueprint and may be found in the mixed-integer programming model specifications below.[5] The second step is to determine the "best," that is, the least water consuming, mix of technology and plant size combinations, given the desired level of oil shale production and probable pattern of shale oil development.

A mixed-integer programming model was utilized because data for plant sizes are discrete. Therefore, only specific plant sizes can be selected for the technological mix. The mixed-integer programming model specified below include seven levels of production in the oil shale industry: 25,000 bbl/day; 50,000 bbl/day; 75,000 bbl/day; 100,000 bbl/day; 150,000 bbl/day; 200,000 bbl/day; and 250,000 bbl/day. The model also has two assumptions: the total quantity of oil produced from shale is exogenously determined and the total amount of oil produced by the in-situ technology will not exceed one-half the total amount of shale oil produced.[6]

The model is specified below:

Minimize:

$$\dot{W} = X_1 W_1 + X_2 W_2 + X_3 W_3 + X_4 W_4$$

---

[5] Federal Energy Administration.

[6] The first assumption is made because shale oil production is so politically involved that political factors, not economic ones, are believed to be dominant. The second assumption is made because in-situ technology is not as well proven as is surface retorting and will therefore be slower in development. It is likely that surface retorting and in-situ plants will both be developed. Furthermore, without this assumption, or one similar to it, in-situ technology would be the only technology used given the specified objective function, a

subject to:

1. $-(X_1 W_1 + X_2 W_2 + X_3 W_3 + X_4 W_4) + H \geq 0$

2. $Q = C_1 W_1 + C_2 W_2 + C_3 W_3 + C_4 W_4$

3. $W_1 + W_2 - 1/2\ W_T \leq 0$

4. $W_T - (W_1 + W_2 + W_3 + W_4) = 0$

X_1 = the amount of water used by a 25,000 bbl/d in-situ plant = 1425 a-ft/yr.

X_2 = the amount of water used by a 50,000 bbl/d in-situ plant - 2850 a-ft/yr.

X_3 = the amount of water used by a 50,000 bbl/d surface plant = 10,600 a-ft/yr.

X_4 = the amount of water used by a 100,000 bbl/d surface plant - 20,000 a-ft/yr.

W_1 = the number of 25,000 bbl/d in-situ plants

W_2 = the number to 50,000 bbl/d in-situ plants

W_3 = the number of 50,000 bbl/d surface plants

W_4 = the number of 100,000 bbl/d surface plants

C_1 = 25,000 bbl/d from an in-situ plant

C_2 = 50,000 bbl/d from an in-situ plant

C_3 = 50,000 bbl/d from a surface plant

C_4 = 100,000 bbl/d from a surface plant

H = consumptive water supply = 416,694 acre-ft/yr.

Q = total amount of oil produced from shale. Q is exogenously determined.

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result which in no way resembles the probable development pattern. This assumption is supported by the Federal Energy Administration's Project Independence Blueprint, Task Force Report on Oil Shale and other government studies.

The mixed-integer model will be evaluated for the following daily outputs:

Q = 25,000 bbl/d

= 50,000 bbl/d

= 75,000 bbl/d

= 100,000 bbl/d

= 150,000 bbl/d

= 200,000 bbl/d

= 250,000 bbl/d/

The solution to this model will indicate the number of plants of specified sizes necessary to minimize water use for each scenario. Given the water requirements for shale development, the effect of water transfers from agriculture for use in the shale industry can be analyzed.

Water supply for oil shale

In Utah, water can be obtained in two different ways. First a prospective user may file for a water right with the State Engineer's Office. If all the proper conditions are met; if there is no other claim on file that would produce a more beneficial use, and if there exists unclaimed water, the water right *may* be granted.[7] Second, the ownership of a water right to a certain amount of water may be purchased[8] in the marketplace.

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[7]Roger O. Tew, "The Impact of Oil Shale Development on Agricultural and Municipal Water Supplies in the Uintah Basin" (MS thesis, Utah State University, 1976), pp. 7-8.

[8]*Ibid.*, pp. 9-10.

The oil shale companies have filed for much of the water that is still claimable in the Uintah Basin. The shale companies' claims for the water rights for which they filed have a low priority because they are so recent.[9] These rights, therefore, are insecure; i.e.: in a drought they may be overridden due to prior claims on the available water. In addition, the water available for claiming is far less than the amount demanded by a mature oil shale industry. The only way out of this dilemma then, is for the oil shale companies to purchase water rights from the existing holder(s). In the Uintah Basin, as in all the Upper Colorado River Basin, the marginal water user, that is, the use which has the lowest value of marginal product, is agriculture.[10]

A residual supply approach can be used to obtain a supply curve for water to the oil shale industry. To do this, four assumptions are made:

1. The shale industry holds no water.
2. All the available water has been claimed.
3. Agriculture is the marginal water user.
4. No agricultural use of water can be valued more highly than municipal and industrial water use. Thus, agriculture's demand for water determines the supply of water to the oil shale industry at various prices.

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[9] Ibid.

[10] U. S. Water Resources Council, 1975 Water Assessment (unpublished paper dated December 1975). A study by M. H. Anderson also supports that statement. In fact, Anderson's study shows that the demand for water for consumptive use varies between 410,000 acre-feet per year at a flow price of $0.64 per acre-foot to 32,700 acre-feet per year at a flow price of $22.64 per acre foot.

The residual supply to one user from another is the difference between the total supply and the second user's demand at all possible prices. (This assumes that all users are price takers and no one individual among either user group can alter the market price.) Mathematically:

$$Sm = So - \sum_{i=1}^{m-1} Di$$

where

Sm = residual supply to firm m

$\sum_{i=1}^{m-1} Di$ = demand for all other users

and

So = total supply.

Thus, the maximum supply of water for oil shale is equal to the total amount of water rights held by agriculture minus the total demand for water by agriculture at any given price (see Figure 3).

The supply of water as an input will be modified to take into account the risk of drought temporarily decreasing the total water supply and thereby proportionately reducing the oil shale companies' water rights. This will be done because:

1. The value of the marginal product of water curve for agriculture is non-stochastic.

2. The value of the marginal product curve for water in the oil shale industry is, at present, unknown; and

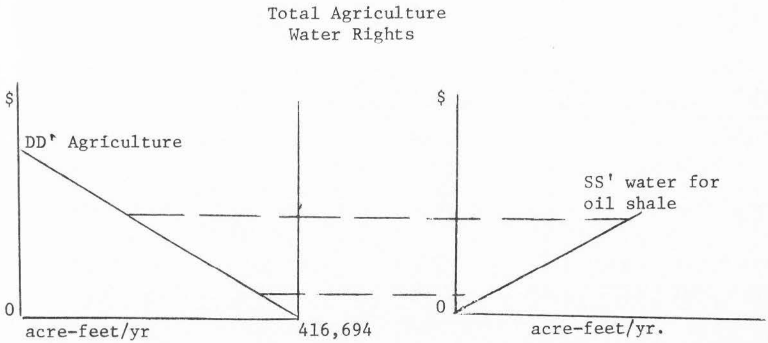

Figure 3. Residual supply of water for oil shale from agriculture in acre-feet per year.

3. The demand curve for water by the oil shale industry, as discussed in that section, is perfectly inelastic. Hence, any change in the risk of a water shortage will have no effect on the quantity of water demanded.

The <u>Project Independence Report</u> and other studies (notably the 1975 Water Assessment of the U. S. Water Resources Council) have assumed that the shale companies will attempt to acquire sufficient water rights to achieve a 98 percent level of confidence, which represents nearly a zero probability of insufficient water over the 20 year lifespan of a plant.[11] Shale producers are assumed to purchase sufficient water

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[11] All water supply information which may be obtained from the U. S. Water Resources Council is expressed in terms of "level of confidence" (l.o.c.). Usually, the information is at the 95 percent l.o.c.; i.e., in only five years out of every 100, <u>on the average</u>,

rights to provide for their needs in years of low flow. This quantity will be significantly greater than the minimum requirements for the production of oil from shale.[12]

Since water is a free resource available for claiming, agriculture's profit is the area under its demand curve for water. Agriculture's change in profit resulting from a change in the amount of water used can be treated as a change in Value Added when entered into the I-O model.[13] This change is also reflected in the Final Demand entry for agriculture. Thus, any change in agricultural profits resulting from the transfer of water to the shale industry will be reflected in Final Demand and eventually in the output of all sectors.[14]

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will the water supply be less than the amount specified. The U. S. Water Resources Council also has water supply information at the 90 percent and 98 percent l.o.c. Water supply at the 90 percent l.o.c. will, obviously, be greater than that at the 95 percent level. Water supply computed at the 98 percent l.o.c. will, similarly, be less than the supply at the 95 percent l.o.c.

The U. S. Water Resources Council's reasoning behind the choice of the 98 percent l.o.c. follows: First, the oil shale plants are assumed to have a 20 year life span. Second, the objective is to operate where, on the average, there is a zero chance in twenty of insufficient water. Since this zero chance in twenty is computed by rounding, in effect there must be less than one-half of one chance in 20 or less than 2.5 percent. This, then, is rounded down to a probability of 2 percent that, on the average, there will be insufficient water. In this way, by the use of rounding, a 98 percent probability, on the average, of a sufficient water supply is enough to indicate an approximately zero in twenty probability of having a shortfall in the supply of water.

[2]A mathematical proof follows:

$A^* = \overline{Q}$

where

A^* = original amount of water rights held by agriculture

$\overline{Q}$ = total water rights granted

and = mean flow of water.

$$A + E = \bar{Q}$$

where

A = water rights held by agriculture after energy development

and E = water rights held by energy.

$$W = Q - A$$

where

Q = total water flow

and W = water energy gets

$$\Pr [W \geq W^*] \geq 98\%$$

where

W^* = minimum water requirements for energy

$$\Pr [Q - A \geq W^*] \geq 98\%$$

$$\Pr [-A \geq W^* - Q] \geq 98\%$$

$$\Pr [A \leq Q - W^*] \geq 98\%$$

Since Q is a random variable with an assumed normal distribution we can normalize the above equation. This is done below:

$$\Pr [A - E(Q - W^*) \leq (Q - W^*) - E(Q - W^*)] \geq 98\%$$

$$\Pr \frac{[A - E(Q - W^*)}{\sigma_Q} \leq \frac{(Q - W^*) - E(Q - W^*)]}{\sigma_Q} \geq 98\%$$

Let $Z = \frac{A - E(Q - W^*)}{\sigma_Q}$.

Then

$$\Pr [Z \geq \frac{A - E(Q - W^*)}{\sigma_Q} \geq 98\%$$

if and only if

$$\frac{A - E(Q - W^*)}{\sigma_Q} \leq K_{.02}$$

where

$K_{.02}$ is on the normal distribution and negative

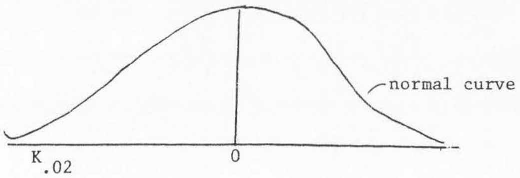

Figure 4. The normal distribution curve.

The result is

$$A \leq E(Q - W^*) + K_{.02}\sigma_Q.$$

Therefore

$$\text{Max } A = E(Q - W^*) + K_{.02}\sigma_Q.$$

Graphically:

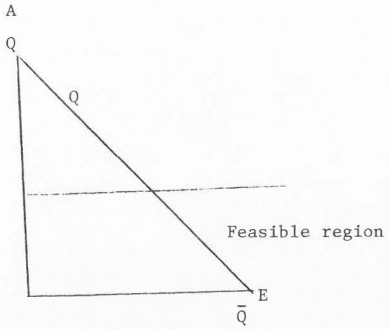

Figure 5. The feasibility curves and region of the amount of water to be purchased by the oil shale industry.

Substituting back into the second equation we get

$$\bar{Q} - W^* + K_{.02}\sigma_Q + E = \bar{Q}.$$

Therefore

Min $E = E_0 = W^* - K_{.02}\sigma_Q$ and since $K_{.02}$ is negative, $E_0 \geq W^*$.

Graphically:

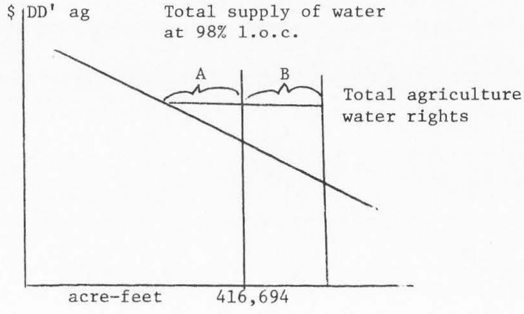

Figure 6. Water required by the oil shale industry under the assumption of 98 percent l.o.c.

Since the companies require quantity of water A at the 98 percent level of confidence, they must purchase A + B amount of water rights to obtain the "secure" water supply shown in Figure 3. Given the total supply of water at the 98 percent l.o.c. the demand for water by agriculture and the water requirements of energy, the effects of a developing oil shale industry on agriculture may then be used to adjust the final demand vector (F) of the input-output model.

[3]Value added includes both payments to proprietors and profits. In the case of the agriculture sector, the two are not generally distinct in the reported data.

[4]The alternative is to distribute the reduced profit proportionally among the sectors to whom products are sold. These sales include both costs and a loss in profits, and the proportion of sales among sector would not change under a reduced profit circumstance. Since the changes in the flows would require rebalancing and reclosing the transactions matrix, interpretation of the resulting flow matrix would be difficult. Further, the process is time-consuming and expensive. Thus, this approach was not used. Note that since households are included in the matrix after closing and balancing, payments to agricultural labor would be reduced proportionally with reduction in final demand. This, explicit consideration of labor payment changes is not required if the final demand approach is used.

CHAPTER IV

THE EMPIRICAL MODEL

In this chapter the implementation of the theory is discussed. In the first section the input-output model which was selected is discussed in some detail. In the second section, the entire process of adapting the selected model to the area of study is discussed. Finally, the method by which the changes in the oil shale industry and the agriculture industry are incorporated is explained.

The input-output model

The input-output model being used in this dissertation is based on the 1972 Utah input-output tables prepared by the University of Utah Bureau of Economic and Business Research. A description of the model appears below:[1]

> The basic analytical construct of interindustry or input-output analysis is the interindustry transactions table. A schematic representation of such a table for a state economy is shown in Table A. Essentially, this table shows how the total output of each consuming sector (reading across rows), or conversely, what the total input of each consuming sector consists of in terms of producing sector source reading down columns. It may be noted that the consuming sectors are comprised of two principal classes: (1) intermediate demand and (2) final demand. The intermediate demand sectors consist of those sectors that purchase inputs for the purpose of transforming them into a different product or service for subsequent sale to another consuming sector. It follows that the intermediate demand consuming sectors are the same as the producing sectors, though

[1] I. E. Bradley and B. L. Fjeldsted, "The Utah Input Output Project," Utah Economic and Business Review 35(10) (October 1975).

Table A

STATE INTERINDUSTRY TRANSACTIONS TABLE

		CONSUMING SECTORS											
		INTERMEDIATE DEMAND								FINAL DEMAND			
		AGRICULTURE	MINING	CONSTRUCTION	MANUFACTURING	TRADE	TRANSPORTATION	SERVICES	OTHER	PERSONS	INVESTORS	OUT OF STATE	GOVERNMENT
PRODUCING SECTORS	AGRICULTURE									Personal Consumption Expenditures	Gross Private State Investment	Net Exports of Goods and Services	Government Purchases of Goods and Services
	MINING												
	CONSTRUCTION												
	MANUFACTURING												
	TRADE												
	TRANSPORTATION												
	SERVICES												
	OTHER												
VALUE ADDED	LABOR	Employee Compensation and Proprietors' Income								GROSS STATE PRODUCT			
	PROPERTY OWNERS AND CORPORATIONS	Property Income, Corporate Profits and Capital Consumption Allowances											
	GOVERNMENT	Indirect Business Taxes											

viewed from the standpoint of their consumption activity. The final demand consuming sectors are those that purchase output from the producing sectors, not for the purpose of further production and resale, but for the purpose of final consumption or use.

Table 1 of the Statistical Appendix (computer printout) provides a provisional interindustry transactions table for the State of Utah for the year 1972. It should be understood that this table has been constructed on the basis of preliminary and incomplete data from the 1972 Bureau of the Census economic censuses, and is therefore subject to revision when final and complete data become available. The basic format and definitions used in this table are the same as those adopted by the Interindustry Economics Division of the United States Department of Commerce, Bureau of Economic Analysis (BEA).

There are, however, some distinguishing, if not unique characteristics of the Utah interindustry transactions table. In the first place, the Utah table is designed in such a way that column totals are equal to industry output, whereas row totals are equal to product output. Industry output is defined as total output of all establishments classified in an industry, including both the output of products primary to the industry and the output of products primary to other industries, i.e., industry and the output of products primary to other industries, i.e., secondary products. Product output is defined as the total output of a given product class, excluding by-products, no matter whether produced by establishments for which the product class is primary or establishments for which the product class is secondary.

The BEA interindustry transactions table for the national economy, however, is of a "balanced" design, i.e., row totals are necessarily equal to corresponding column totals. This balance is achieved by having each entry in the table equal to <u>actual</u> purchases by the consuming industry from the producing industry of products primary to the producing industry <u>plus</u> secondary output of the producing industry that is primary to the consuming industry. It follows that each column total is equal to total output of establishments classified in the industry plus output of products primary to the industry but produced by establishments classified in other industries. Each column total thus exceeds industry output by the value of products transferred in from other industries. It follows, additionally, that each row total in the BEA national table is equal to total output of products primary to the producing industry plus the output of products secondary to the producing industry. Each row total thus exceeds product output by the value of secondary products transferred out.

Since product output is equal to industry output plus the output of secondary products transferred in minus the output of secondary products transferred out, it follows that column totals in the national table (industry output plus transfers in) will be equal to corresponding row totals (product output plus transfers out). In the Utah table the reconciliation of industry output with product output is realized by having the entries in each row equal to sales of the row sector product class to the column sector industry, no matter whether the product sold was produced in Utah establishments for which the product is primary or in Utah establishments for which the product is secondary.

There are two principal advantages of the imbalanced design from the standpoint of regional input-output analysis: First, explicit use of the product output concept facilitates the incorporation of commodity transportation data which is available only on a product basis while explicit use of the industry output concept facilitates the incorporation of commodity transportation data which is available only on a product basis while explicit use of the industry output concept facilitates the incorporation of other economic census data available only on an establishment basis. Secondly, the technological implications of the balanced design are less tenable than those of the imbalanced design. Implicit in the balanced design is the assumption that the technological requirements for the production of secondary products transferred out are the same as those for the industry from which they were transferred. An industry-by-industry examination of secondary product transfers, however, suggests that technological requirements for the production of secondary products are generally nearer to those of the industry to which the secondary products are transferred than from which the transfer takes place.

Another distinguishing characteristic of the Utah interindustry transactions table is the inclusion of a compensation of labor account as a separate value added component. Compensation of labor is defined as employee compensation plus proprietors' income.[2] The account thus includes all payments by establishments for services provided directly by persons.

The third principal conceptual difference between the Utah interindustry transactions table and the BEA national table concerns the handling of scrap and by-products. Output of scrap and by-products is incidental to the production of the main

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[2]The Bureau of Economic Analysis does not distinguish a separate compensation of labor among its value added components. The term compensation of labor as defined here differs somewhat from labor compensation as defined by the U. S. Department of Labor, Bureau of Labor Statistics which includes employee compensation plus an imputation for the value of the personal services of proprietors.

primary products of an industry. Thus a change in final demand for scrap and by-products will not elicit a change in the internal production of scrap and by-products; any change in final demand must be satisfied or accommodated externally, i.e., through an adjustment of exports or imports.

In order to interrupt the flow of scrap and by-products and thus preclude the generation of internal production of scrap and by-products to satisfy a change in final demand, the BEA performs a special scrap and by-products adjustment prior to the calculation of the total requirements matrix. This adjustment involves a transfer of scrap and by-products back from the consuming industry to the producing industry. Thus scrap and by-products are treated as an input to the producing industry, rather than the consuming industry.

In the construction of the Utah Input-Output Tables the problem has been handled through the consolidation of the scrap and used goods account with by-products to create a scrap and by-products account in the interindustry transactions table. The flow of scrap and by-products is then interrupted by simple nullifying the elements in the scrap and by-products column. As a consequence the product output totals of the Utah interindustry transactions table (row totals) do not include the output of primary by-products. The principal advantage of this approach is in distinguishing the demand for industry output from the demand for non-by-product primary product output which is reflected in the coefficients of the total requirements table. Total requirements of scrap and by-products from both internal and external sources are also shown in the total requirements table.[3]

Regionalization

After obtaining the input-output model, the original eighty-two sector transactions matrix was reduced to twenty-three sectors for ease in computer manipulations, and to concentrate on those sectors which might be significantly affected. The new sectors which were created through this aggregation are listed in Table 1.

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[3]See "The Input-Output Structure of the U. S. Economy: 1967," Survey of Current Business 54(2) (February 1974); and Definition and Conventions of the 1967 Input-Output Study," Bureau of Economic Analysis miscellaneous paper (October 1974).

TABLE 1

COMPARABILITY OF NEW AND OLD INDUSTRIAL SECTORS

New Sector	Old Sector(s)	SIC Code[a]
1	Livestock Products	1
2	Other Agriculture Products	2
3	Forestry and Fisher Products	3
4	Agriculture, Forestry and Fisher Services	4
5	Iron Ore Mining	5
	Nonferrous Ore Mining	6
	Coal Mining	7
	Stone and Clay Mining	9
	Chemical and Fertilizer Mining	10
6	Crude Petroleum and Natural Gas	8
7[b]	Oil Shale	
8	New Construction	11
	Maintenance and Repair Construction	12
	Ordinance and Accessories	13
9	Food and Kindred Products	14
10	Tobacco Manufacture	15
	Fabrics, Yarn and Thread	16
	Miscellaneous Textiles and Floor Coverings	17
11	Lumber and Wood Products	20
	Wood Containers	21
	Household Furniture	22
	Other Furniture and Fixtures	23
	Paper and Allied Products	24
	Paperboard Containers	25
	Printing and Publishing	26
12	Chemicals and Chemical Products	27
	Plastics and Synthetic Materials	28
	Drugs, Cleaning and Toilet Products	29
	Paints and Allied Products	30
	Rubber and Miscellaneous Plastic Products	32
13	Petroleum Refining and Related Industry	31
14	Leather Tanning and Industrial Leather	33
	Footwear and Other Leather Products	34
	Glass and Glass Products	35
	Stone and Clay Products	36
	Primary Iron and Steel Manufacturing	36
	Primary Nonferrous Metal Manufacturing	38
	Metal Containers	39
	Heating, Plumbing and Structural Products	40

TABLE 1--Continued

New Sector	Old Sector(s)	SIC Code[a]
14 cont.	Stampings, Screws and Bolt	41
	Other Fabricated Metal Products	42
	Engines and Turbines	43
	Farm Machinery and Equipment	44
	Construction, Mining and Oil Machinery	45
	Material Handling Machinery and Equipment	46
	Special Industrial Machinery and Equipment	48
	Metalworking Machinery and Equipment	47
	General Industrial Machinery and Equipment	49
	Machine Shop Products	50
15	Office, Computer and Accounting Machinery	51
	Service Industry Machinery	52
	Electric, Industry Equipment & Appliances	53
	Household Appliances	54
	Electric Lighting and Wire Equipment	55
	Ratio, T.V., and Communications Equipment	56
	Electronic Components and Accessories	57
	Miscellaneous Electrical Equipment & Supplies	58
	Motor Vehicles and Supplies	59
	Aircraft and Parts	60
	Other Transport Equipment	61
	Scientific and Control Equipment	62
	Optic, Opthalmic and Photographic Equipment	63
	Miscellaneous Manufacturing	64
16	Transport and Warehousing	65
	Communications	66
	Radio and T. V. Broadcasting	67
17	Electric, Gas, Water	68
18	Wholesale and Retail Trade	69
19	Finance and Insurance	70
	Real Estate and Rental	71
20	Hotels, Pers, and Rep. Services	72
	Business Services	73
	Auto Repair and Services	75[c]
	Amusements	76
	Medical, Education Services and Nonprofit	77

TABLE 1--Continued

New Sector	Old Sector(s)	SIC Code[a]
21	Federal Government Enterprises	78
22	State and Local Government Enterprises	79
23	Gross imports	80
24	Business Travel, Entertainment and Gifts Office Supplies Scrap and By-Products	81 82 83

[a]Standard Industrial Classification Code

[b]Created by author

[c]SIC code 74 does not exist

The next task was to create the oil shale sector flow(s). First, the mixed-integer programming model was solved for an oil shale industry of varying capacities to determine the different combinations of technology and plant size which would minimize water use in each of the seven selected scenarios.[4] The results may be seen in Table 2. The second step was to create a 24 element vector of transaction flows for the oil shale industry for each of the seven scenarios. This was accomplished by obtaining the vectors of twenty-four direct co-efficients for each of the four combinations of technology and plant size.[5]

[4]The scenarios of development were shale industrial capacities of 1: 25,000 bbl/d.; 2: 50,000 bbl/d.; 3: 75,000 bbl/d.; 4: 100,000 bbl/d.; 5: 150,000 bbl/d.; 6: 200,000 bbl/d.; and 7: 250,000 bbl/d.

[5]Source data were developed by T. Glover and B. Jensen in W. C. Lewis,

TABLE 2

PLANT SIZE AND TECHNOLOGY MIX FOR EACH SCENARIO RESULTING FROM THE MIXED-INTEGER PROGRAMMING MODEL IN NUMBER OF PLANTS

Scenario of Shale Industry Size	Number of Plants			
	In-Situ		Surface	
	25,000 bbl/d	50,000 bbl/d	50,000 bbl/d	100,000 bbl/d
25,000 bbl/d			1	
50,000 bbl/d			1	
75,000 bbl/d	1			
100,000 bbl/d		1		
150,000 bbl/d		1		1
200,000 bbl/d		2	2	
250,000 bbl/d		2	1	1

These four vectors were arrayed in a 24x4 matrix. Next, a 4x7 matrix of outputs for each of the scenarios shown in Table 2 was generated. This matrix expressed the dollar value of the output of each size and technology type in each of the seven scenarios. This value was calculated multiplying the total output of each combination by $7.64, the 1972 price per barrel of oil.[6] This 4x7 matrix was then premultiplied by the 24x4 matrix to obtain a 24x7 matrix. Each of the seven columns of the new matrix corresponded to the transaction flow column vector

[6]The 1972 price of $7.64 was assumed so as to be consistent with the I-O model, which was developed for 1972.

for the oil shale industry for one of the seven scenarios. The results may be seen in Table 3. The appropriate vector was inserted into the original transactions matrix for each of the seven scenarios.

After creating the 24x24 transactions flow matrices by the addition of the shale sector to the original 23x23 matrix, each of the new matrices were regionalized. In addition, a Base Case, with zero oil shale final demand, was regionalized, in order thatcomparisons could be made. Regionalization required several steps. First, the Regional Gross Output vector was estimated. Second, the Regional Gross Outlay vector was estimated. Third, the transactions flows were reduced to represent the region's economy. Finally, the reduced flow matrices were balanced and "closed."

In order to reduce the State Gross Output and the State Gross Outlay vectors to regional values, a factor of reduction was necessary. Since no regional output or outlay data were available, the most desirable approach would have used a factor based on actual employment within the region compared with state employment for a given sector. However, these data are not available for some of the sectors without primary collection efforts. Consequently, an employment reduction factor equal to the ratio of total regional employment to total state employment was used for all sectors. Table 4 lists employment for the counties, the region, and the state as well as the calculated employment multiplier. State Gross Output and State Gross Outlays were then multiplied by the employment reduction factor to obtain regional values. Once these regional values were obtained, the process of regionalizing the transactions flow matrices could begin.

TABLE 3

SHALE INDUSTRY SECTOR PURCHASES FOR EACH OF THE SEVEN OIL SHALE SCENARIOS FOR USE IN THE TRANSACTIONS FLOWS MATRICES

	Size of Industry (bbl/day)						
Sector	25,000	50,000	75,000	100,000	150,000	200,000	250,000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	146.40	292.80	292.80	585.61	585.61
6	0.00	0.00	899.32	1,798.65	1,798.65	3,597.29	3,597.29
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	662.29	1,324.59	3,297.52	5,270.45	6,567.15	10,540.91	11,837.61
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	13.94	27.89	27.89	55.77	55.77
11	13.94	27.89	188.23	348.58	376.46	697.15	725.04
12	383.43	766.87	1,059.67	1,352.47	2,091.45	2,704.94	3,443.92
13	292.80	585.61	3,597.29	6,608.98	7,166.70	13,217.96	13,775.68
14	488.01	976.01	2,007.79	3,039.57	3,625.18	6,079.15	6,664.75
15	132.46	264.92	508.92	752.92	1,017.84	1,505.84	1.770.76
16	118.52	327.03	1,303.67	2,370.31	2,607.34	4,740.62	4,977.65
17	320.69	641.38	4,078.33	7,515.28	8,128.77	15,030.55	15,644.05
18	390.40	780.81	2,809.51	4,838.22	5,591.14	9.676.44	10,429.36
19	348.58	697.15	955.10	1,213.04	1,910.19	2,426.08	3,123.23
20	550.75	1,101.50	1,826.53	2,551.57	3,653.07	5,103.14	6,204.64
21	2,642.20	5,284.40	5,354.11	5,423.83	10,652.45	10,847.65	16.067.28
22	0.00	0.00	48.80	97.60	97.60	195.20	195.20
23	12,360.74	12,360.74	28,145.34	43,929.94	53,769.33	87,859.88	97,699.27
24	223.09	446.18		1,812.59	2,258.77	3,625.18	4,071.36
Value	50,880.53	114,121.79	151,278.76	188,435.13	305,262.92	376,871.46	493,698.65
G. Output	69,715	139,430	209,445	278,860	418,290	557,720	627,435

[a] *numbers in $(000)   [b] Assuming the 1972 price of $7.64/bbl oil

TABLE 4

EMPLOYMENT BY COUNTY, REGION, AND STATE OF UTAH, 1974

County	Employment by County Number of Employees
Carbon	5,920
Duchesne	5,320
Emery	2,810
Uintah	6,270
Total of Counties	20,320
Total State	468,500
Employment Reduction Factor	0.0433619

Source: Utah Industrial Development Information System, Utah: County and Community Economic Facts, 1974.

Regionalization was accomplished by what is known as the RAS technique.[7] This technique combines two similar computer programs to attain a regional Input-Output table. These two programs will be discussed sequentially. The first program is designed to alter the transactions flow matrix so that the column and row sums are equal to the elements of the Regional Gross Output and Regional Gross Outlay vectors, respectively. This objective is attained by computing the ratio, for each sector, between Regional Gross Output and State Gross Output. Each element in the appropriate row vector is then multiplied by this ratio. When this process is complete for all rows, each column is summed. Each column sum is then examined to see if it equals the appropriate element

7

of the Regional Gross Outlay vector. If it does not, the difference is distributed proportionately among the elements of the column vector. This is done for each column. Then, each row is again summed to see if it equals the appropriate element of the Regional Gross Output vector. If it does not, the difference is distributed proportionately among the elements of the row vector. This is done for each row.

The entire process is then iterated until the difference between the column sums and the elements of the Regional Gross Outlay vector is less than or equal to an exogenously specified amount. When all column sums are sufficiently close to the elements of the Regional Gross Outlay vector, the transactions matrix has been "regionalized."[8]

After regionalization, the matrices were "closed," that is, the Household Demand column vector and the Value Added row vector were added. To do this, the second computer program of the RAS technique was used. For this computer program, Regional Gross Output was increased, sector-by-sector, by the elements of the Household Demand column vector. Likewise, Regional Gross Outlays were increased by the elements of the Value Added row vector. Following the same iterative balancing procedure as in the first computer program, the column and row sums were again made equal to the elements of the new Regional Gross Outlay and Output vectors. The final computer output was a regionalized, balanced, and closed direct coefficient matrix for each of the seven scenarios and the Base Case.

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[8] This process was carried out 8 times: once for the Base Case and once for each of the seven scenarios.

Final demand calculation

After the matrices were regionalized, balanced, and "closed," the State Final Demand vector was created. This was done by aggregating the Investment, Export and Government final demand vectors into one vector. The Regional Final Demand vector for the 23 original sectors was created by multiplying the State Final Demand vector by the employment reduction factor. The second change was to insert the appropriate dollar values for oil shale production for each of the seven scenarios and the Base Case into the Regional Final Demand vector.[9]

The result was eight final demand vectors, one for each of the seven scenarios and one for the Base Case. The seven final demand vectors pertaining to the scenarios then had to be modified to take into account the change in agriculture's (sector 2) final demand resulting from decreased water use. First, a linear regression of quantity over price was run on the water use data for agriculture shown in Table 5. The maximum likelihood estimator indicated that the intercept was \$22.72 and the slope ($\hat{B}$) was -0.0545196.[10] This demand equation was developed using results from a linear programming model. Prices are shadow prices based upon residual net agricultural income for various levels of water use. Integrating over the quantity shown in column 1, Table 6 to obtain the areas under the curve will yield changes in agricultural net income, or profit, as shown in column 2, Table 6.

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[9] The entry for the Base Case was zero.

[10] The variance, using the MLE, is 753.17064.
The X^2_{14} (99.5%) = 31.32.

TABLE 5

DEMAND FOR IRRIGATION WATER ON PRESENTLY IRRIGATED LAND
(REGION 7--UINTAH BASIN)

Water Diverted		Water Consumed		Acres Irrigated		Acre-Ft. per A	
Amount 1,000 Acre-Ft.	Price Dollars	Amount 1,000 Acre-Ft.	Price Dollars	Old Land 1,000 Acres	New Land 1,000 Acres	Diverted Acre-Ft.	Consumer Acre-Ft.
1,104.8	.24	410.1	.64	217.8	.	5.1	1.9
1,088.5	.29	404.0	.79	213.9	.	5.1	1.9
1,082.0	.82	401.7	2.21	212.2	.	5.1	1.9
999.1	1.18	370.9	3.17	196.0	.	5.1	1.9
947.2	1.73	351.6	4.65	185.3	.	5.1	1.9
780.9	1.96	289.9	5.29	154.2	.	5.1	1.9
703.6	2.47	261.2	6.67	139.1	.	5.1	1.9
703.6	3.20	261.1	8.63	139.1	.	5.1	1.9
687.4	3.68	255.2	9.92	139.1	.	4.9	1.8
670.7	4.13	249.0	11.12	135.1	.	5.0	1.8
424.9	4.22	157.7	11.36	87.7	.	4.8	1.8
405.9	5.11	150.7	13.76	87.7	.	4.6	1.7
268.4	5.59	99.6	15.06	56.1	.	4.8	1.8
251.3	6.82	93.3	18.36	56.1	.	4.5	1.7
117.0	7.54	43.4	20.30	26.9	.	4.4	1.6
88.2	8.40	32.7	22.64	26.9	.	3.3	1.2

Source: M. H. Anderson, "An Economic Analysis of Demand and Supply for Irrigation Water in Utah: A Linear Programming Approach," (M.S. thesis, Utah State University, 1974), p. 134.

TABLE 6

PROJECTED CHANGE IN AGRICULTURAL NET INCOME RESULTING FROM
INCREASED USE OF WATER BY THE OIL SHALE INDUSTRY

Level of Oil Shale Production (000 bbl/d)	Water Used by Shale Industry (Acre Feet)	Agriculture Income Lost ($000)
25	10,600	3.0634
50	10,600	3.0634
75	12,025	3.9421
100	13,450	4.9320
150	22,950	14.3586
200	26,900	19.7265
250	36,400	36.1194

As discussed in the section on input-output analysis, these changes in Value Added of Sector 2 may be treated as reductions in the final demand of sector 2 to create new final demand vectors for each of the seven scenarios.

Adjustment for agricultural imports

The eight matrices (Base Case and the seven scenarios) were then subtracted from the identity matrix, inverted, and multiplied by the appropriate final demand vectors. The resultant eight vectors showed Regional Gross Output by sector: one for each scenario and the Base Case. These results indicated that sector 2 (crop production) grew substantially. However, sector 2 was constrained by the reduction in the water supply caused by the introduction of the oil shale sector. The difference between the amount demanded and the quantity the constrained sector could produce was assumed to be imports.

Determining the exact amount of agricultural crop production was in iterative process. First, the Base Case was modified so as to compute the maximum amount that the constrained sector could produce (namely, current production). The modification consisted of reducing final demand in sector 2 to the level calculated for each of the seven scenarios. Then the Base Case was run for each of these seven new final demand vectors. The output for sector 2 was taken to be the maximum value of production possible given the constrained water supply. This amount was then subtracted from the initial results of the seven scenarios. The differences were treated as imports and are shown in Table 7. The new import flows were placed within the regionalized flow matrices and the matrices were re-balanced and "closed." Again, the new matrices were subtracted from the identity matrix, inverted, and posmultiplied by the appropriate final demand vectors. The new results were then compared with the originals. In no case did the new results vary by more than plus or minus 10 percent by sector. The new results were therefore accepted as final.

TABLE 7

IMPORT FLOW CHANGES IN SECTOR 2 (AGRICULTURAL CROPS) RESULTING FROM TRANSFERRING WATER TO THE SHALE SECTOR FROM AGRICULTURE[a]

Scenario	Quantity Produced	Total Required	Imports
Base Case	2,517.334	2,517.334	180.422
Case 1	2,514.152	8,079.252	5,501.859
Case 2	2,514.152	10,107.103	7,860.176
Case 3	2,513.240	11,532.085	8,790.974
Case 4	2,512.211	12,378.173	9,712.303
Case 5	2,502.422	13,404.536	11,540.305
Case 6	2,496.847	14,000.603	12,106.600
Case 7	2,479.822	19,881.036	18,264.513

[a]($000 s)

CHAPTER V

RESULTS AND ANALYSIS

The results of the input-output analysis for each scenario may be seen in Tables 8 through 16. Table 8 indicates the percentage change from the Base Case, while Tales 9 through 16 show the absolute values from which Table 8 was generated. Percentage changes, rather than the absolute changes, were used as a basis for analysis because the region's economy is small and seemingly unimportant absolute changes may evidence substantial shifts from current activity. The sectors which could be classed as "High-Growth" or "Low-Growth" sectors were examined in detail. Finally, certain specific sectors of interest were examined.

It should be noted that the value of output in all the sectors grew and almost all doubled in size. However, due to the economic structure of the region, and the fact that it is not self-sufficient, many sectors must import what they later sell. Thus, while sectoral regional gross output may increase substantially, in many sectors a significant portion of this increase will be supplied from non-regional, rather than regional, sources.

"High-Growth" sectors

Interest was concentrated on those sectors having growth rates in the top 20 percent for each scenario. However, the exact definition of a "High-Growth" sector varies according to which scenario is to

TABLE 8

CHANGE IN OUTPUT FROM THE BASE CASE SCENARIO FOR EACH SHALE SCENARIO ON A SECTOR-BY-SECTOR BASIS IN TERMS OF PERCENT GROWTH

Sector	Case 1 (25,000) bbl/d	Case 2 (50,000) bbl/d	Case 3 (75,000) bbl/d	Case 4 (100,000) bbl/d	Case 5 (150,000) bbl/d	Case 6 (200,000) bbl/d	Case 7 (250,000) bbl/d
1	189.4	271.1	301.0	329.1	429.1	478.2	580.5
2	-0.1[a]	-0.1[a]	-0.2[a]	-0.2[a]	-0.6[a]	-0.8[a]	-1.5[a]
3	274.8	403.8	458.3	494.0	677.3	711.4	868.2
4	113.7	165.0	179.7	195.2	345.6	380.8	459.7
5	14.8	21.5	23.8	25.6	36.4	31.5	35.6
6	150.7	211.7	166.3	129.3	150.9	99.6	114.0
7	[b]	[b]	[b]	[b]	[b]	[b]	[b]
8	23.3	33.1	33.0	33.1	40.0	38.1	44.0
9	269.2	395.9	442.1	483.5	630.6	698.7	654.2
10	263.8	386.7	429.8	473.9	614.1	680.1	832.8
11	141.7	221.9	280.0	268.5	351.6	377.9	455.9
12	85.8	116.0	121.0	124.5	150.6	149.8	162.8
13	152.8	213.1	177.6	156.7	193.1	155.2	182.0
14	21.0	31.5	36.7	42.7	51.7	58.1	64.4
15	49.8	72.3	78.9	84.8	108.1	115.7	138.8
16	136.1	195.9	203.5	197.5	257.8	234.3	280.1
17	143.2	205.0	178.6	161.8	201.8	167.0	197.8
18	171.7	251.6	269.1	287.6	369.1	387.1	464.7
19	223.4	324.2	356.9	387.5	596.3	544.0	651.7
20	165.5	240.6	263.0	281.9	360.8	385.1	459.4
21	74.7	68.2	73.2	78.3	58.5	62.3	54.4
22	[c]	[c]	[c]	[c]	[c]	[c]	[c]
23	161.4	225.0	320.6	405.4	567.2	740.5	899.4
24	125.2	120.9	249.8	144.5	331.9	142.9	160.1
Value Added	173.6	268.4	302.1	336.4	455.4	512.3	633.7

[a]This sector was limited by lack of water. The result was to reduce output in each case. (see Table 7)

[b]Oil Shale sector

[c]This sector was zero in the Base Case. No percent change could there be computed.

TABLE 9

FINAL DEMAND AND REGIONAL GROSS OUTPUT VECTORS FOR THE BASE CASE--NO SHALE

Sector	Final Demand Vector[a]	Regional Gross Output[a]
1	2603.010	10107.810
2	62.660	2517.334
3	0.345	11.677
4	87.797	532.845
5	7073.710	13744.884
6	51.340	3265.151
7	0.000	0.000
8	23290.991	26949.900
9	827.020	21817.683
10	249.460	3633.109
11	635.770	5896.632
12	1201.981	4304.890
13	2273.380	8021.012
14	15236.500	34135.195
15	9735.441	14873.959
16	2558.446	11956.907
17	2981.252	11885.455
18	17044.960	55165.684
19	3145.043	41268.885
20	12268.688	45025.025
21	212.780	1530.520
22	0.000	0.000
23	27230.635	79605.192
24	184.850	2598.448
Value Added	39985.400	260779.430
Total		659627.6

[a]($000s)

TABLE 10

FINAL DEMAND AND REGIONAL GROSS OUTPUT VECTOR FOR CASE 1--25,000 BARRELS/DAY

Sector	Final Demand Vector[a]	Regional Gross Output[a]
1	2603.010	29253.265
2	59.597	8079.252
3	0.345	43.769
4	87.787	1138.817
5	7073.710	15780.009
6	51.340	8184.726
7	69715.000	69715.000
8	22748.747	33242.327
9	827.020	80555.055
10	249.460	13216.565
11	635.770	14844.769
12	1118.597	7997.528
13	274..544	20274.560
14	15235.500	41289.997
15	9668.870	2281.979
16	2535.411	28232.402
17	2916.015	128906.910
18	16932.255	149900.277
19	3121.937	133471.959
20	12136.261	119548.272
21	81.964	2674.498
22	0.000	0.000
23	28454.753	208094.275
24	172.116	5852.098
Value Added	39985.450	713437.037
Total		1756015.0

[a]($000s)

TABLE 11

FINAL DEMAND AND REGIONAL GROSS OUTPUT VECTOR FOR CASE 2--50,000 BARRELS/DAY

Sector	Final Demand Vector[a]	Regional Gross Output[a]
1	2603.010	37514.813
2	59.597	10666.976
3	0.345	58.976
4	87.797	1412.330
5	7073.710	16699.090
6	51.340	10177.318
7	139430.000	139430.000
8	22231.168	35862.758
9	827.020	108202.751
10	249.460	17683.871
11	635.770	18981.530
12	1046.030	9297.917
13	2657.618	25113.073
14	15236.500	44877.374
15	9603.203	25627.509
16	2512.788	35379.466
17	2853.571	36253.837
18	16821.027	193989.710
19	3099.168	175050.322
20	12006.662	153367.774
21	50.629	2574.528
22	0.000	0.000
23	29585.580	266701.149
24	161.022	7039.631
Value Added	39985.440	980811.759
Total		2332774.0

[a] ($000s)

TABLE 12

FINAL DEMAND AND REGIONAL GROSS OUTPUT VECTOR FOR CASE 3--75,000 BARRELS/DAY

Sector	Final Demand Vector[a]	Regional Gross Output[a]
1	2603.010	40529.705
2	58.718	11532.085
3	0.348	65.193
4	87.797	1490.413
5	7073.710	17018.775
6	44.721	8693.778
7	209445.000	209445.000
8	20820.069	35845.041
9	827.020	118268.957
10	249.460	19249.901
11	635.770	22404.560
12	996.657	9513.613
13	2021.209	22268.817
14	15236.500	46673.956
15	9494.546	26603.462
16	2325.995	36291.373
17	2320.917	33108.764
18	16265.800	203642.801
19	3082.532	188562.231
20	11840.215	163439.904
21	50.124	2650.877
22	0.000	49.429
23	33292.545	334843.136
24	134.479	9089.726
Value Added	39985.440	1048664.284
Total		2609946.0

[a] ($000s)

TABLE 13

FINAL DEMAND AND REGIONAL GROSS OUTPUT VECTOR FOR CASE 4--100,000 BARRELS/DAY

Sector	Final Demand Vector[a]	Regional Gross Output[a]
1	2603.010	43369.619
2	57.728	12378.173
3	0.345	69.362
4	87.797	1573.032
5	7021.868	17260.798
6	37.411	7487.258
7	278860.000	278860.000
8	19577.413	35867.831
9	827.020	127298.742
10	248.898	20949.967
11	635.770	21731.277
12	951.735	9663.462
13	1630.707	20592.758
14	15236.500	48704.980
15	9368.787	27487.457
16	2165.052	35566.256
17	1955.836	31116.062
18	15746.053	213833.621
19	3066.074	201198.957
20	11678.617	171970.212
21	49.628	2728.192
22	0.000	98.995
23	36389.750	402339.014
24	155.447	6352.053
Value Added	39985.440	1137973.516
Total		2876372.0

[a] ($000s)

TABLE 14

FINAL DEMAND AND REGIONAL GROSS OUTPUT VECTOR FOR CASE 5--150,000 BARRELS/DAY

Sector	Final Demand Vector[a]	Regional Gross Output[a]
1	2603.010	53478.831
2	48.301	15349.069
3	0.345	86.090
4	87.797	2374.491
5	7021.868	18741.585
6	37.411	8131.398
7	418290.000	418290.000
8	18838.419	37740.576
9	827.020	159405.420
10	248.898	25943.663
11	635.770	26626.748
12	854.528	10788.502
13	1574.378	23513.151
14	15236.500	51781.538
15	9246.260	30950.066
16	2132.265	42796.875
17	1902.421	35867.552
18	15561.510	258803.100
19	3022.458	246103.732
20	11440.657	207483.607
21	28.496	2426.403
22	0.000	97.462
23	37987.727	531162.761
24	105.680	11221.814
Value Added	39985.440	1448277.587
Total		3667492.0

[a] ($000s)

TABLE 15

FINAL DEMAND AND REGIONAL GROSS OUTPUT VECTOR FOR CASE 6--200,000 BARRELS/DAY

Sector	Final Demand Vector[a]	Regional Gross Output[a]
1	2603.010	58443.887
2	42.934	16787.649
3	0.345	94.744
4	87.797	2562.067
5	6888.933	18067.736
6	28.194	6517.580
7	557720.000	557720.000
8	16885.189	37216.888
9	827.020	174249.396
10	247.128	28372.763
11	635.770	28177.651
12	787.734	10753.436
13	1145.183	20471.391
14	14906.202	53951.736
15	9029.749	32084.378
16	1876.513	39973.114
17	1455.285	31731.965
18	14631.093	268717.911
19	2990.973	265758.721
20	11142.154	218436.369
21	28.050	2484.396
22	0.000	195.202
23	43114.163	669058.183
24	83.934	6311.987
Value Added	39985.440	1596748.045
Total		4144887.0

[a] ($000s)

TABLE 16

FINAL DEMAND AND REGIONAL GROSS OUTPUT VECTOR FOR CASE 7--250,000 BARRELS/DAY

Sector	Final Demand Vector[a]	Regional Gross Output[a]
1	2603.010	68784.545
2	26.541	19881.036
3	0.345	113.051
4	87.797	2982.593
5	6888.933	18642.683
6	28.194	6989.007
7	627435.000	637435.000
8	16332.599	38817.991
9	827.020	209173.556
10	247.128	33889.493
11	635.770	32777.861
12	719.948	11313.744
13	1117.115	22616.651
14	14703.989	56110.166
15	8914.900	35515.038
16	1851.834	45446.526
17	1425.503	35389.940
18	14471.627	312060.045
19	2949.453	310221.449
20	10925.614	251857.484
21	19.766	2363.643
22	0.000	195.132
23	44564.224	795556.917
24	78.649	6759.770
Value Added	39985.440	1913249.366
Total		4857149.0

[a] ($000s)

be considered. This is so that only those sectors having growth rates in the top 20 percent would be considered. In Case 1, "High-Growth" is defined as growth of more than 200 percent; in Case 2, the definition is of growth of more than 300 percent; Cases 3 and 4 have "High-Growth" defined as more than 400 percent; Cases 5 and 6 define "High-Growth" as more than 500 percent; and Case 7 has a "High-Growth" cut-off of 600 percent.

The first two scenarios are similar in that the same four sectors in all three cases exhibit extreme growth. These sectors are 3, 9, 10, and 19 which represent Forestry and Fishery Products; Food; Tobacco, Fabric and Textiles; and Finance, Insurance and Real Estate. Sectors 3, 9 and 10 are extreme cases for two reasons: first, they are small in absolute terms so any growth will be large percentage wise. Second, the demand for the products of these sectors will increase substantially as the household sector increases.[1] The fourth sector, sector 19, will grow both for these two reasons and because of the rapid growth of the labor force caused by the expanding shale industry.[2]

In the third scenario extreme growth continues in sectors 3, 9 and 10 but sector 19 slows its growth slightly. This reduction in the sector's speed of growth is probably due to the introduction of in-situ technology and a concomitant reduction in the proportion of new households required for a constant dollar increase in production.

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[1] See the section on employment below.

[2] Ibid.

In the fourth scenario sectors 3, 9 and 10 continue to grow. Sector 19 grows, but not at an extreme rate, probably for the same reasons as in Case 3. Sector 23, Imports, however, shows extreme growth for the first time. This is to be expected since the region must import most of its consumer goods. The reason the imports sector was not considered an extreme growth sector in Case 1, 2 and 3 is because it is a large sector in absolute terms and, although it grew substantially, its growth rate was not quite sufficient to be termed "extreme."

Case 5 continues the identical pattern of Case 4 with one exception: sector 19. Although not quite classified as "extreme" growth it is so close to the cut-off line of 500 percent as to be worthy of comment: 496.3 percent.

The sixth scenario shows two changes from the fifth. First, sector 19 again grows sufficiently to be considered "extreme" for the same reason mentioned above. The second change is that growth in Value Added becomes "extreme" as the primary, secondary, and tertiary effects of oil shale development begin to dominate. The reasons why Value Added was not "extreme" in the earlier cases are that, first, Value Added is large in absolute terms in the Base Case; and second, the primary, secondary, and tertiary effects of the oil shale industry's development are slower to affect this sector.

Finally, Case 7 shows no significant changes in the "extreme" growth sectors from Case 6.

"Low-Growth" sectors

Those sectors exhibiting "low" growth rates will be examined in this section. Unlike the "high-Growth" sectors, the definition of "Low-Growth" does not vary according to which scenario is being examined. In all of the cases, "Low-Growth" is defined as growth of less than 100 percent.[3]

In Case 1 there are only five sectors which could be classified as "Low-Growth." These are sectors 5, 8, 12, 14, and 15 representing the Mining; Construction; Chemical; and Heavy Industries (14 and 15). Sector 5, Mining is small in absolute terms and unaffected by either the shale industry or by any induced demand created by the shale industry. The fact that the construction sector, sector 8, is a "Low-Growth" sector might seem confusing in view of the fact that there is high growth in the real estate sector. This is explained, however, by the fact that housing construction is included in sector 19 (Real Estate etc.). The Chemical Industry, sector 12, is a "Low-Growth" sector because it is small in absolute terms and unaffected by either the shale industry or by any induced demand created by the shale industry.

Sectors 14 and 15 (Heavy Industry) may seem surprising in view of the growth in the shale industry. Nonetheless, their lack of growth may be explained in three ways. First, they are large sectors so that any growth will be small in percentage terms. Second, most of their product is imported so there will be minimal impact on the region. Finally, the shale industry is assumed to import directly almost all its needs for heavy industrial equipment.

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[3]Sector 21 will be discussed in a later section.

In Case 2 sector 12 grows sufficiently to be no longer classified as a "Low-Growth" sector. With that exception, Case 2 is similar to Case 1. Scenarios three and four follow the same pattern as Case 2 with no further changes in the "Low-Growth" sectors.

In the fifth scenario sector 15 crosses the cut-off line and can no longer be considered to be a "Low-Growth" sector. Nonetheless, its growth cannot be termed large. In fact, its growth is still less than all but the "Low-Growth" sectors. Finally, the sixth and seventh scenarios follow the pattern of Case 5 with no further changes.

Anomalous sectors

Sector 6, Petroleum production, doubles in size and then stabilizes. This is believed to be the result of increasing Household demand for refined petroleum products offset by reduced demand for both gasoline and fertilizers as crop production diminishes.

Sector 13, Petroleum Refining, does increase as additional demands from the household sector appear. This sector, however, is unaffected by the oil shale industry since all of the oil produced from shale is exported. It should be noted that the increases in this sector and in sector 6 are closely related to each other.

Sector 18, Wholesale and Retail Trade, is not one of the "extreme" growth sectors. This is due to the fact that it was one of the largest sectors in the Base Case. As a result, even with enormous increases in absolute terms it does not grow as much, percentage wise, as some of the others. Nonetheless, its expansion is dramatic and should not be overlooked.

Other sectors of interest

There are four other sectors which deserve mention in this analysis. They are sector 2, Crop production; sector 17, Gas and Electric; sector 21, Federal Government Enterprise; and sector 22, State and Local Government Enterprise. The titles of the last two are, unfortunately, ambiguous. In actuality these two sectors describe governmental social services of one form or another.

Sector 2 would be constrained by the transfer of water from agriculture to the shale industry. Nonetheless, the actual effect of that water transfer is quite small. It should be noted that, although Tables 9 through 16 show this sector growing dramatically, all this growth is due to increased crop imports as shown in Table 7.

The Gas and Electric sector does not grow at an extreme rate. Nonetheless, it does expand between 150 and 200 percent. This expansion, of course, has serious implications for the local public utilities. Such a dramatic increase in the demand for gas and electricity must require the construction of additional facilities. Obtaining the financing to build the new facilities may prove to be a problem for the region's public utilities due to the amount needed.

Sector 22 does not appear on Table 8 because, in the Base Case, it was zero and percentages were impossible to compute. Nonetheless, both sectors 21 and 22 (Federal, State, and Local Government enterprises) indicate a reasonable growth in governmental services in absolute terms. Sector 21 could easily be considered a "Low-Growth" sector since its increase is never more than 80 percent. Therefore, growth in sector 21 will not create financial disturbances in the region. Sector 22 grows from zero to approximately $195,000. Growth in this sector however, will create some financial disturbance in the region. Obtaining the necessary local funds to provide the required services will be difficult even without the competition from sector 17. Obviously, priorities will have to be set by the government entities involved so that an adequate, even if not a sufficient level of both services can be maintained.

Employment

In addition to the effects on the growth rates of the various sectors, which were analyzed above, the introduction of the oil shale industry will have a measurable impact on employment. In 1974 the total employment in the region was 20,320 persons. As may be seen from Table 17, with the presence of the shale industry, employment will increase enormously.

These results were obtained by twice subtracting Imports from Total Regional Gross Output for each scenario.[4] Then, Value Added and the Oil Shale Sector were subtracted. The result, expressed in dollars, is the value of regionally produced output net of oil shale and profits, salaries, and wages. Next a ratio of net regional output for each scenario to the corresponding value for the Base Case was created. This ratio may be seen in column 1 of Table 17. Then, the 1974 employment in the region was multiplied by this ratio to produce New Indirect Employment in the region. This is shown in column 2 of

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[4] Imports is subtracted twice because of the double counting mentioned earlier.

TABLE 17

NEW REGIONAL INDIRECT EMPLOYMENT UNDER THE ASSUMPTION OF A CONSTANT GROSS OUTPUT TO EMPLOYMENT RATIO

Scenario	Multiplier[a]	New Indirect Employment[b]
1	0.414	8,412
2	0.725	14,732
3	0.733	14,895
4	0.664	13,492
5	0.876	17,800
6	0.657	13,350
7	0.843	17,130

[a]Regional Gross Output (scenario i) -(2 * Imports + Value Added + Oil Shale)/Regional Gross Output (Base Case) -(2 * Imports + Value Added).
[b]Rounded to nearest whole numbers.

Table 17.[5] The fluctuation of these employment data is explained by the shifts in technology from relatively labor intensive surface retorting to in-situ, which occur in the fourth, fifth, and sixth scenarios. This can be seen in Table 2. This employment increase, the result of the presence of the shale industry, implies large scale in migration resulting in "boom town" type growth. Aside from the shale sector, most of the growth will come in the "High-Growth" and Wholesale and Retail Trade sectors. This is reasonable due to the lack of other industries in the region, and the large increase in households with a concomitant increase in the demand for services.

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[5]The central assumption of this method is that the ratio between locally produced Regional Gross Output and employment is constant. This assumption, however, may not be valid.

These employment numbers are high when compared to the results of other studies. Lewis,[6] for example, shows indirect employment to be 3,450 persons for a 100,000 bbl/d. oil shale complex. For the same size plant, Wiseman[7] shows 2,006 persons indirectly employed. In Wiseman's study, the employment multiplier is quite low, since he used the "minimum requirements" approach.[8] The difference between their estimates and this dissertation's may be attributed to four things. First, the employment multiplier created from the input-output model used in this dissertation is a Type II multiplier; re: it includes the household sector. Second, the multiplier used in this dissertation for estimating employment assumes a constant ratio of employment to dollar value of output. Third, the I-O model used reflects the economic structure of the state of Utah, not the Uintah Basin. Finally, the second assumption made to create an I-O model implies that the output of all sectors will grow in proportion to the growth of any one sector. Thus, all four factors cause predicted employment to be somewhat high.

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[6] W. C. Lewis, A. B. Crawford, H. H. Fullerton, Socio-Economic Impact Study of Oil Shale Development in the Uintah Basin (Providence, Utah: Western Environmental Associates, Inc., November 1975), p. xi.

[7] A. Wiseman, R. Logan, S. Albrecht, and B. D. Gardner, Anticipated Socio-Economic Impacts in the Uintah Basin of Utah Resulting from Oil Shale Development in the Area (Logan, Utah: Bureau of Land Management, Department of the Interior and Utah State University, 1976), p. 41.

[8] Ibid., pp. 155-159.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The overall purpose of this study was to examine the economy of the Uintah Basin--a four-county region in East-Central Utah--under the impact of a developing oil shale industry. More precisely, this dissertation examined three things. First, the direct effects of seven scenarios of oil shale development were examined. Second, the effects of these scenarios of shale development on agriculture were determined. Finally, the indirect effects of the first two changes on the other sectors of the economy were analyzed.

In order to accomplish these goals, an input-output model of the region was developed. Several sub-goals had to be accomplished to achieve this objective. First, the original regional input-output model had to be developed. Second, the seven levels of oil shale development had to be determined. Third, sectors describing the oil shale industry had to be created. Fourth, the regional input-output model had to be modified to take these new sectors into account. Fifth, a technique designed to relate the scenarios of oil shale industrial development to agriculture had to be developed. Sixth, oil shale's impact on agriculture in each of the scenarios had to be determined. Finally, the direct and indirect effects of the changes in agriculture and oil shale for each of the scenarios had to be examined.

To accomplish the first sub-objective, the 1972 State of Utah Input-Output model was used. Since this model applied to the entire State of Utah, it was necessary to modify it so that it would more accurately describe the economy of the Uintah Basin. This was accomplished by using a series of computer programs known jointly as the RAS technique. The RAS technique is applied to the original state transactions flow matrix to adapt it to a vector of estimated regional gross output. The estimated regional gross output vector was obtained by developing an employment multiplier which was applied to the vector of State Gross Output.

Once the regional input-output model was created, the scenarios of various levels of oil shale development had to be chosen and the oil shale sectors had to be developed. These sectors were then inserted into the regional input-output model. Eight scenarios were chosen: The Base Case, with no shale development; and seven levels of shale development (25,000; 50,000; 75,000; 100,000; 150,000; 200,000; and 250,000 bbl/d.). A mixed-integer programming model was then used to determine what combination of plant size and technology would minimize the amount of water required for each scenario. Once the model was solved, the direct coefficients for each plant size/technology combination were obtained from other sources. The actual transactions flows for each scenario were created using the 1972 price of $7.64/bbl of oil. These flows were then inserted into the regional input-output matrix. The result was a set of eight matrices showing shale development of from zero to 250,000 bbl/d.

In order to relate the oil shale industry to agriculture, several interrelated steps had to be taken. First, it was recognized that the supply of water to the oil shale industry was the residual supply of water from agriculture. The mixed-integer programming model indicated the minimum amount of water for the shale industry which must be transferred away from agriculture. Since agriculture's demand curve for water in the Uintah Basin is known, it was possible to determine the change in agriculture's value added (or profit) resulting from this transfer of water to the shale industry.

To accomplish the final subobjective, new vectors of final demand had to be created to take the changes in the final demand of agriculture and oil shale into account. This was a three-step process. First, the fector of state final demand was modified via the regional employment multiplier. Thus, a vector of regional final demand was obtained. Second, the eight dollar values of oil shale production (representing zero to 250,000 bbl/d) were individually inserted into the vector. The result was a set of eight different vectors of final demand. Finally, these eight vectors were modified to take into account the decrease in agriculture's final demand (profit) under each scenario. Once the final demand vectors were created, they were premultiplied by the appropriate regional input-output matrix. The result was a set of eight vectors showing Regional Gross Output for each of the eight scenarios. These eight vectors were then analyzed to provide information about the direct and indirect effects of oil shale development and the related changes in agriculture.

Conclusions

After examining the results several conclusions could be drawn:

1. The transfer of water to the shale industry should have only a small effect on crop production since the sale of water by agriculture would be expected to come from the least productive sites; i.e., where water has a low marginal value. This may be seen from Table 8 and its supporting tables. Annual crop production decreases by no more than 1.5 percent under the assumption described in the Theoretical Chapter. This is a minimal impact, expecially when the changes in the other sectors are considered.

2. There would be a dramatic increase in employment with a concomitant increase in population. This increase in population would cause major increases in several service-oriented sectors. This assumes that there exists a stable relationship between employment and output. If this assumption is violated, the increase might not be as dramatic. Nonetheless, all available evidence indicates that there will be substantial growth in employment and in the service-oriented industrial sectors.

3. The service industries, Wholesale and Retail Trade, and Imports are the sectors that would show the most significant growth. This may be seen from Table 8 and its supporting tables. The reasons for this extreme growth include population growth and the increase in demand for the services of the industries, plus the limited capacity of the region to produce these goods and services.

4. The Heavy Industry sectors (14 and 15) and the Chemical Industry grow the least. Although some growth is shown, both absolutely and on a percentage basis, most of it can be accounted for by imports into the region. It is possible, however, that new industry (especially in the Chemical sector) might move into the region.

5. Government service sectors which would have to expand would require long-term debt financing. This is no more than expected considering the forecast population growth. The requirements of a growing population for roads, schools, hospital and sewer facilities could not be financed locally. Inevitably, the national bond markets would have to be approached.

6. Public Utilities (sector 17) would have to expand, also requiring long-term debt financing. The reasons for this expansion are the same as for (5) above. National bond markets would have to be approached to find the necessary funds in this case too.

7. The availability of financing for both local government projects and public utilities might prove to be a constraint as may be deduced from conclusions (5) and (6) above. It might prove necessary for the regional governments to obtain financing from non-regional sources (such as the banks in New York City). It would be prudent for local decision makers to establish their priorities in advance so as to be prepared for this eventuality. Overhasty setting of priorities could create long-term difficulties while solving short-term troubles.

These conclusions agree generally with other studies of the impact of shale development. It is apparent that if oil shale does become an economically feasible energy resource source, the Uintah Basin governments and industries will be required to provide substantial increases in goods and services.

Shortcomings and recommended further research

There are three major problems for which no satisfactory solutions were found by this study. These are, first, the demand for water by both the shale industry and agriculture is not well known. More research should be done in estimating the demand for water by agriculture. Similarly, the value of the marginal product of water in the shale industry needs to be estimated. This study was conducted using fixed proportions, a theoretical fault for which there is no remedy.

Second, this study was conducted using an input-output model for the State of Utah and then regionalizing the data. In this same vein, a vector of Shale Transactions flows for the region should be developed instead of attempting to regionalize the state vector of shale transactions flows. More, and better, data specific to the region would make more precise the measurement (estimation) of the impacts and effects of oil shale developments on the various economic sectors of the Uintah Basin. Finally, an employment multiplier was used to obtain both the regional gross output and new employment. Better techniques are available, but the data to use them are lacking.

These are several points which could be further researched.

1. Minimizing cost, or maximizing profits would be a more appropriate approach for the programming model.

2. The effect of the Central Utah Project on the water available to the region may be substantial.

3. The dynamic impacts of the development analyzed in this study on the region's economy are not considered.

4. The effect of a "Kapairowits" type project on shale development may be substantial.

Finally, there is some question as to the efficacy of Input-Output analysis in estimating regional impacts when the region's economy is small and the incipient industry is relatively large. This problem was accentuated when the changes in employment were computed. No other study has such high estimates of employment. That is probably due to the four underlying assumptions discussed in the Employment section. Certainly, the entire question merits additional study to determine the reliability of Input-Output projections under these circumstances. On the other hand, the great detail with which the region's economy is described in an input-output analysis and the intricate changes which may be analyzed, certainly makes this methodology worthwhile. Further refinements and the use of other studies as comparisons, should make the regionalized input-output model an excellent tool for projecting regional economic changes.

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