WATER RESOURCES AND REGIONAL ECONOMIC GROWTH IN THE UNITED STATES, 1950–1960*

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I. INTRODUCTION

The role of natural resources in facilitating or restraining economic growth has been a topic of interest and debate among economists since Malthus and Ricardo. One interesting body of research has attempted to determine the importance of long run diminishing returns caused by increasing resource scarcity [e.g. Barnett and Morse, 1963; Potter and Christy, 1962]. Another large body of work from von Thünen and Weber to the present has been concerned with the determinants of the spatial distribution of economic activity, among them natural resource endowments and transportation possibilities [e.g. Lösch, 1954; Isard, 1956]. Most of these works, however, have not dealt with water as a constraint on growth or as a locational determinant. The major reasons for ignoring water may have been that, in many regions, water historically has been very nearly a free good and that very few good statistics on water costs and uses have been available.

This paper attempts to marshal available, albeit imperfect, evidence on the relationship between water availability and economic growth in the United States over the 1950–1960 decade. Since water resource investments are currently being planned on a very large scale as tools for promoting regional economic development (e.g. Appalachia and the Southwest) and since past water resource developments have frequently been defended in terms of their favorable impact on regional development [Tennessee Valley Authority, 1966; American Waterways Operators, 1962], evidence on this relationship should be valuable as a guide to future policy.

The concept of water availability has several dimensions other than location: quantity, quality, reliability, cost, and legal status. Each of these attributes of a region's water supply may have an influence on the region's ability to grow or to attract certain types of economic activity. The United States roughly can be divided along the 100th meridian into a humid East of plentiful precipitation and streamflow, and (omitting the Pacific Northwest) an arid or semi-arid West. Within these major regions, however, there are places and times of substantial deviation from this simple characterization. During the recent Northeastern drought, agriculture was severely damaged in some areas and many municipalities had to curtail water use or turn to emergency sources. Reduced streamflow and ground water levels led to salt water intrusion and other types of water quality degradation, often requiring expensive treatment or use of higher cost supplies, and causing unpleasant environmental changes. These incidents reflect the importance of water quality and *hydrologic uncertainty* as features of water availability.

In the West are found areas typically characterized as arid, yet having practically limitless supplies available for those activities which can afford the cost. Albuquerque is in an area certainly considered arid by any popular conception of aridity. Yet it is located over a vast ground water supply. This supply is exploitable at costs easily borne by industrial and municipal users but too costly for irrigation.

Private costs incurred by users in obtain-

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ing water do not adequately characterize conditions of water availability. A withdrawing party with an established appropriative right to water from a stream like the Colorado may be able to pump or divert his allotment at very low unit cost. This is not, however, indicative of the conditions faced by new activities which might locate there, for great legal complexities surround the transfer of water rights and the establishment of new ones.

While unit cost is probably the best single measure of water availability, it must be thought of in terms of a schedule relating cost to quantity, quality, and the reliability of the source.

Historically, water as an agricultural and industrial input and as a mode of transport was quite important in determining the pattern of economic development in the United States. It is unquestionably the case today that a continuation of some historical regional patterns of growth will depend upon a continual augmenting of regional supplies of water. In particular, continued growth of irrigation agriculture in the West under existing techniques of water distribution and application can continue only if large water imports are obtained.[1] Except for agriculture, it is much less clear that "cheap" water or the availability of water transportation are today either sufficient or even necessary conditions for rapid regional economic growth. Technological change in transport and the highway program have reduced the costs of alternatives to water transport. In industrial processes, water costs are a relatively small part of production costs, even in such "water-intensive" industries as pulp and paper, beet sugar, thermal electric generation, and steel [Bower, 1965].[2] Improved water re-use technologies have served to make industry much less dependent on large water supplies, and current work on improved waste disposal promises even less water dependence in the future. There are many existing examples of "water-intensive" industries choosing to locate in water deficient areas because of market or non-water input considerations [Bower, 1964]: Kaiser Steel in Fontana, California; petroleum refineries at Big Spring and Amarillo, Texas; a petrochemical complex at Odessa, Texas; a major steam plant of Arizona Public Service in the Four Corners area; and Bethlehem Steel at Sparrows Point where sewage effluent provides the major water source.

It is necessary to distinguish between the impact of a water resource investment during the construction phase (e.g. during the construction of a reservoir) and the longer term impact of the changed conditions of water availability on the comparative advantages of the region for particular types of activity. While it isn't possible empirically to separate these two impacts because of possible regional multiplier effects and resulting induced investment, this study is concerned with the longer term impacts and not with the possible use of water resource investments as anti-cyclical instruments.[3]

It would be desirable to have, for the present analysis, complete models of regional growth for various regions of the United States so that increments of growth attributable to improved water availability conditions and related amounts of investment could be isolated. Such a model might consist of production functions for the major

[1] This certainly isn't meant to imply the desirability of expanding irrigation agriculture or of importing water. It has been estimated that an increase in irrigation efficiency of 5 per cent in the Southwest would permit a doubling of municipal and industrial uses with no new imports. Thus, continued growth of the Southwest clearly isn't dependent on new water importation schemes.

[2] See also the industry studies sponsored by Resources for the Future, Inc.: *Water Demand for Steam Electric Generation* by Paul H. Cootner and George O. G. Löf, Resources for the Future, Inc., 1965; Canning Industry Study (nearing completion) by Blair Bower of RFF; *The Economics of Water Use and Waste Disposal in the Beet Sugar Industry* (in manuscript) by George O. G. Löf and Allen V. Kneese of RFF; Petroleum Refining Study (in process) by Herbert Mohring of the University of Minnesota.

[3] Regarding business cycle impacts, see Robert Haveman and John Krutilla, "Unemployment, Excess Capacity, and Benefit-Cost Investment Criteria" forthcoming.

regional industries with water as an input, plus water and labor supply functions and product demand functions. It would then be possible to compare actual economic growth with the growth that would have been experienced in the absence of changed water availability conditions.

The analysis which follows is, in fact, much simpler and, as a result, restricted in its findings. Economic growth is measured by the growth of employment over the 1950–1960 decade. Water availability is measured by three *physical* variables: the availability of water transportation (which also implies well regulated flows available for industrial process and waste disposal uses), streamflow, and average annual runoff. The building blocks of the analysis are the individual counties of the coterminous United States which are classified by the various measures of water availability. The significance of these classifications is then tested and the growth experienced by the different classes of counties is summarized. Section II summarizes national growth experience for the 1950–1960 decade, and the third section tests a specific hypothesis set forth by Bower concerning the importance of water in the location of economic activity [1964, pp. 2, 3].

II. NATIONAL EMPLOYMENT GROWTH AND ALTERNATIVE MEASURES OF WATER AVAILABILITY

The basic data used are the 1950 and 1960 employment data by county as published by the Office of Business Economics [Ashby, 1965]. Employment is a less than ideal statistic for the measurement of economic growth for obvious reasons, but it is the only statistic available by county with industrial breakdowns for the years 1950 and 1960.

For each county, a simple percentage decade rate of growth is computed. Data on employment in 32 rather broad economic sectors within each county are also available for more detailed analyses. A percentage competitive effect (or differential shift) is computed for each county. Notationally, let

ρ_{ij} ≡ the simple 1950–1960 decade rate of growth of employment in sector i of county j

$\rho_{i.}$ ≡ national decade rate of growth of employment for sector i

$\rho_{..}$ ≡ national decade rate of growth of employment

N_{ij} ≡ number of persons employed in sector i of county j in 1950.

The total decade employment growth rate of county j is then given by

$$r_j^t = \frac{\sum_i N_{ij}\,\rho_{ij}}{\sum_i N_{ij}} \tag{1}$$

The total decade change in employment, ΔN_j, can be partitioned as follows:

$$\begin{aligned}\Delta N_j = {} & \rho_{..} \sum_i N_{ij} \\ & + \{\sum_i N_{ij}\,\rho_{i.} - \rho_{..}\sum_i N_{ij}\} \\ & + \{\sum_i N_{ij}\,\rho_{ij} - \sum_i N_{ij}\,\rho_{i.}\}\end{aligned} \tag{2}$$

This partitioning was first introduced by Dunn [1960] in his studies of regional employment shifts. The first term can be referred to as the "national growth effect," the second as the "industry mix effect," and the third as the "regional (or county) competitive effect." The competitive effect is a useful measure of a county's peculiar economic advantages (or disadvantages) which result in the county's ability (inability) to increase its share of national employment in those sectors which are important in its economic structure.[4] Thus a county whose total decade growth rate was low (or negative) might still exhibit a positive competitive effect if its major sectors grew at rates which, while low, were more than the national averages for those sectors. This would indicate a continuation, over the decade, of conditions such as market accessibility or factor availability which give the county a comparative ad-

[4] The author is indebted to Charles Tiebout for pointing out that the magnitude of the competitive effect (and in some cases, even its sign) depends upon the degree of industry aggregation used in the analysis. For this reason, primary emphasis is placed on the rates of growth.

vantage vis-à-vis other counties in those sectors which account for the major portion of its employment.

The competitive effect can be expressed in percentage terms as

$$r_j^c = \frac{\sum_i N_{ij}\,\rho_{ij} - \sum_i N_{ij}\,\rho_{i\cdot}}{\sum_i N_{ij}} \qquad (3)$$

The counties of the coterminous United States, each characterized by r_j^t and r_j^c, are the building blocks of the following analyses. Any scheme for classifying counties which is considered relevant to economic growth can be tested formally by running an analysis of variance using r_j^t as the dependent variable. An interesting comparison is then provided by running the same analysis of variance using r_j^c as dependent variable. Classification schemes found significant can then be analyzed further in terms of their industry composition.

Growth Experience by Waterway Class

When a county is contiguous with a navigable waterway, e.g. the inland rivers and canals, the Great Lakes, the intra-coastal waterways, or nonwaterway coastal areas, it provides the potential advantages of water transportation and plentiful process water. If, in fact, these attractions result in concentrations of economic activity, the growth

TABLE I

DECADE RATES OF EMPLOYMENT GROWTH BY WATERWAY CLASS

Waterway Class	No. counties	r^t (%)	r_w^t (%)	r^c (%)	r_w^c (%)
1. Inland Navigable I	265	0.6	7.2	−2.9	−8.7
2. Inland Navigable II	74	1.0	8.6	−1.9	−4.5
3. Gulf Coast	56	27.2	29.4	20.2	11.7
4. East Coast with SWN	115	30.7	28.3	18.1	5.8
5. Coastal without SWN	95	36.2	25.9	18.7	2.1
6. Great Lakes	83	10.3	9.4	−0.1	−11.3
7. All other	2406	0.2	12.6	0.5	2.7

experience of waterway contigous and non-waterway contigous counties should be different. Thus, the counties of the coterminous United States have been partitioned into the following seven classes according to their contiguity or non-contiguity with different types of waterways:

1. high quality inland navigable waterway;
2. lower quality inland navigable waterway;
3. Gulf Coast (also having shallow water navigation, i.e. barge service);
4. East Coast (also having shallow water navigation);
5. coastal but without shallow water navigation;
6. Great Lakes;
7. all other counties.

A decade rate of growth of employment and a percentage county competitive effect were computed for each county. The relevance of the above 7-fold classification was then tested using analysis of variance on both the decade rate and competitive effect variables. The analysis of variance indicates significant differences in growth behavior among the 7 regions.

Analysis of Variance: r^t

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	251,589.1	6	41,931.5	49.5
Within Groups	2,613,639.9	3087	846.7	(2.8 at 1%)
Total	2,865,229.0	3093		

Analysis of Variance: r^c

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	87,787.5	6	14,631.2	21.8
Within Groups	2,072,519.5	3087	671.4	(2.8 at 1%)
Total	2,160,307.0			

Table I summarizes the employment growth experience of the 7 waterway classes by listing for each class of counties the unweighted average decade rate of growth, $\bar{r}^t$, the weighted (by 1950 employment) average rate of growth, $\bar{r}_w^t$, the unweighted average competitive effect, $\bar{r}^c$, and the weighted average competitive effect, $\bar{r}_w^c$. For purposes of comparison the national decade rate of employment growth was 15.4%.

Data are available also on the employment growth of five rather broad categories of industry, each of which contains one or more industries which have been either large users of inland water transportation or heavy users of water for process purposes or waste disposal. Corresponding to the five columns of Table II, the relevant industries are: petroleum extraction (shipped by barge); beet sugar, canning, and meat products (process water and waste disposal); chemical manufacture (process water and waste disposal); pulp and paper, petroleum refining, and primary metal (process water and waste disposal); electric generation (cooling water). Clearly, it would be desirable to have a more detailed breakdown.

The following observations are made on the basis of the data in Tables I and II.

1. The inland navigable water way and Great Lakes counties' (classes 1, 2, 6) growth performance appear quite similar in that:
   a. they had very low decade rates of employment growth relative to the national average;
   b. they displayed negative competitive effects, i.e. all experienced decreasing proportions of the national employment in their major industries;
   c. they exhibited only low to average rates of growth in most of the water intensive industry groups.
2. The coastal areas (classes 3, 4, 5) appear similar in growth experience in that:
   a. they had high decade rates of growth, relative to the national average;

TABLE II

DECADE RATES OF EMPLOYMENT GROWTH BY MAJOR INDUSTRY GROUP

Region	Mining, Gas & Petroleum Extraction	Food Products	Chemicals and Related Products	Mfg., incl. Pulp & Paper Petro. Rfg., Pri. Metal	Electric Generation, Water, Electric & Gas Utilities
1. Inland Navigable I	−53.9	17.7	33.9	6.1	13.9
2. Inland Navigable II	−33.9	8.3	27.4	28.2	13.6
3. Gulf Coast	57.3	26.1	100.3	25.7	38.5
4. East Coast with SWN	15.9	33.8	28.1	21.0	20.0
5. Coastal without SWN	9.9	30.2	25.5	26.1	7.9
6. Great Lakes	7.5	6.5	16.9	4.9	1.6
7. All other	−31.1	41.3	33.1	26.2	18.9

   b. they displayed positive competitive effects;
   c. they exhibited moderate to high growth rates in most of the water intensive industry groups.

The differential experiences of the waterway classes clearly indicate that the areas contiguous with the inland waterways have not, on average, grown rapidly, either overall or in terms of the water intensive industries. The negative competitive effects for these classes demonstrate that the slow employment growth was not due solely to the regions having a comparative advantage in nationally slow-growing industries, but that they failed to maintain their share of national employment in their most important industries.

Undoubtedly, some counties along the inland waterway system have grown rapidly. For example, the performance of the Tennessee Valley region (see Section III) was quite good. The Ohio Valley has been highly publicized as a rapidly growing area, but the following figures indicate employment growth rates for the counties along the Ohio River which are substantially below the national average: Pennsylvania 2.5%, Ohio

9.3%, Indiana 1.0%, Illinois −18.9%, West Virginia −1.5%, and Kentucky 11.9%.

The coastal areas expanded employment at rates substantially in excess of the national average. It appears that the Gulf and East Coast areas served by shallow water transport grew at slightly higher rates than those coastal areas not served by shallow water transport, and they also seem to have fared better in attracting the water intensive industries. Much of the latter, however, is due to the large expansion of petroleum extraction and petro-chemical production along the Gulf Coast, activities which are clearly raw-material oriented.

Streamflow and Growth

There are many streams in the United States which, while not sufficiently large or regular in flow for navigation purposes, provide large and reliable supplies of water. It could well be argued that the preceding system of classification failed to isolate many counties which, while not having direct access to water transport, still had access to large quantities of surface water for process and waste disposal purposes. To investigate this possibility, an 11-fold classification of counties was constructed according to the characteristics of the largest stream passing through or along the borders of the county. The classes were defined as follows:

Class No.	Average Flow of Record (cfs)	Minimum Flow of Record (cfs)
1	0–2999	all flows
2	3000–5999	<100
3	3000–5999	≥100
4	6000–9999	<200
5	6000–9999	≥200
6	10,000–29,999	<1500
7	10,000–29,999	≥1500
8	30,000–79,999	<1500
9	30,000–79,999	≥1500
10	80,000+	all flows
11	Great Lakes	

The hypothesis is that if water attracts economic activity and if economic water availability is measured by streamflow, average rates of growth and competitive effects will increase with streamflow. The definition of the classes was essentially arbitrary, the minimum flow condition being added to the class definition to take into account reliability of the flow.[5]

The results were negative. There appears to be no regular increase in rate of growth or competitive effect with higher streamflow values. Technically, the classification of counties by streamflow was significant at 1% for both r^t and r^c ($F = 3.7$ versus a critical value of 2.32 and $F = 3.0$ versus 2.32), but interpretation of the classification scheme in the present context depended upon observing some regular relationship between class rank and average growth rate. The output data are given in Appendix Table 1. It is possible that class No. 1 has been defined in terms of such a broad range of flows that a threshold value has been left undetected. However, on the basis of the present evidence, we reject the hypothesis that water availability, as measured by streamflow, plays a dominant role in determining economic growth.

Annual Runoff and Growth

Runoff, as used here, is expressed in inches per year and consists of two major components: (1) water which falls on streams or runs directly over the land surface to them, and (2) water that moves through the ground to streams. Thus it represents a good approximation to the (non-imported) total water supply of a region. [See McGuinness, 1963, pp. 12–15 and Plate 1]. In the United States, runoff ranges from zero over vast areas of the West to 80 or more inches per year in a few small mountain areas of the Pacific Northwest. Most of the United States East of the 100th meridian averages from 15 to 20 inches per year, while Western areas average less than 2.5. The counties were grouped into 6 classes defined on page 483. The results are presented in Table III. The

[5] The county classifications were performed using the maps and tables found in Committee Print No. 4, U.S. Senate, 1960.

Class No.	Annual Runoff (inches)
1	$0 \leq x < 2.5$
2	$2.5 \leq x < 5.0$
3	$5.0 \leq x < 10$
4	$10.0 \leq x < 15$
5	$15.0 \leq x < 20$
6	$20 \leq x$

analyses of variance using the total decade rate of growth, r^t, and the percentage competitive effect, r^c, as dependent variables were significant at the 1% level ($F = 5.3$ for r^t versus a critical value of 3.02, and $F = 5.2$ for r^c versus 3.02). In Table III, one discerns some tendency for growth rates, $\bar{r}^t$, to increase with runoff. However, the pattern is broken by the presence of one large class with a value of -1.3%. There is no evidence of any pattern of regularity in the values of the average percentage competitive effect.

Thus, it seems reasonable to conclude once again that water availability, as measured by average annual runoff, does not play a dominant role in determining economic growth.

TABLE III

DECADE RATES OF EMPLOYMENT GROWTH BY RUNOFF CLASS

Runoff Class	No. Counties	$\bar{r}^t$ (%)	$\bar{r}^c$ (%)
1	641	2.9	5.8
2	281	3.7	1.9
3	473	3.5	−0.3
4	643	6.5	2.3
5	703	−1.3	−1.0
6	353	6.0	1.1

III. REGIONAL AND INTRA-REGIONAL GROWTH PATTERNS

There are many factors which affect the decisions of entrepreneurs to locate one place or another. Particular regions are characterized by accessibility to market centers, availability of natural resource and labor inputs, climate, etc. Thus it is entirely possible that the effect of water availability was swamped in the preceding analyses by differences in these other factors. If the United States were partitioned into regions which tended to be internally homogeneous with respect to the other factors, the growth experiences of counties having different water endowments could be compared *within* each region with a higher probability of isolating water availability effects.

Bower [1964, pp. 2, 3] has formulated a compound hypothesis relating particularly to the industrial location decision:

1. "... the availability of water as defined herein is not a major factor in *macro-location* decisions of industry. Since availability is related to cost, this can also be expressed as 'total water utilization costs from intake to outlet represent a relatively minor factor in the macro-location of industry.' ... By macro-location decisions are meant decisions relating to location in major geographic areas or regions such as river basins."
2. "... the availability of water at the intake end and/or the effluent end has been and can be a major determinant in *micro-location* decisions of industry."

These hypotheses were defended in a general way in Bower's paper, but little direct empirical evidence was brought to bear on them. They have recently received limited support from studies under way at North Carolina State University. Ben-David [1966] has related employment in the paper, chemical, petroleum, and primary metals industries in the counties of Pennsylvania to the availability of water as measured by miles of stream with minimum flow of 400 cfs or more, urban population, and distance to major marketing area. At the county level, a significant positive impact was found (a marginal increase in employment in those industries of 19 per mile of stream). However, when state data for the United States (year not indicated) were used, the water availability variable was generally not significant. It is not possible to tell without further investigation whether or not the micro-locational effect found within Pennsylvania holds on a larger scale.

TABLE IV

DECADE RATES OF EMPLOYMENT GROWTH BY WATER RESOURCE REGION

Region	No. Counties	Approx. Runoff	$\bar{r}^t$ (%)	$\bar{r}^t_w$ (%)	$\bar{r}^c$ (%)	$\bar{r}^c_w$ (%)
1. New England	59	20	13.7	13.2	−2.7	−7.9
2. Delaware & Hudson Rivers	67	20	21.3	13.1	3.0	−9.6
3. Chesapeake Bay	160	15	13.3	13.9	2.8	−5.7
4. Southeast	468	15	7.2	20.3	9.4	14.6
5. Tennessee River	94	30	0.4	6.5	2.6	2.9
6. Cumberland River	44	20	−6.6	4.1	−0.7	−2.1
7. Ohio River	340	15	−1.2	5.9	−4.3	−8.1
8. Eastern Great Lakes	70	15	14.7	13.0	1.6	−5.9
9. Western Great Lakes	120	15	10.9	13.1	2.7	−6.8
10. Upper Mississippi River	286	10	−0.1	6.7	−2.7	−5.7
11. Lower Mississippi River	107	15	−7.1	0.2	−0.6	−3.0
12. Lower A-R-W Rivers	153	15	−12.8	−0.6	−11.5	−6.1
13. Lower Missouri River	89	10	−7.6	4.3	−6.5	−4.6
14. Upper Missouri River	365	<2.5	−4.6	10.8	0.6	4.0
15. Upper A-R-W Rivers	135	<2.5	−3.0	11.3	−4.2	−0.8
16. Western Gulf	217	5	3.3	23.3	2.2	9.7
17. Upper Rio Grande & Pecos	44	<2.5	6.8	43.6	6.3	27.5
18. Colorado River	51	<2.5	23.6	65.2	23.6	56.1
19. Great Basin	45	<2.5	18.3	34.0	17.4	21.6
20. Pacific Northwest	125	20	7.1	14.6	3.6	−0.9
21. Central Pacific	48	10	30.4	33.9	21.1	15.2
22. South Pacific	7	<2.5	96.7	61.8	76.0	36.6

The United States Geological Survey has provided a breakdown of the United States into 22 major drainage basins or water resource regions [McGuinness, 1963, Plate 4]. These regions provide a natural breakdown of the country consistent with the Bower hypothesis not only in terms of surface and ground water characteristics, but in terms of natural communication and transport linkages, climate and, to some extent, natural resource endowments. These regions are used in the following test of Bower's hypothesis.

A preliminary question is "Are the Water Resource Regions relevant units for the study of regional growth in the 1950–1960 decade?" If they are, what have the growth experiences of these regions been? Table IV describes the regions and gives for each: the number of counties, the approximate water runoff as a measure of overall natural water availability,[6] the arithmetic average of county employment growth rates, $\bar{r}^t$, the weighted average growth rate, $\bar{r}_w{}^t$, the arithmetic average of county percentages competitive effects, $\bar{r}^c$, and the weighted average percentage competitive effect.

Analyses of variance, using county values of r^t and r^c as dependent variables, indicate that this regional scheme of classifying counties is significant. The 22 regions exhibited different growth experience for the decade, differences presumably explained largely by factors other than conditions of water availability.

Analysis of Variance: r^t

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	302,286.1	21	14,394.6	17.3
Within Groups	2,562,943.0	3072	834.3	(1.87 at 1%)
Total	2,865,229.1	3093		

[6] See Section II, p. 14 for the definition of runoff.

Analysis of Variance: r^a

Between Groups	179,459.5	21	8,545.7	13.3
Within Groups	1,980,847.4	3072	644.8	(1.87 at 1%)
Total	2,160,306.9	3093		

Table IV provides some observations worth noting prior to proceeding with the test of Bower's hypothesis. Remembering that the national growth rate of employment for the decade was 15.4% and that the 100th meridian provides a rough dividing line of the country into a relatively water plentiful East and semi-arid or arid West (with the exception of parts of the Pacific Northwest) [this grouping corresponds roughly to water resource regions 1 through 13, and 14 through 22 (excepting 20) and is reflected in the average runoff figures], the following observations can be made:

1. the Eastern regions had growth rates $\bar{r}_w{}^t$ less than the national average, with the exception of the Southeast;
2. all Eastern regions displayed negative competitive effects with the exception of the Southeast and Tennessee Valley;
3. the regions containing rivers having sufficient flow for regular water transportation (5, 6, 7, 10, 11, 13) had very low rates of growth and, with the exception of the Tennessee, displayed negative competitive effects;
4. the instances of spectacular growth (regions 17, 18, 19, 21, 22) occurred in the areas of heavy natural water deficit, areas characterized by heavy water importation or ground water mining.

Thus there appears to be no evidence in the above data of dominant economic advantage for water plentiful regions *versus* water deficit areas. It should be remembered that while substantial quantities of water are imported into the Southwestern regions, water is in fairly "tight" supply from the point of view of acquiring water rights for new or expanding activities (including the constraints of water law).

Table V presents decade rates of growth of employment in the five industry categories within which are found the industries traditionally classified as water intensive (either with respect to process water inputs, liquid waste disposal, or having inputs and/or outputs which are suited to shallow water transportation).[7] Again, these categories are very gross and contain activities other than the ones which are most relevant to this study, so their growth can be taken only as suggestive of the regional growth of the particular *water intensive* industries.[8]

The Southeast and Tennessee Valley fared very well in the employment growth of the presumably water intensive industries, averaging decade rates of growth in excess of 35%. If we arbitrarily choose a 35% average rate of growth of the "water intensive" industries as a dividing line for classifying the regions, we find that the following regions exceed that growth rate:

Region	Decade Growth of Employment in Water Intensive Industries (%)	Overall Decade Rate of Growth of Employment (%)
Southeast	39.2	20.3
Tennessee	35.7	6.5
Lower Mississippi	43.5	0.2
Upper Missouri	40.0	10.8
Western Gulf	38.0	23.3
Upper Rio Grande & Pecos	57.0	43.6
Colorado	76.3	65.2
Great Basin	64.6	34.0
S. Pacific	46.2	61.8

A fairly clear distinction between the first 3 or 4 regions (Eastern) and the remaining ones (Western) in the above list indicates that the highest rates of growth of the water intensive industries were found in the West.

The data on the water resource regions reveal no evidence that conditions of natural

[7] See p. 10 for a more detailed description of these industries.

[8] It is also relevant that some of the "water intensive" industries have experienced substantial automation.

TABLE V

DECADE RATES OF EMPLOYMENT GROWTH BY MAJOR INDUSTRY GROUP

Region	Mining, Gas & Petroleum Extraction	Food Products	Chemicals and Related Products	Mfg, incl. Pulp & Paper Petro. Rfg., Pri. Metal	Electric Generation, Water, Electric, Gas Utilities
1. New England	−4.4	32.0	11.6	6.0	0.5
2. Delaware & Hudson Rivers	−47.4	25.1	25.5	8.2	−0.7
3. Chesapeake Bay	−66.0	28.8	9.7	17.7	7.8
4. Southeast	−22.8	71.0	50.9	59.5	37.6
5. Tennessee River	−38.6	66.3	52.3	54.6	43.8
6. Cumberland River	−60.0	30.2	−19.8	45.8	35.9
7. Ohio River	−52.2	22.0	40.8	3.6	12.7
8. Eastern Great Lakes	−11.4	25.7	16.3	7.2	4.5
9. Western Great Lakes	5.9	4.6	33.1	11.4	6.1
10. Upper Mississippi River	−44.6	18.8	20.3	15.7	10.2
11. Lower Mississippi River	71.5	29.4	44.9	38.4	33.2
12. Lower A-R-W Rivers	−16.3	51.8	20.3	49.8	25.6
13. Lower Missouri River	−29.4	13.4	18.9	31.5	8.9
14. Upper Missouri River	26.1	19.7	73.2	60.3	20.3
15. Upper A-R-W Rivers	−5.8	20.3	5.2	26.5	25.6
16. Western Gulf	16.2	36.2	67.3	37.2	32.1
17. Upper Rio Grande & Pecos	47.4	83.8	−35.3	139.2	50.0
18. Colorado River	27.8	82.5	69.2	155.0	47.1
19. Great Basin	6.6	41.3	197.0	57.8	20.4
20. Pacific Northwest	−36.4	43.3	44.1	34.2	8.2
21. Central Pacific	−20.9	39.6	38.0	78.5	19.3
22. South Pacific	−6.4	45.4	58.9	104.5	28.9

water abundance result in higher rates of growth nor that such conditions impart a comparative advantage to particular regions in attracting the presumably water intensive industries, nor is there any evidence of a water constraint on economic growth in the Western regions.

Intra-Regional Growth Patterns

According to Bower's hypothesis, water availability might prove a dominant factor in the location of activity within a region while exerting very little influence on the choice of regions by new or established activities. Thus, if we look at each region in isolation, assuming that interregional differences in average decade rates of growth are due primarily to non-water related considerations, we might expect to find county growth rates correlated with conditions of water availability such that water plentiful counties experience growth rates above the regional average and relatively water deficient counties experience growth rates below the regional average.

The analysis of Section II utilized three measures of water availability: water navigation status, stream flow, and runoff. Since runoff conditions tend to be uniform within a given water resource region, the following analyses use only navigation status and streamflow.

Intra-Regional Growth and Water Navigation

Table VI presents a two-way classification of mean county growth rates by region and waterway class. For many of the regions, the intra-regional classification was not significant by analysis of variance, but interesting regularities stand out nonetheless. First, the above-average growth rates of coastal areas are again shown without exception.

TABLE VI

County Rates of Employment Growth by Region and Waterway Class

Region	Mean Rate of Growth (%)							
	All Counties	1	2	3	4	5	6	7
1. New England*	13.7					17.4		11.3
2. Delaware & Hudson Rivers*	21.3		10.7		34.5	32.6		12.7
3. Chesapeake Bay	13.3				24.2			7.7
4. Southeast	7.2	−10.3	−22.5	34.5	37.3	65.6		0.8
5. Tennessee River*	0.4	4.8						−1.7
6. Cumberland River*	−6.6	2.3						−9.5
7. Ohio River*	−1.2	1.2	0.4				28.4	−2.4
8. Eastern Great Lakes*	14.7		16.9				19.6	12.7
9. Western Great Lakes*	10.9	34.4					7.1	14.3
10. Upper Mississippi River*	−0.1	2.9	10.2					−1.2
11. Lower Mississippi River	−7.1	−15.4		21.7				−14.1
12. Lower A-R-W Rivers*	−12.8		−8.0					−13.0
13. Lower Missouri River*	−7.6	−2.5	0.1					−11.1
14. Upper Missouri River*	−4.6		3.0					−4.9
15. Upper A-R-W Rivers*	−3.0							−3.0
16. Western Gulf	3.3			28.1†				0.8
17. Upper Rio Grande & Pecos*	6.8							6.8
18. Colorado River*	23.6							23.6
19. Great Basin*	18.3							18.3
20. Pacific Northwest*	7.1	4.2				11.3		6.7
21. Central Pacific*	30.4		31.3			48.1		19.1
22. South Pacific*	96.7					100.3		87.7

* indicates either that the waterway classification within the region is not significant by F test at 1 per cent or that all counties fall within one class.
† includes Houston Ship Channel.

Secondly, the columns for waterway classes 1 and 2—those counties having access to shallow water inland navigation—show that in the following regions, class 1 and 2 counties exhibited growth rates *above* their regional averages: 5, 6, 7, 8, 9,10, 12, 13, 14, and 21. In regions 2, 4, 11, and 20, class 1 and 2 counties exhibited growth rates *below* their regional averages: 2, 4, 11, and 20. The first set of regions, with the exception of 21, constitutes what might be called mid-America, essentially the Midwest and Great Plains. The second set consists of regions having large coastal areas.[9]

Thus it appears that in mid-America, a region which produces much of the country's bulk agricultural output, steel and steel products, thermal electric power, and which consumes or produces large volumes of petroleum and chemical products, intra-regional growth is positively correlated with access to navigable rivers and their regulated flows. Coastal regions, on the other hand, having different economic structures, exhibit a negative correlation between growth and access to navigable waterways.

These observations appear to be consistent with the Bower hypothesis when it is remembered that his concern was with the heavier water-using industries. The results do not prove that past public investments in waterway improvement have been either warranted or unwarranted. Each project

[9] If regional average growth rates are recomputed for regions 2, 4, 11, and 20 omitting the more rapidly growing coastal counties, it remains true that the growth rates of class 1 and 2 counties fall below the recomputed regional averages.

must be evaluated on the basis of its own benefits and costs. It is indicated, however, that, given the activity structure of the mid-continent, waterway contiguous counties possess locational advantages not shared by others.

Intra-Regional Growth and Streamflow

The counties were classified within regions according to the streamflow scheme defined earlier. If water availability has an impact on relative growth within a region (as was suggested by the preceding analysis of water-way characteristics) and if streamflow is a valid measure of the economic availability of water, then it would be expected that higher streamflows, at least up to some level, would be associated with higher rates of growth. This has not proven to be the case. In only 4 of the 22 regions did the streamflow classification prove significant by analysis of variance, and in only 3 regions of the 22 was the expected correlation found.

This suggests two possibilities, reinforcing what was found in Section II: (1) that streamflow is not a good measure of the economic availability of water; (2) that the particular streamflow categories used were too gross and that the first class in particular may have hidden any threshold between areas having too little water and those having sufficient supplies.

IV. CONCLUSIONS

It is naive to presume that the complex phenomena of regional growth can be explained by physical (as opposed to economic) measures of the conditions of availability of one factor of production. Water is clearly a necessary input for all types of economic activity, but it can be transported, imported, conserved, recycled, refined, and reused at sufficiently low cost that its abundance in the natural environment is not necessary for most types of economic activity. The evidence of the 1950–1960 decade as analyzed in preceding sections demonstrates that water did not constitute a bottleneck to rapid economic growth in the water deficit areas of this country, nor did its presence in large quantities in other regions guarantee the rapid growth of these regions. In particular, with the exception of the Tennessee region, the regions served by the inland waterways performed poorly in employment growth in spite of the very large past and present public investments in waterway improvement. Again, this does not prove that those investments were not warranted. It merely demonstrates that the availability of abundant water and water transport is not a sufficient condition either for the attraction of rapidly growing industries or for attracting an increasing proportion of the slower growing and declining industries.

The analysis of growth patterns *within* regions indicated a *positive* relationship between access to navigable rivers (and their regulated flows) and growth *relative* to the regional average for a large part of the mid-continent. A negative relationship existed, however, between the same two factors for regions having large coastal areas. That particular advantages should accrue to waterway contiguous areas in the mid-continent but not on the coasts is undoubtedly due to the relative importance of industries utilizing or producing bulk, low value input.

While caution is required in drawing policy conclusions from the observations of this study, the evidence clearly indicates that water availability, including water transport, does not outweigh the other attributes possessed by regions which make them attractive or unattractive as the locus of different industries. It is clearly suggested that water resource developments are likely to be poor tools for accelerating regional economic growth if markets, factor availabilities, and other amenities of living are lacking.

APPENDIX TABLE I

AVERAGE COUNTY RATES OF GROWTH BY STREAMFLOW CLASS

Streamflow Class	No. Counties	$\bar{r}^s$ (%)	$\bar{r}^e$ (%)
1	2123	2.1	1.4
2	58	−2.2	−4.1
3	137	5.9	2.1
4	81	4.3	2.9
5	104	14.8	13.3
6	146	8.5	3.3
7	62	−0.9	−1.8
8	60	−0.2	−1.9
9	104	0.1	−2.9
10	136	4.7	2.9
Great Lakes	83	10.3	−0.1

APPENDIX TABLE II

REGIONAL DISTRIBUTION OF COUNTIES BY SEVEN WATERWAY CLASSES

Region	Number of Counties							
	Total	1	2	3	4	5	6	7
1. New England	59					23		36
2. Delaware & Hudson Rivers	67		13		13	16		25
3. Chesapeake Bay	160				55			105
4. Southeast	468	11	3	14	47	15		378
5. Tennessee River	94	27						67
6. Cumberland River	44	11						33
7. Ohio River	340	83	17				2	238
8. Eastern Great Lakes	70		2				19	49
9. Western Great Lakes	120	1					60	59
10. Upper Mississippi River	286	72	2					212
11. Lower Mississippi River	107	30		22				55
12. Lower A-R-W Rivers	153		7					146
13. Lower Missouri River	89	1	27					61
14. Upper Missouri River	365		14					351
15. Upper A-R-W Rivers	135							135
16. Western Gulf	217			20*				197
17. Upper Rio Grande & Pecos	44							44
18. Colorado River	51							51
19. Great Basin	45							45
20. Pacific Northwest	125	14				19		92
21. Central Pacific	48		4			17		27
22. South Pacific	7					5		2

* Includes Houston Ship Channel.

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