THE IMPACT OF WATER TRANSPORT ON THE OKLAHOMA ECONOMY

James C. Chang and Daniel D. Badger*

Anticipation of rapid regional growth in Oklahoma has prevailed in the state since the 1970 completion of the McClellan-Kerr Arkansas River Navigation System, the largest civil works project ever undertaken by the Corps of Engineers. Major functions of the multipurpose project include navigation, flood control, water supply, hydro-electric power generation, and recreation. Economic growth, as foreseen by the public, is expected to be induced by expansion of the manufacturing sector, which in turn is generated by incoming firms and industries in response to the available low-cost waterway transportation.

The major objective of this study was to determine the net impact of the waterway transport on the Oklahoma economy. The study area chosen for analysis was the state of Oklahoma. Although the economic impact of the Arkansas River may reach other states, selection of the state of Oklahoma as the study region facilitated the data collection.

Results of several previous studies on location of industries or firms, based upon interview techniques, showed that transportation, among many factors, did play a role in the selection of location (Carrier and Schriver; Greenhut and Colberg, Mueller et al.). However, these studies failed to show the quantitative relationship between the location advantage in terms

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of transportation and industrial growth. Procedures applied to fulfill the objective of the study should give some insight of the transmitting mechanism, whereby initial effects of waterway transport can be conveyed to a locational advantage, and then to economic growth. Therefore, an alternative approach which is described below, was adopted.

Procedures

Because empirical studies showed different industries had different responses to location factors, procedures for studying the waterway impacts should be designed to reflect the effects of water transport on individual industries. An alternative of applying input-output techniques has been suggested by Lewis et al to estimate the net effect of water transportation. Input-output analysis provides a broad coverage and a precise reflection of the state of the economy and technology. Furthermore, many industries of interest may be included and trade relationships may be specified. Therefore, an input-output model was used as the basic analytical tool for the study.

Baseline Model

Under the assumption that the pattern of interregional trade for the final demand sector is the same as that for the processing sector, an interregional input-output model can be written in matrix form as (Schreiner, et al)

(1) $X = T\bar{A}X + TY$

where X and Y are column vectors representing output and final demand, respectivity; T is trade coefficient matrix; and $\bar{A}$ is technical coefficient matrix which does not account for interregional trade.

The Arkansas River Navigation System provides a low-cost means of transportation. Producers using water transport to ship their products could expand their market area. Raw materials imported from outside the state would be less expensive if they were shipped by barge (Lewis, et al). This suggests a change in the pattern of interregional trade. Consequently, a two-region input-output coefficient matrix for 1967, which included Oklahoma (designated as Region 1) and the rest of the U.S. (designated as Region 2) was constructed.

Let (2)
$$T = \begin{bmatrix} T^{11} & \vdots & T^{12} \\ \cdots & & \cdots \\ T^{21} & \vdots & T^{22} \end{bmatrix}$$

and (3)
$$\bar{A} = \begin{bmatrix} A^{1} & \vdots & 0 \\ \cdots & & \cdots \\ 0 & \vdots & A^{2} \end{bmatrix}$$

Each submatrix, T^{uv}, in T (Chang) is a diagonal matrix of which the i-th element in diagonal indicates the proportion of goods or services of the i-th industry purchased by region v from region u. Submatrices A^1 and A^2 in A denote the 1967 input-output coefficient matrices, of Oklahoma (Chang) and the U.S. (USDC, 1974) respectively. Since the study area constitutes only a small protion of the U.S. economy, it may be assumed that the input-output coefficient matrix for the rest of the U.S. is the same as that for the U.S.

Thus, (4)
$$T\bar{A} = \begin{bmatrix} A^{11} & \vdots & A^{12} \\ \cdots & & \cdots \\ A^{21} & \vdots & A^{22} \end{bmatrix}$$

where (5)
$$A^{uv} = [a_{ij}^{uv}] = [t_i^{uv} \cdot a_{ij}^{v}]$$

Each a_{ij}^{uv} in A can be interpreted economically as the amount of input required from the i-th industry in region u by the j-th industry in region v to produce one-dollar output.

Hence, (6)
$$X = (I - T\bar{A})^{-1} TY$$

or (7) $$X = (I - A)^{-1} TY$$

The input-output model contains 79 endogenous industries in each region. The matrix $(I-A)^{-1}$ thus has 158 rows and 158 columns. Because of space limitations, these relevant matrices will not be presented here.

The baseline output projections for 1980, which depict the projected output levels based on the assumption of no waterway facility, were estimated from the 1980 final demand projections (Scheppach) and $(I-A)^{-1}$. The baseline employment and income projections were computed from the employment-output and income-output ratios as well as output projections. These estimates are presented in Table 2 by broad industry category.

Estimating the Impact

As indicated by Lewis, et al., industries that can ship their products via water should catch a larger share of the market since the costs of water transport are lower. As a result,

(8) $$\hat{t}_i^{12} \geq t_i^{12}$$

where t_i is the trade coefficient before the waterway was completed, and $\hat{t}_i$ is the new coefficient which reflects the new trade patterns after the water transportation became available. Moreover, imports of the state may be expected to rise. That is,

(9) $$\hat{t}_i^{21} \geq t_i^{21}$$

Data for commodity shipment on the Arkansas River collected by the Corps of Engineers, Tulsa District, indicated a few industries in the manufacturing sector as major users of the Arkansas waterway. Thus new trade coefficients were estimated for these industries: Chemical, Plastics and Synthetics, Petroleum, Primary Iron and Steel, and Fabricated Metal.

Since trade coefficients were calculated from flows of interregional trade, absolute levels of commodity flow for each of the selected industries had to be estimated first. Although the volume of trade (either import or export) can be expected to have an inverse relationship with geographical distance between Oklahoma and other states, some industries ship their products farther than others because of different degrees of production concentration in terms of location and product characteristics. Therefore, the geographical distance should be adjusted for an industry's "average shipping distance" of products. The average shipping distance for an industry was calculated from transportation census data (USDC, 1966) by dividing ton-miles of shipment by tonnage of shipment of the industry. Given the locations of production and consumption, the average shipping distance may affect the trade volume since it reflects transportability. However, the average distance of shipping depends on characteristics of products (such as durable or nondurable), capability of bearing transport cost, mode of transportation, and transport costs required for an industry. Hence, the first step in estimating trade was to establish the relationship between shipping distance and the relevant variables. Each of the input-output industries in the manufacturing sector, except Ordnance (IO-13) and Printing and Publishing (IO-26) for which data were not available, was used as an observation. The results obtained were:

(10) $$D = 640.4148 + 5.0878\ W + 0.0042\ V - 77.7587\ T$$

$$(16.0254) \quad (2.7682) \quad (2.6502) \quad (-4.5406) \text{ t statistics}$$

$$R^2 = 0.43 \qquad F = 11.4010 \text{ at 46 and 3 degrees of freedom}$$

where

D = average shipping distance in miles;

W = percentage of tonnage shipped by water in 1963 (USDC 1966);

V = value of shipment per ton in dollars in 1963 (USDC 1966 and 1971); and

T = inputs required from Transportation and Warehousing per dollar of output in cents, which is a proxy variable for the transport cost of an industry (USDC 1969).

The second step of the estimating procedure was to develop models of Oklahoma imports and exports for each of the selected industries. Again, these models are simple as compared to economic theories underlying supply and demand, and interregional trade, due to a lack of appropriate data. The least square regression equations were estimated in the form of

$$(11) \quad x_i^{lv} = a_o \left(\frac{M^{lv}}{D_i}\right)^{a_1} (y_i^v)^{a_2}$$

for Oklahoma exports; and

$$(12) \quad x_i^{ul} = b_o \left(\frac{M^{lv}}{D_i}\right)^{b_1} (y_i^u)^{b_2}$$

for Oklahoma imports; where

x_i^{lv} = Oklahoma exports to state v for the i-th industry in 1963, measured in $1,000 (Rodgers);

M^{lv} = geographical distance measured in highway miles between Oklahoma City and capital of state v;

D_i = average shipping distance in miles for industry i;

y_i^v = final demand gross product of state v for the i-th industry in 1963, measured in $1,000 (Polenske, et al.); and

x_i^{ul} = Oklahoma imports from state u for the i-th industry in 1963, measured in $1,000 (Rodgers).

Since the coefficients in a Cobb-Douglas function represent elasticities of the dependent variable with respect to the corresponding independent variables, coefficients (exponents) a_1 (or b_1) and a_2 (or b_2) can be regarded as Oklahoma export (or import) elasticities with respect to transportation and demand, respectively. The estimated elasticities are presented in Table 1.

Since the section of the Arkansas River Navigation System was not opened until 1970, the imported and exported goods of Oklahoma in 1963 would have would have been shipped by means other than water. In other words, the percentage of tonnage of water transportation was zero for all industries in the 1963 base period. The proportion of output of Oklahoma industries transported by water has not been estimated. Hence, the national percent distribution of water transport in 1972 (USDC 1975) is assumed to prevail in Oklahoma in 1980.

The projected trade volume in 1980 for the industries selected in the study was made by first substituting the 1972 percent figures of total tonnage shipped by water into equation 10 to obtain the increase in the average shipping distances for those industries. Then by using the increases in shipping distances and final demand projections for 1980, as well as elasticities (listed in Table 1) the percent increase in trade from 1963 to 1980 was computed. The projected trade coefficients for 1980 for the selected industries were calculated from the trade projections.

The changes in the trade coefficients caused changes in the interregional input-output coefficients (eq. 5). Therefore, a new matrix $\hat{A}$, was obtained. The levels of output for Oklahoma that may be reached under the new patterns of interregional trade was calculated as follows:

(13) $$\hat{X} = (I - \hat{A})^{-1}\hat{T}Y$$

Procedures for estimating employment and income were used again to obtain employment and income projections which showed the effects of the waterway.

Results

The differences in output, employment, and income between the two sets of projections can be used to measure the <u>net</u> effects of the Arkansas River Navigation System on the state economy. The results are presented in Table 2.

The 1980 state output will increase by $1.8 billion (1967 price levels) or 7.8 percent above the baseline level. The increase of output primarily arises from the Petroleum, Mining, Fabricated Metal, and Finance, Insurance and Real Estate (FIRE), which account for $825, $349, $207, and $123 million, respectively. Although the absolute gain in output is not impressive for Chemical and Primary Metal industries, the percent increase exceeds 10 percent above the baseline output of these industries. The results in Table 2 indicate that the expansion of the trade area for Oklahoma, because of the availability of low-cost water transportation, does have positive effects on the state economy. Conceivably, if port facilities and barge transport techniques are improved so that more commodities are adapted to water transportation, the economic impact will be enlarged.

An additional 36,000 jobs or 3.3 percent of the employment level of baseline model, will be created in 1980 (Table 2). Absolute gains are mainly found in Fabricated Metal, Mining, Petroleum, Wholesale and Retail, and Other Services. However, Fabricated Metal, Primary Metal, Mining, Petroleum, and Chemical industries have the largest percent increase. The absolute increase in employment for manufacturing and non-government services account for 40 and 33 percent of the total, respectively.

Total personal income in 1980 for the state is increased by $301 million (1967 price levels), or 4.5 percent due to the existence of the Arkansas River Navigation System. The greatest increases will come from Mining, Fabricated Metal, Petroleum, and Transportation, Communciation and Utilities. The non-government services industries will gain an additional $74 million over the baseline projection, which accounts for 25 percent of the total income increase. Although not all industries will realize the income gains, none will experience declines. Several industries are simply too small in terms of the share of state economy to reflect the benefits resulting from waterway transportation.

Summary

Significant impacts on the state output, employment, and income of the availability of water transport can be expected. The study showed that the manufacturing sector will grow rapidly; new firms will be attracted to the state and/or existing firms will expand their capacities. However, the importance of the services sector should not be underestimated as emphasis is focused on economic growth by means of expansion of manufacturing. Insufficient facilities and manpower in the services sector can impede the growth of manufacturing sector and thus the whole economy. A firm may not build a plant in an area without direct access to maintenance and repair services. Therefore, while the state attempts to attract new manufacturing firms, expansion of the services sector also should be accomplished.

It should be noted that reserves of crude oil and natural gas were not taken into consideration in this study. The additional output, employment, and income generated from the Mining are substantial. This suggests a strong linkage between the state economy and nonrenewable resources. Rapid depletion of oil and gas in the state will adversely affect the economic growth.

TABLE 1

TRANSPORTATION AND DEMAND ELASTICITIES FOR OKLAHOMA IMPORTS AND EXPORTS FOR SELECTED INSUDTRIES[a]/

Industry	Elasticities Transportation	Demand	R^2	F
	Oklahoma Imports			
IO-27 Chemical	-2.6867 (-5.6804)	0.7726 (4.7482)	.63	26.1840
IO-28 Plastics and Synthetics	-1.5855 (-3.0545)	0.7817 (5.9032)	.46	19.4184
IO-31 Petroleum	-3.3227 (-5.9201)	0.9103 (2.8639)	.51	24.2326
IO-37 Iron and Steel	-2.8911 (-4.3368)	0.9891 (5.3433)	.47	20.2256
IO-40 Fabricated Metal	-3.0741 (-7.5227)	1.3790 (6.4476)	.69	50.5614
	Oklahoma Exports			
IO-27 Chemical	-1.0780 (-4.9063)	0.5329 (7.9063)	.61	35.3231
IO-28 Plastics and Synthetics	-1.2041 (-3.2958)	0.7121 (7.6397)	.57	31.0179
IO-31 Petroleum	-5.2799 (-7.1398)	0.8757 (2.0908)	.57	30.1175
IO-37 Iron and Steel	-1.4364 (-5.6139)	0.6745 (9.4921)	.70	53.1341
IO-40 Fabricated Metal	-3.1267 (-4.1392)	0.7279 (1.8410)	.31	10.4960

[a]/Figures in parentheses under estimated elasticities indicate t-statistics for the corresponding elasticities. All t-values are significant at the 1 percent level except those for demand elasticity for Oklahoma exports of Petroleum (IO-31) and Fabricated Metal (IO-40); those are significant at the 5 and 10 percent level, respectively. All F-values are significant at the 1 percent level.

TABLE 2. OUTPUT, EMPLOYMENT, AND INCOME PROJECTIONS FOR 1980, OKLAHOMA

Industry Group	Output ($1,000) Baseline	Output ($1,000) Increase	Employment Baseline	Employment Increase	Income ($1,000) Baseline	Income ($1,000) Increase
Agriculture	1,610,101	3,826	82,606	217	363,579	936
Mining	1,508,405	349,061	34,310	7,617	467,226	92,251
Construction	2,212,283	38,645	81,496	662	565,887	5,570
Manufacturing	6,316,209	1091,436	146,892	15,076	1,136,229	124,529
Ordnance & Accessories	65,646	2	302	0	98	0
Food & Kindred Products	981,843	1,511	16,397	25	143,569	221
Textile Mill Products	5,139	2	119	0	697	0
Apparel	111,447	15	11,937	2	36,526	5
Lumber & Wood Products	42,270	130	2,240	7	15,523	48
Furniture & Fixtures	43,979	1	3,044	0	13,258	0
Paper & Allied Products	57,532	143	2,919	7	10,510	27
Printing & Publishing	211,169	4,522	11,994	257	88,689	1,899
Chemical & Allied Pcts.	165,496	20,661	2,699	408	19,125	1,880
Petroleum & Coal Pcts.	1,479,820	823,814	5,714	3,181	80,365	44,739
Rubber & Plastic Pcts.	222,118	619	4,711	13	33,574	94
Leather & Leather Pcts.	6,953	9	746	0	2,590	0
Stone, Clay & Glass	262,416	3,456	9,647	125	98,599	1,227
Primary Metal	219,667	25,428	4,936	1,150	52,530	8,539
Fabricated Metal	388,190	206,345	17,721	9,799	100,659	64,966
Machinery, excl. Elect.	555,115	1,790	20,034	61	150,986	436
Electrical Machinery	509,805	491	16,507	11	165,734	151
Transportation Equipment	895,886	1,744	11,939	21	102,173	189
Instruments	41,623	129	551	2	7,031	23
Misc. Manufacturing	50,075	124	2,735	7	13,993	35
Transp., Commun., & Uts.	2,031,154	87,345	57,476	2,673	501,826	23,774
Wholesale & Retail	2,716,405	32,969	269,547	3,271	1,350,917	16,396
Fin., Insur., & R.Estate	3,508,475	123,001	72,142	1,897	462,077	12,064
Other Services	2,665,932	44,884	342,390	4,181	1,827,002	21,845
Federal Gov't Enterprises	161,485	3,663	12,126	275	103,294	2,343
State & Local Gov't Ent.	163,285	5,366	7,117	234	26,288	864
TOTAL	22,893,734	1,780,196	1,106,102	36,103	6,744,325	300,572

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ABSTRACT

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The main objective of this study was to determine the net impact of waterway transport on the Oklahoma economy. An input-output model was the basic analytical tool. 1980 projections of impacts of the waterway since 1963 were as follows: $1.8 billion increase in state output, an additional 36,000 jobs; and an increase of $301 million personal income.

THE IMPACT OF WATER TRANSPORT
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BIOGRAPHICAL SKETCH

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