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THE MACROECONOMIC IMPACT OF ENERGY DEVELOPMENT IN THE LAKE POWELL AREA

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LAKE POWELL RESEARCH PROJECT

The Lake Powell Research Project (formally known as Collaborative Research on Assessment of Man's Activities in the Lake Powell Region) is a consortium of university groups funded by the Division of Advanced Environmental Research and Technology in RANN (Research Applied to National Needs) in the National Science Foundation.

Researchers in the consortium bring a wide range of expertise in natural and social sciences to bear on the general problem of the effects and ramifications of water resource management in the Lake Powell region. The region currently is experiencing converging demands for water and energy resource development, preservation of nationally unique scenic features, expansion of recreation facilities, and economic growth and modernization in previously isolated rural areas.

The Project comprises interdisciplinary studies centered on the following topics: (1) level and distribution of income and wealth generated by resources development; (2) institutional framework for environmental assessment and planning; (3) institutional decision-making and resource allocation; (4) implications for federal Indian policies of accelerated economic development of the Navajo Indian Reservation; (5) impact of development on demographic structure; (6) consumptive water use in the Upper Colorado River Basin; (7) prediction of future significant changes in the Lake Powell ecosystem; (8) recreational carrying capacity and utilization of the Glen Canyon National Recreational Area; (9) impact of energy development around Lake Powell; and (10) consequences of variability in the lake level of Lake Powell.

One of the major missions of RANN projects is to communicate research results directly to user groups of the region, which include government agencies, Native American Tribes, legislative bodies, and interested civic groups. The Lake Powell Research Project Bulletins are intended to make timely research results readily accessible to user Groups. The Bulletins supplement technical articles published by Project members in scholarly journals.

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ABSTRACT

In this Bulletin the impact of power production in the Lake Powell area on the economy of the Southwest is investigated using the Metzler Model of interregional trade. Secondary data (of the input/output variety), organized by regional industrial sector, are used in application of the model. The impacts demonstrated are regional change in gross national product (GNP) and regional additions to employment. These impacts are generated by the initial changes in the pattern of trade occasioned by energy exports from the Lake Powell area, and the resulting regional expansion in energy-consuming activities. The model takes into account the effect of imports and exports among regions on the determination of GNP, through multiplier effects on local exogenous expenditures. The resulting changes include direct as well as indirect effects.

The specific sources of power generation considered in the study are the Glen Canyon Powerplant (hydroelectric) for the years 1972 and 1973 and the coal-fired Navajo Generating Station for a hypothetical year during full power production. The regions delineated are Arizona, California, Colorado, Nevada, New Mexico, Utah, and a region we call "Rest of the United States," exclusive of the Southwestern states.

The multipliers depicting the effect of an additional dollar spent locally on the GNP of a region are found to be: 1.19 (Arizona), 1.52 (California), 1.32 (Colorado), 1.07 (Nevada), 1.07 (New Mexico), 1.31 (Utah), and 1.90 (Rest of the United States).

According to results obtained from the model, the overall impact of current energy development in the Lake Powell area (using 1973 Glen Canyon figures and those projected for the Navajo Plant) is to generate a total increase in GNP of 1.25 billion dollars and an increase in employment of approximately 76,000 people. Of this overall increase in GNP, 47 percent goes to Arizona, reflecting the fact that this region contains the generating stations under analysis and obtains a large direct expenditure from them; 24 percent goes to the region "Rest of the United States" (excluding the Southwest), reflecting the importance of indirect expenditures resulting from interregional trade; 13 percent goes to California, a relatively closed and

highly integrated economy with a large local multiplier; and 16 percent goes to the Southwestern states, Colorado, Nevada, New Mexico, and Utah, which are regions with large propensities to import.

Using state employment coefficients, these changes in regional GNP are found to generate total changes in employment of 15,847, 13,287, and 60,286 workers for the cases of Glen Canyon in 1972 and 1973 and the projected full operation of the Navajo Generating Station, respectively.

THE MACROECONOMIC IMPACT OF ENERGY DEVELOPMENT IN THE LAKE POWELL AREA

I. INTRODUCTION

The Southwest is perhaps one of the few remaining sections of the United States which can expect major changes in both distribution of population and regional economic structure. Clearly these developments will require additional production from western energy sources, both to meet local demands and to satisfy increasing demands for energy exports. The purpose of this Bulletin is to indicate the macroeconomic impact of a portion of this expansion in energy production in the Lake Powell area. By macroeconomic impact we refer to growth in the gross national product (GNP) and employment by region (Arizona, California, Colorado, Nevada, New Mexico, Utah, and a region we call "Rest of the United States" exclusive of these Southwestern states), as it is affected by energy development within the Lake Powell area. Currently, power production near Lake Powell is limited to generation of electricity at the Glen Canyon Powerplant (hydroelectric) and at the coal-fired Navajo Generating Station. This Bulletin will detail the impact of these installations, and a future report will consider the impact of proposed coal development on the Kaiparowits Plateau where additional electrical generating facilities and, possibly, coal gasification are planned.

The value of a macroeconomic impact study of energy production lies in the way it shows how energy production in one region can affect growth and employment in surrounding regions. Clearly the political forces framing future energy development in the Southwest will be shaped by these as well as by other factors. Although the macroeconomic model developed here uses a relatively simple approach to interregional trade (that developed by Metzler), it does capture basic economic structure well enough to be a useful planning tool. In effect, we develop a one-sector interregional input/output model for the Southwest and the rest of the United States, with separate coefficients for determination of energy use and employment effects. Thus, the model can also be used to determine future energy requirements given population or GNP projections.

The model developed in this study is used to predict changes in GNP and employment by region, given an initial change in the pattern of trade or exchange which is caused by changes in exports of energy from the Lake Powell area to surrounding regions. It should be noted that these changes in GNP include indirect as well as direct effects, i.e., not only the increase in value of production made available by additional power, but also the indirect increase in production caused by multiplier (respending) effects. Only the first or direct portion of this overall increase can be equated to the economist's notion of gross benefits. Thus, we wish to emphasize that the primary purpose of this Bulletin is to estimate the impact of energy production in the Lake Powell area on regional growth, and not to assess some measure of economic benefits.

The report is organized in such a way that Section II can be read by the lay reader; it contains a summary of the methodology used and results of the modeling effort. Section III provides details of the theoretical model and the methodology employed in this analysis, while Section IV presents the estimated Metzler Model. Some final remarks are presented in Section V.

II. IMPACT OF ENERGY DEVELOPMENT ON THE LAKE POWELL AREA

The macroeconomic model which we use to estimate the impact of power production on GNP by region is based on the Metzler Model of interregional trade. We derive the impact of power production at the Glen Canyon Powerplant and at the Navajo Generating Station on the GNP by region for Arizona, California, Nevada, New Mexico, Utah, and the region Rest of the United States.

The Metzler Model takes into account the effect on GNP of imports and exports between regions through multiplier (respending) effects on local exogenous expenditures. Clearly a region which spends a large proportion of its income on imports will have a smaller multiplier effect on expenditures than will a more self-contained economy. The multiplier is lower because a larger proportion of initial expenditures is lost each time they are respent on imports into the region (i.e., the money leaves the region). Thus, it is important to adjust for such effects when considering impacts in an economically connected area such as the Southwest.

The first step in estimating the impact of additional electrical power on GNP by region is to determine the allocation of that power and the resulting direct increase in expenditures (final demand) necessary to support such an increase in power use. In order to do this, energy coefficients which translate increased power use into increased dollar expenditures are derived for each region from Input/Output (I/O) data on energy consumption by industry. It is assumed that the industrial mix within each region remains proportionally similar as output expands with increased energy availability. The coefficients which are used to accomplish this task are derived by disaggregating national energy consumption, measured in British Thermal Units (BTU), into economic sectors. Then a direct correspondence between energy consumption and the economic data for each sector in the I/O table is derived. This coefficient gives the amount of energy used per dollar of sales for each sector.[1] Thus, from increased energy purchased by region, one can derive the resulting direct expenditures. These are then "multiplied" by the Metzler Model to give total changes in GNP by region after certain adjustments have been made, as outlined below, to give net direct expenditures.

Clearly, a region which experiences an increase in direct and indirect expenditures as prescribed by the Metzler Model will experience an increase in employment. Using state employment coefficients which relate total regional output to the total number of persons employed in the region, an incremental change in employment for a region can be calculated given the change in the GNP of that region. Note that we are considering the longer term employment change as a result of energy production, not as a result of initial construction of a particular powerplant.

In order to apply this methodology to obtain direct and indirect expenditures and incremental employment changes, certain assumptions are used in applying the data.

In 1973 Glen Canyon Dam provided 65 percent of the total power marketed by the Colorado River Storage Project.[2] Total power included power produced and that purchased from other sources in order to fulfill existing contracts. Power production at Glen Canyon Dam for 1972 was 64 percent of the total. The allocation of megawatt-hours for 1973 and 1972 is derived on the assumption that 65 percent and 64 percent, for each respective year, of the power marketed by the Colorado River Storage Project to each region was produced at Glen Canyon Dam. This assumption must be made since it is nearly impossible to determine where power goes once it enters the transmission grid.

The production assumptions for the coal-fired Navajo Generating Station are different, primarily because the plant is not yet in full production. A probable scenario for future plant production has been developed in order to derive the allocation of megawatt-hours. Over the life of the plant (35 years), it is estimated that a plant factor of 75 percent for the station is reasonable. At this level of operation, the estimated cost per kilowatt-hour would have to be 13.7 mills in order to provide full return on the investment of the participants. This is not the charge that the participants will levy on customers, but is in a sense their payment to the Navajo Generating Station to cover respective shares of capital and operating costs.[3]

The direct expenditures resulting from increased power availability presented in Table 1 must be adjusted as is shown in Tables 2 and 3 before applying the Metzler Model. The adjustments take three forms. First, the Glen Canyon Project, which the Bureau of Reclamation supervises, requires payback to the federal government; and, second, the Navajo Generating Station, which is managed by the Salt River Project in which the participants are primarily private firms, requires an allocation of the return on investment. Third, operating costs must be allocated as regional expenditures. For the Glen Canyon case, the adjustments are as follows: (1) payments for the power sold by the Colorado River Storage Project from regions to the United States Treasury must be subtracted; (2) these payments are then redistributed to all regions proportional to the fraction of total federal purchases made in each region after subtracting operations and maintenance expenditures for Glen Canyon; and (3) operation and maintenance expenditures are returned to Arizona.

Tables 1 and 2 present results for the Glen Canyon case. Noting from Table 1 that Arizona received 994,854 megawatt-hours in 1973 from Glen Canyon Dam, and given that this was the largest allocation, it is not surprising to see the largest resultant direct expenditure from the additional power, $40,136,000. From this amount, $6,942,000 is returned to the Treasury, and $184,000 is allocated back to Arizona as federal expenditures. Since the powerplant is located in Arizona, the operations and maintenance expenditures are assumed to remain there. The result is a net direct expenditure of $41,000,000.

The adjustments for the Navajo Generating Station are as follows: (1) payments for power "purchased" by the participants must be subtracted; (2) profits from the power generation must be redistributed back to the regions; and (3) operation and maintenance expenditures are returned to Arizona. The result is then, in both cases, net direct expenditures which are "multiplied" by the Metzler Model into changes in GNP by region.

Table 1: Direct Expenditures as a Result of Additional Power

	.948x10^{-3}	x	Allocation of power by state (megawatt-hours)	x	State Energy Coefficient ($1,000/10^{6}BTU)	=	Direct Expenditures from Additional Power ($1,000)
1973 Glen Canyon							
Arizona			994,854		42.56		40,136
California			139,333		40.58		5,360
Colorado			816,013		37.99		29,386
Nevada			374,970		41.64		22,774
New Mexico			377,435		37.62		8,750
Utah			913,332		31.07		26,901
Rest of U. S.			271,909		36.14		9,317
1972 Glen Canyon							
Arizona			969,643		42.56		39,119
California			62,115		40.58		2,389
Colorado			674,614		37.99		24,294
Nevada			262,291		41.64		10,355
New Mexico			358,276		37.62		12,778
Utah			757,148		31.07		22,301
Rest of U. S.			204,532		31.14		7,008
Projected Navajo Plant							
Arizona			9,978,201		42.56		402,552
California			3,133,890		40.58		120,554
Colorado			0		37.99		0
Nevada			1,670,418		41.64		65,945
New Mexico			0		37.62		0
Utah			0		31.07		0
Rest of U. S.			0		36.14		0

Even though there are six participants [1] in the Navajo Generating Station when aggregated by region, only three gross allocations are traceable. (Of the six, four market electricity in Arizona, one in California, and one in Nevada.) Thus, for the Navajo Generating Station, net direct expenditures are zero for Colorado, New Mexico, Utah, and the region Rest of the United States. As we will see this does not necessarily preclude GNP changes effected through the regional multipliers.

These changes are presented in Table 4 in which indirect expenditures have been singled out to give some idea of the magnitude of respending effects for different regions. Note that among the individual regions included in the Table, California's indirect expenditures are largest in proportion to direct expenditures, while Nevada's are the smallest. This result is obtained because the California economy is better integrated and less dependent on imports than is the Nevada economy, and it implies that an increment in power sold to California will have a greater increase in local GNP, and consequently in local employment, than will a similar increment sold to Nevada.

Table 2: Composition of Net Direct Expenditures by State ($1,000)

	Direct Expen. from Additional Power	−	Payment to Federal Treasury for Glen Canyon Power	+	Payment Returned to States as Federal Expenditures	+	Operations and Maintenance	=	Net Direct Expenditures
1973 Glen Canyon									
Arizona	40,136		6,942		184		7,623		41,000
California	5,360		799		2,685		0		7,246
Colorado	29,386		5,038		249		0		24,598
Nevada	22,774		2,088		63		0		20,748
New Mexico	8,750		2,084		134		0		6,801
Utah	26,901		5,028		140		0		22,012
Rest of U. S.	9,317		1,590		15,623		0		23,350
1972 Glen Canyon									
Arizona	39,119		6,476		164		5,989		38,796
California	2,389		329		2,400		0		4,460
Colorado	24,294		4,089		223		0		20,428
Nevada	10,355		1,607		56		0		8,804
New Mexico	12,778		1,951		120		0		10,948
Utah	22,301		4,145		125		0		18,281
Rest of U. S.	7,008		1,646		13,964		0		19,326

Table 3: Composition of Net Direct Expenditures by State ($1,000) for Projected Navajo Plant

	Direct Expen. from Additional Power	−	Payment to Navajo Plant To Cover Cost	+	Profits Returned to States	+	Operation and Maintenance	=	Net Direct Expenditures
Arizona	402,552		123,001		2,176		163,178		444,905
California	120,554		42,934		605		0		78,224
Colorado	0		0		0		0		0
Nevada	65,945		22,885		322		0		43,383
New Mexico	0		0		0		0		0
Utah	0		0		0		0		0
Rest of U. S.	0		0		0		0		0

The impact of power production on employment in the various regions can be seen in Table 5. Given that the employment coefficients are quite similar in magnitude, it is not surprising that the regions which receive a large proportion of the power also experience large employment changes. Recalling the 1973 Glen Canyon case in Table 4, we note the large indirect expenditure of $64,838,000 for the category "Rest of the United States." This results in a relatively large change in employment due to indirect expenditures for this category. This example well illustrates the interdependence of the regional economies when exogenous effects are traced through the Metzler Model.

The total impact of current energy development in the Lake Powell area (using 1973 Glen Canyon figures and those projected for the Navajo Generating Station) is an increase in GNP of 1.25 billion dollars and an increase in employment of approximately 76,000 people. Of this overall increase in GNP, 47 percent goes to Arizona, reflecting the fact that this region contains the generating stations under analysis and obtains a large direct expenditure from them; 24 percent goes to the region listed as "Rest of the United States" (exclusive of the Southwest), reflecting the importance of indirect expenditures resulting from interregional trade; 13 percent goes to California, a relatively closed and highly integrated economy with a large local multiplier; and 16 percent goes to Southwestern states other than California and Arizona (Colorado, Nevada, New Mexico, and Utah), which are regions with large propensities to import.

Several points should be made concerning these results. Although economists are generally concerned with the measurement

Table 4: Impact on GNP ($1,000) of Power Production in the Lake Powell Area by Region

	Net Direct Expenditures	+	Indirect Expenditures	=	Impact on GNP
1973 Glen Canyon					
Arizona	41,000		10,214		51,214
California	7,246		11,223		18,469
Colorado	24,598		9,828		34,426
Nevada	20,748		5,666		26,414
New Mexico	6,801		2,988		9,789
Utah	22,012		11,331		33,343
Rest of U. S.	23,350		64,838		88,188
				TOTAL	261,868
1972 Glen Canyon					
Arizona	38,796		9,327		48,123
California	4,460		8,630		13,090
Colorado	20,428		8,221		28,649
Nevada	8,804		4,443		13,247
New Mexico	10,948		2,858		13,806
Utah	18,281		9,378		27,659
Rest of U. S.	19,326		54,882		74,208
				TOTAL	218,782
Projected Navajo Plant					
Arizona	444,905		86,020		530,925
California	78,224		62,545		140,769
Colorado	0		11,749		11,749
Nevada	43,383		16,641		60,024
New Mexico	0		9,798		9,798
Utah	0		24,815		24,815
Rest of U. S.	0		210,448		210,448
				TOTAL	988,528

of direct expenditures to define benefits, large increases in indirect expenditures with consequent employment effects are important in the political decision-making process. The second largest increase in GNP (24 percent) occurs completely out of the Southwest and is composed almost entirely of indirect expenditures. This suggests that energy-related development in the Southwest has a broad expansionary influence even when the energy is consumed locally. Finally, indirect expenditures should be counted as benefits when unemployed resources (e.g., labor) are used in the expansion of output. It must be noted, however, that even with existing unemployment, expansion of GNP may simply escalate prices of scarce types of labor or increase overtime, leaving levels of unemployment unchanged.

Table 5: Incremental Change in Employment

	Region Employment Coefficient (people/$1,000)	x	Change in GNP ($1,000)	=	Increment in Employment (# of people)
1973 Glen Canyon					
Arizona	.0632		51,214		3,237
California	.0562		18,469		1,038
Colorado	.0634		34,426		2,183
Nevada	.0621		26,414		1,640
New Mexico	.0672		9,789		658
Utah	.0590		33,343		1,967
Rest of U. S.	.0581		88,188		5,124
				TOTAL	15,847
1972 Glen Canyon					
Arizona	.0632		48,123		3,041
California	.0562		13,090		736
Colorado	.0634		28,649		1,816
Nevada	.0621		13,247		823
New Mexico	.0672		13,806		928
Utah	.0590		27,659		1,632
Rest of U. S.	.0581		74,208		4,311
				TOTAL	13,287
Projected Navajo Plant					
Arizona	.0632		530,925		33,554
California	.0562		140,769		7,911
Colorado	.0634		11,749		745
Nevada	.0621		60,024		3,727
New Mexico	.0672		9,798		658
Utah	.0590		24,815		1,464
Rest of U. S.	.0581		210,448		12,227
				TOTAL	60,286

III. THEORY AND METHODOLOGY

The Metzler Model [4] can be described briefly as follows. Where i or j denotes the ith or jth region, we have by definition in which regional income (Y_i) is equal to regional consumption (C_i) plus exogenous expenditures including investment and government (E_i), plus the sum of exports minus imports ($X_{ij} - M_{ij}$) over all other regions plus exogenous net expenditure

$$(1) \quad Y_i = C_i + E_i + \sum_{\substack{j \\ j\neq 1}} (X_{ij} - M_{ij}) + Z_i, \qquad i = 1,2,\ldots,n \quad j = 1,2,\ldots,n$$

flows between regions (Z_i). Assuming the usual relationships for a long run consumption function

$$(2) \qquad C_i = b_i Y_i \qquad i = 1,2,\ldots,n$$

and for imports and export flows

$$(3) \qquad M_{ij} = m_{ij} Y_i \qquad i = 1,2,\ldots,n$$

$$(4) \qquad X_{ij} = x_{ij} Y_j$$

where b_i is the marginal and average propensity to consume, m_{ij} are the marginal and average propensities to import, and x_{ij} are the marginal and average propensities to export, we can derive changes in regional income (ΔY_i) from changes in net direct expenditure flows (ΔZ_i) from the following relationship, using the Metzler matrix:

$$(5) \qquad \begin{bmatrix} (1 + \sum_j m_{ij} - b_1) & -x_{12} & \cdots & -x_{1n} \\ -x_{21} & & & \\ \vdots & & & \\ -x_{n1} & \cdots & \cdots & (1 + \sum_j m_{nj} - b_n) \end{bmatrix} \begin{bmatrix} \Delta Y_i \\ \vdots \\ \Delta Y_n \end{bmatrix} = \begin{bmatrix} \Delta X_i \\ \vdots \\ \Delta Z_m \end{bmatrix}$$

The ΔZ_i values can be taken from Tables 2 and 3 to produce ΔY_i as shown in Table 4. The coefficients for the model above were derived from economic data for 1963 taken from References [5], [6], and [8].

The question of the stability of multiple market models is extremely important if one is to view the results of such a model with confidence. In connection with the controversy over Hicksian stability conditions, various contributions have been made that clarify the situation. Hicks viewed a market as stable if an excess supply results when a good's price is above the equilibrium value, and the converse for excess demand. This is considered to be true regardless of the conditions of other markets. Hicks' analysis was criticized by others on the grounds that the above classifications were not derived from an explicit dynamic model.

Although Metzler did not fully resolve this issue, his contribution in this area offers progress in terms of multisectoral trade models such as the one employed in this paper. He concentrated on what is called the gross substitute case. This case exists when a rise in the price of commodity j will reduce excess supply of commodity i. If a situation of gross substitutes exists, then the Hicksian conditions are both necessary and sufficient for the stability of equilibrium in a system of m interrelated markets.

Specifically, for stability in the case of the Metzler matrix, the diagonal coefficients of the matrix must have the characteristic that all are of the same sign, while the off-diagonal coefficients must all have the opposite sign to those on the diagonal. Additionally, in order to fit into the gross substitutes class, all of the import propensities must be greater than zero and the marginal propensity to spend (b_i) minus the sum of the import propensities (Σm_{ij}) must be less than unity for each region. If the above conditions are fulfilled, then the model is stable. Instability for the Metzler Model implies that the marginal propensity to spend is greater than unity. In this case the model would fail to converge to a new equilibrium level. Additionally, if the import propensities are negative, then in essence, given the structure of the model, they become export propensities. This condition would imply that suddenly more of a good is being exported than imported, thus prohibiting convergence toward a new equilibrium.

The derivation of the terms m_{ij} and x_{ij} required a new approach because interregional trade data are not readily available.[4] This new methodology used data compiled and organized by Polenske et al. [6] Their work contains figures for state product, in each of 87 industrial classes, and state final demand, for the same industrial classes, disaggregated into six demand classifications. The demand figures for each industrial class were simply added to obtain state final demand, disaggregated only into consumption and (for our purpose) exogenous expenditures.

Intermediate demand (direct requirements) was determined by using coefficients developed by the Department of Commerce [5] for the 1963 national input/output model, which assumes identical technology in all regions. With δ_{hk} = dollar value of industrial product k required per dollar output of industrial product h , intermediate demand in region i for industrial product k (ID_{ik}) can be seen to be the sum of the appropriate δ_{hk} times the regional product (P_{ih}):

$$(6) \qquad ID_{ik} = \sum_{h} \delta_{hk} P_{ih}$$

Total exports $(\hat{X}_{ik})$ and imports $(\hat{M}_{ik})$ for each region i of industrial product class k were derived by subtracting regional intermediate demand (ID_{ik}) from regional product:

$$(7) \qquad \hat{X}_{ik} = \begin{cases} 0 \text{ if } P_{ik} \leq FD_{ik} + ID_{ik} \\ P_{ik} - FD_{ik} - ID_{ik} \text{ if } P_{ik} > FD_{ik} + ID_{ik} \end{cases}$$

$$(8) \qquad \hat{M}_{ik} = \begin{cases} FD_{ik} + ID_{ik} - P_{ik} \text{ if } P_{ik} < FD_{ik} + ID_{ik} \\ 0 \text{ if } P_{ik} \geq FD_{ik} + ID_{ik} \end{cases}$$

Note here that each region is seen to be either a pure importer or a pure exporter of any particular class of industrial products. If an assumption of competitive trade in the United States is made, no distortion results, although some understatement of trade flows results from the aggregation.

The device for allocating these aggregated exports and imports is the assumption that the exports of region i to region j of class k industrial goods ($\tilde{X}_{ijk}$) would have the same relationship to total exports from region i of class k industrial goods ($\tilde{X}_{ijk} \equiv \hat{X}_{jk}$) as do exports from all regions to region j of class k industrial goods ($\sum_i \tilde{X}_{ijk} \equiv \hat{M}_{jk}$) to total exports of class k goods.

Thus, we have:

$$(9) \qquad \frac{\tilde{X}_{ijk}}{\sum_j \tilde{X}_{ijk}} = \frac{\sum_i \tilde{X}_{ijk}}{\sum_i \sum_j \tilde{X}_{ijk}}$$

which can be reformulated as:

$$(10) \qquad \tilde{X}_{ijk} = \frac{\sum_j \tilde{X}_{ijk} \cdot \sum_i \tilde{X}_{ijk}}{\sum_i \sum_j \tilde{X}_{ijk}}$$

Keeping in mind that $\tilde{X}_{ijk} = \tilde{M}_{ijk}$, it might be more convenient to think of equation (10) as stipulating that all regions importing class k industrial products allocate their purchases among the exporting regions in the same proportion; e.g., if 10 percent of all class k industrial goods in interregional trade were exported from region i, all importing regions would purchase 10 percent of their imports of class k goods from region i.

The resulting terms $\tilde{X}_{ijk}$ and $\tilde{M}_{ijk}$ were then reaggregated to yield

$$(11) \qquad X_{ij} = \Sigma \tilde{X}_{ijk} \quad \text{and} \quad M_{ij} = \sum_k \tilde{M}_{ijk}$$

Having thus obtained all the items in equations (2), (3), and (4), equation (1) was merely the result of division and addition:

$$(12) \qquad b_i = C_i/Y_i; \; x_{ij} = X_{ij}/Y_j; \; m_{ij} = M_{ij}/Y_i$$

In order to convert increased energy availability in each region to resulting direct expenditures, the following methodology was used. Letting

EC_k = energy coefficient (the amount of energy used per dollar sales for each sector k)

P_{ik} = output in region i for industry k

EU_{ik} = energy used in region i by industry k

FP_{ik} = the factor of proportionality relating energy used by kth industry to region total

ΔE_i = the increment increase in power that is going to region i

ΔP_{ik} = additional output resulting from ΔE_i

The system of equations for calculating direct expenditures is as follows:

$$(13) \qquad (EC_k)(P_{ik}) = (EU_{ik})$$

$$(14) \qquad (EU_{ik})/(\sum_k EU_{ik}) = (FP_{ik})$$

$$(15) \qquad \Delta EU_{ik} = (FP_{ik})(\Delta E_i)$$

$$(16) \qquad \Delta P_{ik} = (\Delta EU_{ik})/EC_k$$

Equation (13) enables the determination of the quantity of energy used in the ith region by the kth sector. Relating a particular sector to the total used in the region in equation (14) allows the derivation of a factor of proportionality. Thus, given an exogenous introduction of power into a region, equations (15) and (16) allow the calculation of direct expenditures for each region. This of course assumes that as the total output of a region increases, the structure of the sectors remains constant. It should be pointed out that by assuming these coefficients are constant, we ignore both technical change and the role of relative changes in factor prices, and also that no causality is implied here, but rather power is assumed to be a requirement necessary to allow regional growth to occur.

IV. THE ESTIMATED METZLER MODEL

The estimated Metzler Model is presented in Tables 6 through 9. Table 6 can be interpreted using the following example. Selecting Arizona in the vertical listing of regions, one can find the export propensity to California which is 0.00779. Note that the elements of the principal diagonal are zero. This may be easily understood, since a region cannot export or import to itself. It is interesting to note in Table 6 that the export coefficients for the category "Rest of the United States" are lower in magnitude for the more integrated economies such as that of California. This aspect of the model confirms our theoretical expectations concerning the structural relationships that exist in the real world.

The marginal propensities to spend are presented in Table 7. These numbers indicate the percentage of each additional dollar of income that will be consumed by the region. The value is always assumed to be less than unity; thus for an additional dollar a certain portion will be consumed and the rest will be saved. For instance, an additional dollar to Arizona will create $0.58 in consumption with $0.42 being contributed to savings and taxes. In addition, in Table 8 we can see that the stability conditions for the model are fulfilled. The diagonal of the Metzler matrix begins with 0.84688 in the a_{11} location and ends with 0.53938 in the a_{77} location. All these coefficients are of the same sign, which is positive, and the off-diagonal coefficients are all negative. The marginal propensity to spend minus the sum of the import propensities is less than unity for each region. Thus, since the conditions are fulfilled, the matrix under discussion is stable.

Table 6: Export Propensities (x_{ij})

	Arizona	California	Colorado	Nevada	New Mexico	Utah	Rest of the U.S.
Arizona	0.0	0.00779	0.01296	0.00591	0.00778	0.01195	0.01306
California	0.01536	0.0	0.02278	0.02814	0.03646	0.01764	0.01962
Colorado	0.01190	0.00807	0.0	0.01033	0.01480	0.00551	0.00279
Nevada	0.01377	0.00805	0.01517	0.0	0.02390	0.03159	0.01771
New Mexico	0.01011	0.00357	0.00497	0.00327	0.0	0.01148	0.01328
Utah	0.02546	0.01550	0.00971	0.03794	0.03429	0.0	0.00265
Rest of U.S.	0.16955	0.04267	0.11179	0.18504	0.23630	0.11085	0.0

Table 7: The Marginal Propensities To Spend (b_i)

Arizona	0.58
California	0.55
Colorado	0.64
Nevada	0.48
New Mexico	0.58
Utah	0.59
Rest of U.S.	0.65

Finally, Table 9 presents the inverse Metzler matrix. Elements on the main diagonal are multipliers on local expenditures. The off-diagonal elements are regional multipliers of out-of-region expenditures. Thus, a dollar expended locally will in all cases create respending in excess of a dollar as all multipliers are greater than unity. This matrix multiplied by the vector of net direct expenditures gives regional changes in GNP. Net direct expenditures were derived in Section II and were presented in Tables 2 and 3.

Table 8: The Metzler Matrix

	Arizona	Cali-fornia	Colo-rado	Nevada	New Mexico	Utah	Rest of the U.S.
Arizona	0.84688	-0.00779	-0.01296	-0.00591	-0.00778	-0.01195	-0.01306
California	-0.01536	0.66250	-0.02278	-0.02814	-0.03646	-0.01764	-0.01962
Colorado	-0.01190	-0.00807	0.76116	-0.01033	-0.01480	-0.00551	-0.00279
Nevada	-0.01377	-0.00805	-0.01517	0.94546	-0.02390	-0.03159	-0.01771
New Mexico	-0.01011	-0.00357	-0.00497	-0.00327	0.93942	-0.01148	-0.01328
Utah	-0.02546	-0.01550	-0.00971	-0.03794	-0.03429	0.76502	-0.00265
Rest of U.S.	-0.16955	-0.04267	-0.11179	-0.18504	-0.23630	-0.11085	0.53938

Table 9: The Inverse Metzler Matrix

	Arizona	Cali-fornia	Colo-rado	Nevada	New Mexico	Utah	Rest of the U.S.
Arizona	1.18884	0.01714	0.02600	0.01528	0.01992	0.02452	0.03066
California	0.04384	1.51685	0.05739	0.06014	0.07870	0.04853	0.06068
Colorado	0.02163	0.01753	1.31670	0.01744	0.02483	0.01265	0.00922
Nevada	0.02767	0.01750	0.02875	1.06828	0.03991	0.05123	0.03777
New Mexico	0.01949	0.00857	0.01215	0.01049	1.07318	0.02114	0.02772
Utah	0.04439	0.03328	0.02177	0.05677	0.05443	1.31368	0.01206
Rest of U.S.	0.40881	0.14561	0.30527	0.39592	0.51267	0.31099	1.89790

V. FINAL REMARKS

The structural model of the Southwest economy developed in this Bulletin is based on 1963 data. Clearly, since the Southwest is undergoing rapid economic changes, a more recent data base for the modeling effort would be useful both (1) to improve the accuracy of our estimates of GNP and employment effects, and (2) to provide an indication of the type of structural model with a more recent version.

Other future plans for development of the model include integration with another model, already constructed, of the local Lake Powell area economy, and estimation of the regional impacts of recreation and water diversions. We have estimated that total recreation expenditures in the Lake Powell area were 6.6 million dollars in 1973, and we have data on the sources of visitors so that changes in trade flows associated with recreation at Lake Powell can be identified to derive corresponding impacts on regional GNP and employment. Similarly, water-use coefficients by sector are readily available to translate water diversions associated with construction of Glen Canyon Dam and related projects into changes in direct expenditures. These topics will be treated in a future Bulletin in this series.

One additional comment is appropriate. The estimates of state GNP used in this study do include some double counting which is consistent with the definition of GNP used in Reference [6], but which is inconsistent with national accounting data. For purposes of this study the relative magnitudes of changes in GNP between regions will be unaffected by such definitional matters. However, regional GNP figures produced by this model cannot be summed in a manner consistent with aggregate accounting data.

FOOTNOTES

1. State energy coefficients were derived from data taken from Reardin [7] and from Rodgers [8].

2. See Bureau of Reclamation References [2] and [3]. We thank Ralph Derrick of the Bureau of Reclamation, Salt Lake City, for assistance.

3. We thank Bing Brown, Supervisor of Public Information for the Salt River Project, who kindly provided the estimates.

4. This methodology was developed by Regan Whitworth.

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GLOSSARY

gross national product (GNP) — a measure of the value of all goods and services produced by an economy

gross benefits — the value to users of the direct products of an activity

input/output model — a type of linear fixed technical coefficient model of an economic system

multiplier — a term which relates a given level of exogenous expenditures to a different (usually larger) change in gross national product which results from that exogenous expenditure

exogenous expenditures — expenditures in an economic system which are not determined by elements of that system. They may result from such diverse causes as governmental policy, natural phenomena, and changing technology

plant factor — load factor; the ratio of actual output of a given production unit to nominal or possible output during a given length of time

long-run consumption function — the relationship between consumption and income after transient adjustments to new income level have been completed

macroeconomic — pertaining to variables of the economic system at a high level of aggregation; as opposed to microeconomic, which refers to disaggregate units in the economy

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