FACTOR ANALYSIS, INDUSTRIAL LINKAGES, AND INDUSTRIAL STRUCTURE*

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Introduction

Analytical discussions of regional economic problems have largely revolved around four major areas of inquiry: (1) the nature of the region's export base; (2) intra-regional linkages of economic activity reflecting the secondary and tertiary industry required to service the export base industries; (3) the condition of the labor and the other factor markets within the region; and (4) the "field of force" argument that suggests a region's industrial structure should be looked at from the standpoint of the way the region's industries interact with the national industrial structure. The regional cycle discussion exemplified by the work of Borts and Vining and the attempts to describe regional economic development in terms of regional export industries--Douglass North and other exponents of the economic base concept--are examples of this first type of regional discussion.[1] The second approach is concerned with the importance of economic linkages within the region. This line of theorizing deals with the input-output relations among regional economic activities as well as the viability of residentiary industries within the region.[2] The third approach is represented by the work of Nicholls and the other economists who have defined the problem of leading and lagging regions in terms of their factor markets and social value systems--in the case of the South, the well-defined racial caste system; in the case of northern urban areas, the phenomenon of the ghetto.[3] The fourth approach to regional development involves the derivation of a measure of the region's industrial structure--this derivation will be based on the "field of force" argument suggested by Francois Perroux--and is the subject of this paper.[4]

It is desirable to develop a measure of regional industry interaction that is not "containerized," so as to include only the relationships associated with intra-regional activity, or with exports. It is the aim of this paper to construct a measure which will reflect both the complementarity of industrial activity within a state and between the state and the nation. Complementarity, for purposes of this paper, refers to the activities of industries located in a specific geographic area as they interact with "national" as well as regional economic space. The measure of complementarity developed in this paper does not distinguish between complementarity among regional industries and the complementary relationship among regional and national industies. The aim of this analysis is to present a technique which allows the regional researcher to measure the industrial complementarity of a group of regional industries, which reflects the interactions of the entire "economic zone of influence" of a region. Thus, the industrial structure of a region is looked at as a "field of forces" reflecting industrial inputs and outputs which are associated with economic activity both inside and outside the region. Time series data will be used in this analysis.

The Texas industrial structure will be considered from the standpoint of the complementarity of the various industries, with and without the influence of trend. This analysis will show the overriding importance of trend in effecting the complementarity of the industries making up the industrial structure of the state. It will be argued that time series movements (in which trend is uncorrected for) may furnish a better basis for evaluating regional linkages than other types of data because the trend element in the time series is the most "dynamic" aspect of the movement of an intercorrelated set of economic data. The term dynamic, as it is used here, refers to the changes in input-output relations and trading patterns which occur over time.

The purpose of this paper is to illustrate the application of factor analysis (specifically to the components of an industrial production index) to the fourth approach of regional analysis.[5] This analysis will furnish a new method of describing the industrial structure of a region that will measure industrial complementarity (in a crude fashion) in terms of related time series movements.[6] For purposes of this paper, industrial complementarity, and the external economics associated with this phenomenon, can be logically divided into two categories, horizontal and vertical complementarity.[7] Horizontally complementary industries are those that for any one stage of production show common movements (the same direction) because of negative demand cross elasticities of either price or income that result from the fact that final demand is for groups of goods rather than for individual items. On the other supply side, horizontal complementarity is reflected in the case of joint products. In contrast, vertical complementarity is related to changing input requirements associated with a change in output of some other industry. However, the factor analysis technique can provide only "sufficient" grounds for categorizing any product as being complementary with another commodity--the technique will not indicate the specific cause of the complementarity (or lack of it). Furthermore, the argument cannot show "necessary" conditions, because the analysis is based on correlation coefficients, and direct causation cannot be imputed from correlation coefficients. This last point is not necessarily a severe failing. It has been suggested that the "necessary and sufficient" argument of economic methodology is too severe a stricture to incorporate in all operational analysis.[8] However, this critique of the measure ought to emphasize the importance of using this measure of industrial structure as only one "appraisal" of the industrial complementarity (or linkages) making up a regional or state economy.

Factor Analysis, Industrial Structure, and Linkage

The measure of industrial structure developed for this analysis is an index of industrial linkage or association; it can be useful in analyzing the economic growth of several regions during a particular time span as well as the analysis of different business cycles or fluctuations, generated in the same region. Practically, the index could constitute one of the bases for evaluating the "developmental potential" of private investment flows in particular industries in large geographic areas; or the index could be useful in evaluating industrial subsidy programs in depressed areas. The index, and related measure which will be developed later, shows in one summary measure the relationships between changes in industry output in one industry and all other industries comprising the industrial structure of the region. Time series, rather than cross-section, data were used in this demonstration of the technique, because these data present an historical view of the region's industrial structure and thus measure an additional dimension of a region's industrial activity--that is, change over time.

The primary step in the factor analysis procedure is the development of a correlation matrix based on the simple correlation between each of the major industry group indexes of the Texas (Federal Reserve Bank of Dallas) Industrial Production Index and again for the Federal Reserve Board's National Index.[9] Production indexes were selected for comparison because the components of this type of index presumably yield a better measure of what is usually meant by the term industrial structure than either employment or man-hour data. However, employment data would be more desirable if the center of interest were on labor markets. This approach constitutes a useful historical complement to the analysis of value-added distributions, the period comparisons of shift-share analysis, and regional input-output studies, which are the primary measures of industrial structure now used.[10] Unfortunately, analysis of highly aggregated industry group indexes rather than industry or product indexes conceals a great deal of inter-industry variation. However, for many small areas and states there is little chance of obtaining time series finer than two-digit Standard Industrial Classification (SIC) categories--this was largely the case for the Texas data used in this analysis. Thus, for the present the argument is largely limited to a demonstration "technique"; at this level of aggregation the analysis is so general as to be of little practical use in evaluating particular projects.

The use of production indexes or other forms of time series data makes possible a temporal analysis of the industrial structure of the region.[11] This

TABLE 1

FACTOR ANALYSIS
OF THE COMPARABLE INDUSTRY GROUPS
OF THE STATE AND NATIONAL INDUSTRIAL PRODUCTION INDEXES
(1956 -1966)*

SIC Code	Industry Name	TEXAS Factors 1	TEXAS Factors 2	TEXAS Factors 3	TEXAS h^2**	NATION Factors 1	NATION Factors 2	NATION Factors 3	NATION h^2**
14	Mining and quarrying, non-metallic, except fuel ...	.78	.53	-.26	.95	.99	-.10	.12	1.00
20	Food and Kindred Products ...	.96	-.33	.12	1.00	.98	-.20	.01	1.00
22	Textile Mill Products ...	.84	.56	-.29	1.00	1.00	.09	.10	1.00
23	Apparel ...	1.00	-.14	.16	1.00	1.00	-.06	.04	1.00
24	Lumber and Wood Products ...	.93	.20	-.09	.91	.92	.27	.16	.95
25	Furniture and Fixtures ...	.90	.33	-.18	.96	1.00	-.02	.04	1.00
26	Paper and Allied Products ...	.98	-.26	.15	1.00	1.00	-.08	.02	1.00
27	Printing, Publishing and Allied Industries ...	1.00	.12	.02	1.00	.99	-.16	.00	1.00
28	Chemicals and Allied Products ...	1.00	-.09	.16	1.00	.99	-.16	-.01	1.00
29	Petroleum, Refining and Related Industries ...	.91	.32	-.22	.97	.99	-.10	-.01	1.00
30	Rubber and Miscellaneous Plastic Products ...	1.00	.04	.09	1.00	1.00	-.02	.01	1.00
31	Leather Products ...	-.47	1.01	.53	1.00	.78	.52	.38	1.00
32	Stone, Clay, and Glass Products ...	.98	-.26	.12	1.00	1.00	.06	-.04	1.00
33	Primary Metal Industries ...	1.00	.03	.06	1.00	.75	.59	-.36	1.00
34	Fabricated Metal Products ...	.96	-.35	.10	1.00	1.00	.06	-.05	1.00
35	Machinery, except Electrical ...	.68	.84	-.27	1.00	.99	.08	-.11	1.00
36	Electrical Machinery, Equipment, and Supplies ...	1.00	-.13	.16	1.00	1.00	.00	-.01	1.00
37	Transportation Equipment ...	.85	.03	-.06	.72	1.00	.06	-.11	1.00
19,38,39	Ordnance, Instruments, Miscellaneous ...	.93	.32	-.17	1.00	1.00	-.07	.06	1.00
131	Crude Petroleum ...	-.31	1.00	.45	1.00	.97	.14	-.13	.97
131A	Natural Gas ...	1.00	-.13	.14	1.00	.99	-.21	-.05	1.00
132	Natural Gas Liquids ...	1.00	-.02	.09	1.00	1.00	.42	-.10	1.00
491	Electric Companies & Systems ...	1.00	-.06	.15	1.00	.98	-.22	-.07	1.00
492	Gas Companies & Systems ...	.99	-.23	.16	1.00	.98	-.24	.01	1.00
	Sum of Squares of Factors ...	20.03	4.22	1.05		22.75	1.02	0.40	
	Sum of Squares of Communalities ...				25.30				24.36

Sources: Federal Reserve Board
Federal Reserve Bank of Dallas

*Data is seasonally adjusted quarterly time series.

**The communality or, h^2, shows the percentage of total variation of a particular variable accounted for by the factor analysis. The individual communalities will not equal the sum of squares of communalities because of rounding.

is particularly important in the case of regional analysis, because industry mix and competitive effects at the regional level may exercise differential impacts on the regional economy over the business cycle.[12] Because of this problem, time series data, particularly monthly or quarterly data, may furnish a firmer analytical foundation for the investigation of many regional problems than analysis based on cross-section data. Furthermore, interesting contrasts can be drawn between the analysis of absolute time series data and first differences of the time series data.

The factor analysis of the quarterly time series sub-components of the Texas Industrial Production Index (and for the national index as well) involved the computation of a 24 x 24 matrix of correlation coefficients representing the intercorrelation of the 24 major industry groups (seasonally adjusted) in the mining, manufacturing, and utilities sectors. The matrix of correlation coefficients was then collapsed into the smallest possible number of independent columns; each column represented a reference plane or factor which contained cell values that were independent of one another across factors.[13] These factor loadings--which make up the cell values of the reference planes--can be interpreted as partial correlation coefficients (or principal components) that independently partition the variation associated with any one variable among the factors.[14] (See Table 1.)

The factors that emerge from the analysis represent the underlying variates whose movements are reflected in the data series which are being analyzed. Thus, the factor loadings can also be interpreted as representing the relative importance of each variable on each factor, while the amount of variation in the set of data, attributable to a particular factor, reflects the relative importance of the factors that emerge from the analysis. Furthermore, the factors are useful in categorizing the variables into common groups which exhibit associated movements.[15] Since we initially start with a matrix of correlation coefficients that are highly intercorrelated, the factor analysis problem becomes one of presenting the matrix of correlation coefficients in as few columns as possible so that each column is linearly independent of the others.

The output of the factor analysis program results in two economically useful pieces of information which can be used to develop an index of linkage, or association, for each industry appearing in the analysis. First, cell loadings, or partial correlation coefficients, showing the relation between the variable and the factor indicate the degree of linkage between the variable and each independent factor. Secondly, the proportion of variance in the whole set of data attributable to a particular factor is also an output of the analysis. These two concepts can be used to develop a measure of linkage, or complementarity, between the variables amking up the set of data.

In mathematical terms, the principal axis factor analysis problem is that of determining the characteristic roots or eigenvalues, λ, of a set of data.[16] If the matrix of correlation coefficients is described by A, then:

1) $Ax = \lambda x$, where x, is the eigenvectors.
The problem is solved by setting:

2) $(A - \lambda I)\, x = 0$, and simultaneously solving for λ and x, where, I is the identity matrix.

Once a solution has been reached for the eigenvalues, λ's, we are in a position to determine the proportion of the variation of the set of data which reflects the influence of a specific factor. This last concept can then be used to develop a weight that can be used in formulationg a measure of the industrial structure of the region, and by performing the factor analysis on both state and national data, the industrial structure of the two geographic areas can be directly compared. This conceptual argument can be made operational by using the eigenvalues to develop a weighting factor, σ_{f1}. The weight, σ_{f1}, is given by:

3) $\sigma_{f1} = \lambda_1 / \sum_{f=1}^{m} \lambda$, where σ_{f1} is the weight for the first eignevector or factor;

and where, λ_1, is the eigenvalue associated with the first eigenvector of a set of, m, eigenvectors (and eigenvalues).

TABLE 2

INDEXES COMPUTED FOR
INDUSTRIAL PRODUCTION CATEGORIES
FOR TEXAS AND THE NATION
1956- - 1966

Code	Industry Name		State Linkage	National Linkage	State-National Ratio
			Indexes of:		
SIC 14	Mining and quarrying, non-metallic, except fuel	...	52.3	91.5	.57
20	Food and Kindred Products	...	71.6	90.4	.79
22	Textile Mill Products	...	61.5	94.1	.65
23	Apparel	...	80.0	93.2	.86
24	Lumber and Wood Products	...	69.2	79.7	.87
25	Furniture and Fixtures	...	66.5	93.8	.71
26	Paper and Allied Products	...	75.0	93.0	.81
27	Printing, Publishing and Allied Industries	...	79.7	91.2	.87
28	Chemicals and Allied Products	...	80.2	91.6	.88
29	Petroleum Refining and Related Industries	...	66.8	92.5	.72
30	Rubber and Miscellaneous Products	...	81.7	93.8	.87
31	Leather and Products	...	00.6	57.7	.01
32	Stone, Clay and Glass Products	...	74.5	94.5	.79
33	Primary Metal Industries	...	79.4	53.1	1.50
34	Fabricated Metal Products	...	71.1	94.5	.75
35	Machinery, except Electrical	...	48.1	92.3	.52
36	Electrical Machinery	...	79.2	94.0	.84
37	Transportation Equipment	...	57.1	92.6	.62
19,38&39	Ordnance, Instruments and Miscellaneous	...	70.4	93.0	.76
131	Crude Petroleum	...	-04.7	87.4	-.05
131A	Natural Gas	...	79.0	90.6	.87
132	Natural Gas Liquids	...	79.7	92.6	.86
491	Electric Companies & Systems	...	80.9	89.6	.90
492	Gas Companies & Systems	...	76.5	89.1	.86

The index of linkage (IL), or association, between an industry and the other industries that make up the regional economy is defined as:

4) $$IL_{is} = \sum_{f=1}^{m} \left(r_{is}^{2} \cdot \sigma_f \right) 100$$ where the sign of the partial correlation coefficient, r, is retained and the subscripts, s and f, refer to the state, and the factors (or eigenvectors) that emerge from the factor analysis.[17] The subscript, i, refers to the particular industry in question. The IL for the nation is defined as:

5) $$IL_{in} = \sum_{f=1}^{m} \left(r_{is}^{2} \cdot \sigma_f \right) 100$$ where the subscript, n, refers to the nation.

This measure shows how the changes over time of any one national industry, i, are associated with the rest of the national economy. The weight, σ_f, is developed in the same way as (3) except national data are used. This measure is simply the partial coefficient of determination for the industry (with the sign retained) and each factor weighted by the amount of total variation in the set of data accounted for by the particular factor, σ_f. To get the total linkage index, we take the row sum across m factors. (See Table 2). The industrial linkage index reflects the state's (or nation's) inter-industry relationships and shows the degree of complementarity between each industry and the whole set of industries. The variation in this index reflects differences in the basic forces of technological and institutional change which appear as cyclical and secular time series movements. The weights, σ_f, used in the computation of the linkage index can be thought of as the ratios of the sum of squares of factors and the sum of squares of communalities. Thus, the weights actually show the proportion of the variation of the whole set of data accounted for by particular factors.

The IL can range from a negative number to an index number of 100. A high IL might result from four causes. (1) The regional industry may furnish inputs directly to other regional industries. (2) A regional industry may purchase inputs directly from other regional industries. (3) A regional industry may be integrated with other regional industries through indirect ties with national industries. These indirect ties could involve either the purchase of, or sale of, products outside the region which will have secondary effects on the industrial structure of the region. (4) Finally, a high IL for a particular regional industry might reflect any combination of the three preceeding possibilities. An industry having an IL of close to 100 can be said to be a "strategic" industry in that production in this industry is closely associated with changes in production levels in the rest of the regional economy. It is a strategic industry because its output is complementary to that of other industries in the set. Where a closed economy is considered, the index of linkage is both necessary and sufficient to unambigiously show industrial complementarity of the "containerized" region. At the state (or regional) level where the economy is open, the complementarity may result from regional relationships or may represent interrerelationships at the national level--that is, the expansion of output of industries located in some other geographic area. However, this does not invalidate the concept of complementarity at the local level. This only means that complementarity may not be direct but rather may be indirect, reflecting the interaction of economic linkages with other geographic areas.

The strategic industries are analogous, to some degree, to the "key industries" derived from input-output analysis--the key industries measure is developed from the backward linkages of the technical coefficients of the inverse of the input-output transactions table.[18] Similarly, the strategic industries emerging from the factor analysis are related to the industries posting high multipliers in input-output analysis.[19] However, both the key industries (a summary measure of inputs required in the production of a particular industry) measure and the input-output multiplier are computed for a particular short time period and are incapable of presenting an historical view of regional industrial structure. In order to get a perspective view of the historical structure of industry, the input-output table would have to be reworked repeatedly, and this would be a very expensive process. The more simple measures of industrial structure, such as distributions of industry employment or value added, are virtually costless, but unfortunately they cannot measure interindustry activity within the region or between regions. The IL index strikes a medium in that it supplies a summary measure of interindustry activity with the added bonus that this activity is measured over time, and the analysis (of employment series, for instance) involves only minimal data collection costs can be done for states and smaller areas such as Standard Metropolitan Statistical Areas and involves no serious computational problems in the era of the computer. Furthermore, the data limitations of principal factor analysis would be even less serious where cross-section data were used.

Discussion of the Analysis

It must be emphasized that the IL is computed for each variable of a set of data. The IL for a particular variable measures the correlated movement of that variable with all the others of the set. The analysis is incapable of showing which variables are dependent and which variables are independent. However, the IL is a statistic for describing industrial linkages (or associations) in a more "dynamic" way than input-output coefficients. The linkage measure shows not only the technical coefficients but also the changes in these coefficients over time. In an open economy, such as a state, the measure also shows complementarity of the various state indexes which results from a common source of variation at the national as well as at the state level. The measure indicates, in a summary way, how industries have been related to others over a particular historical period. However, it must be emphasized that it is not possible to argue (in an open economy) that industries having high IL's are necessarily users of each other's products. The high linkages do mean that the industries respond to trend and cyclical movements in much the same way and with the same timing, which reflects complementarity with certain national changes in economic activity as well as local interindustry relationships.

Furthermore, it should be noted that some of the Texas industries which have the lowest linkage indexes are also important export industries. This occurs because the industrial activities are being considered over time; and lack of trend in a particular series, which is part of a trend-dominated set of data, reduces the relationship between that series and the other series comprising the set. This does not compromise the analysis, but rather emphasizes the importance of the secular growth relationships between the export industry and the other industries in the set.

As would be expected, the national IL's are considerably higher than the corresponding state indexes. However, SIC 33, the primary metals industry group, furnishes an exception to this rule. The explanation of the differential between the state and the national IL reflects the different industrial mixes of the state and the nation. In the United States primary metal production is largely associated with iron and steel production. However, in Texas about half of this industry group represents the production of non-ferrous metals, particularly aluminum. Although non-ferrous metals are not mined in Texas, reduction and refining facilities are concentrated there because of low-cost natural gas used to generate the electricity required to refine the non-ferrous metals. In other words, the primary metals industry in Texas is a fast-growing industry associated with a leading sector of the state's "fuel economy"--natural gas. The national primary metals industry, in contrast, is associated with the slow growth iron and steel industries.

However, the most interesting linkage index emerging from the analysis is the IL of -4.7 for crude oil production. This production category, SIC 131, accounts for more than three-quarters of the mining sector; and the mining component of Texas industrial production accounts for about 37 percent of the total production index. In terms of value added, crude petroleum production in 1963 accounted for $3.7 billion, more than half the total value added in manufacturing in the state.

The weakness of the link between this extremely important production category and the movement of industrial production indexes in the rest of the state reflects the unique institutional position Texas occupies with respect to the production of crude oil. Since Texas is a major producer of crude oil and since the Railway Commission of Texas, the state regulatory body involved in controlling crude oil production, has chosen to interpret its conservation mandate to mean "market" conservation, the Commission plays the part of a major oligopolist establishing production quotas and limiting production in order to support crude oil prices in the United States.[20] These quotas reflect the recommendations of the major integrated oil companies that are exporting either crude or refined products out of the state.

Thus, Texas Railway Commission practices apparently result in crude oil production levels that are not closely related to fluctuations in industrial activity in the rest of the state economy. The flexibility of the Commission regulating practices is further limited by the fact that "stripper," or low productivity wells, are exempt from proration. Thus, only the "more productive wells" are subject to production quotas; in contrast, the marginal wells produce to the limit of their capacity. The failure of Texas wells to increase their production sufficiently in 1965 to meet their allowables, and rising demand, may reflect the failure of producers to maintain producing wells subject to proration.

Another industry group, SIC 35--non-electrical machinery, also exhibits a low complementarity relationship with the other industrial series representing the Texas economy. This low linkage relationship between that industry group and the other industries of the state possibly reflects the uniqueness of the machinery industry in Texas--a major producer and exporter of oil well equipment, construction equipment, and air conditioning equipment.

The factor analysis of an industrial production index has other advantages as well as furnishing the bases for a measure of industrial structure via the industrial linkages. The factors represent the underlying relationships of the series being analyzed and thus may be assumed to represent underlying patterns of causation.[21] It is often possible to appropriately name the factors emerging from the factor analysis and to get some idea of the structural relationships among the variables. Since time series data were used, it was hypothesized that the emerging factors were likely to represent the trend, cycle, and erratic elements underlying the movement of the time series. This appeared to be the case for both the nation and the state. The first two factors to emerge from the analysis appeared to be related to trend and cycle. The data had been seasonally adjusted to begin with, as the Texas index was conveniently available only in the seasonal adjusted form, so no seasonal factor could be expected to develop from the analysis. The resulting factor analysis shows how each variable is related to trend, cycle, and a residual category which was not named. In order to determine whether the first factor represented trend, time was introduced as a proxy variable in an early phase of the analysis, and it was found to be highly loaded on factor one and had low loadings on the other factors. No proxy variable was used to furnish evidence of the nature of the second factor; however, the raw data was graphically inspected, and those industries having high positive loadings on factor two also showed pronounced cyclical behavior. Thus, it appears that the inter-relations in this analysis are primarily expressed in terms of trend and cycle.

In the case of the first factor (trend), a positive factor loading indicates that the industry associated with this particular partial correlation coefficient is directly related to trend. Conversely, a negative factor loading indicates an inverse relationship between the industry and trend. In the case of the second factor a positive cell value indicates that the variable is directly related to movements in the business cycle--as that cycle is reflected in the movements of the set of data. A negative cell loading indicates that the particular industry is not related to the business cycle as it occurs in the set of data being analyzed. This does not mean that all industries not having a high

TABLE 3A

FACTOR ANALYSIS OF
INDUSTRY GROUPS (FIRST DIFFERENCES) OF
THE TEXAS INDUSTRIAL PRODUCTION INDEX
(1956-1966)*

SIC Code	Industry Name		Factors 1	2	3	4	5	6	7	8	9	10	h^2**
14	Mining and quarrying, non-metallic, except fuel	...	-.12	-.04	.09	.27	.69	.33	-.15	-.07	.17	.54	1.00
20	Food and Kindred Products	...	.12	-.79	-.47	-.12	.17	-.25	-.09	.07	-.06	.17	1.00
22	Textile Mill Products	...	.42	.45	-.35	-.28	.12	-.17	.12	.16	-.29	.19	.78
23	Apparel	...	.38	.66	-.12	.04	-.09	.23	.30	.18	.37	-.01	.90
24	Lumber and Wood Products	...	.59	-.13	-.24	-.12	.60	-.14	-.06	.35	.14	-.12	.99
25	Furniture and Fixtures	...	.71	.05	-.17	-.31	-.06	-.19	.49	-.12	.38	-.09	1.00
26	Paper and Allied Products	...	.35	.38	-.29	.12	-.34	.38	-.08	.56	-.21	-.12	1.00
27	Printing, Publishing and Allied Industries	...	.62	-.74	-.24	.17	-.12	.13	.19	-.12	.15	-.01	1.00
28	Chemicals and Allied Products	...	.47	.13	-.11	-.42	.42	.28	-.37	-.27	.01	-.34	1.00
29	Petroleum, Refining and Related Industries	...	.56	-.37	.00	.59	-.07	-.05	-.27	-.15	-.28	-.16	1.00
30	Rubber and Miscellaneous Plastic Products	...	.71	-.23	-.41	.18	.05	-.09	.05	.23	-.28	.14	.93
31	Leather Products	...	.57	-.66	.03	-.47	-.02	.29	.02	.23	.02	.06	1.00
32	Stone, Clay, and Glass Products	...	.29	.13	.47	-.03	.18	.10	.60	-.02	-.34	.03	.84
33	Primary Metal Industries	...	.38	.71	-.10	.31	.12	.33	.00	-.24	-.18	.09	.98
34	Fabricated Metal Products	...	.27	.80	-.07	-.05	.36	-.14	.06	.00	-.13	-.14	.91
35	Machinery, except Electrical	...	.70	-.11	-.08	.00	.22	.60	-.06	-.31	.11	.11	1.00
36	Electrical Machinery, Equipment, and Supplies	...	.26	.17	-.68	-.28	-.32	-.03	-.39	-.21	-.03	.04	.94
37	Transportation Equipment	...	.16	.64	-.13	-.29	-.13	-.34	-.29	-.19	.01	.26	.86
19,38,39	Ordnance, Instruments, Miscellaneous	...	.50	-.20	.34	-.39	-.18	-.13	.25	-.35	-.29	.24	.94
131	Crude Petroleum	...	.65	.29	.15	.60	-.17	-.23	-.06	-.08	.19	.07	1.00
131A	Natural Gas	...	.53	.19	.54	-.40	-.19	-.19	-.32	.22	.17	.20	1.00
132	Natural Gas Liquids	...	.65	-.04	.02	.63	.04	-.38	-.01	.03	.13	.03	.98
491	Electric Companies & Systems	...	.64	-.13	.67	-.09	.19	-.14	-.17	-.17	.06	-.30	1.00
492	Gas Companies & Systems	...	.33	-.01	.85	-.03	-.13	.13	-.30	.34	.00	.11	1.00
	Sum of Squares of Factors	...	5.87	4.42	3.09	2.44	1.69	1.55	1.53	1.29	0.99	0.88	
	Sum of Squares of Communalities	...											23.75

Source: Federal Reserve Bank of Dallas

* Data is seasonally adjusted quarterly time series

** The communality or, h^2, shows the percentage of total variation of a particular variable accounted for by the factor analysis. The individual communalities will not equal the sum of squares of communalities because of rounding.

TABLE 3B

FACTOR ANALYSIS OF
INDUSTRY GROUPS (FIRST DIFFERENCES) OF
THE NATIONAL INDUSTRIAL PRODUCTION INDEX
(1956-1966)*

SIC Code	Industry Name		Factors								
			1	2	3	4	5	6	7	8	h^2**
14	Mining and quarrying, non-metallic, except fuel	...	.72	-.20	.19	-.56	.00	-.13	.13	-.09	.96
20	Food and Kindred Products	...	.44	.20	-.50	-.49	.24	.18	.03	.35	.93
22	Textile Mill Products	...	.85	.06	.47	-.13	-.03	.02	-.09	-.19	1.00
23	Apparel	...	.93	-.01	.05	-.05	-.07	.05	-.20	.09	.93
24	Lumber and Wood Products	...	.56	.11	-.32	.25	-.31	.48	.29	-.05	.90
25	Furniture and Fixtures	...	.79	.09	-.38	.21	-.17	-.37	-.14	.13	1.00
26	Paper and Allied Products	...	.96	.11	.05	-.13	-.01	.21	.02	-.09	1.00
27	Printing, Publishing and Allied Industries	...	.56	-.29	.33	-.03	.24	-.47	.37	.11	.93
28	Chemicals and Allied Products	...	.99	-.13	.09	-.10	-.05	-.00	-.03	.06	1.00
29	Petroleum, Refining and Related Industries	...	.51	-.08	.54	-.56	.25	.08	-.28	-.05	1.00
30	Rubber and Miscellaneous Plastic Products	...	.83	-.17	-.19	.07	-.24	-.04	-.36	-.21	.99
31	Leather Products	...	.82	-.03	.16	.04	.01	.33	-.18	.08	.84
32	Stone, Clay, and Glass Products	...	.68	-.13	-.56	-.08	.14	-.07	.38	-.27	1.05
33	Primary Metal Industries	...	.38	.69	.04	.09	.63	.07	.10	.04	1.05
34	Fabricated Metal Products	...	.93	-.08	-.25	.31	.26	.07	.05	-.04	1.10
35	Machinery, except Electrical	...	.92	-.18	-.12	.10	-.09	-.26	.11	.03	1.00
36	Electrical Machinery, Equipment, and Supplies	...	.96	.16	.13	.05	-.10	-.08	.05	.07	.99
37	Transportation Equipment	...	.79	-.00	.02	.47	.28	.02	-.17	.30	1.00
19,38,39	Ordnance, Instruments, Miscellaneous	...	.69	-.07	.28	-.07	-.47	-.00	.13	.41	.96
131	Crude Petroleum	...	.68	-.31	.53	-.14	-.06	.29	.24	-.16	1.00
131A	Natural Gas	...	.21	.03	.65	.63	.03	.09	.13	-.07	.90
132	Natural Gas Liquids	...	.81	.13	.21	.21	.14	-.19	-.22	-.31	.96
491	Electric Companies & Systems	...	.20	.87	.18	-.12	-.34	-.17	.04	-.10	1.00
492	Gas Companies & Systems	...	.16	.98	.15	-.12	-.13	-.06	.09	-.03	1.00
	Sum of Squares of Factors	...	12.65	2.65	2.53	1.87	1.33	1.06	0.90	0.74	
	Sum of Squares of Communalities	...									23.72

Source: Federal Reserve Board

* Data is seasonally adjusted quarterly time series

** The communality or, h^2, shows the percentage of total variation of a particular variable accounted for by the factor analysis. The individual communalities will not equal the sum of square of communalities because of rounding.

TABLE 4

INDEXES COMPUTED FOR
INDUSTRIAL PRODUCTION CATEGORIES
(FIRST DIFFERENCES)
FOR TEXAS AND THE NATION
1956 - 1966

Code	Industry Name	State Linkage	Indexes of: National Linkage	State-National Ratio
SIC 14	Mining and quarrying, non-metallic, except fuel	5.5	25.3	.22
20	Food and Kindred Products	-14.5	6.7	2.16
22	Textile Mill Products	5.9	36.2	.16
23	Apparel	12.9	46.2	.28
24	Lumber and Wood Products	10.9	16.8	.65
25	Furniture and Fixtures	13.2	31.1	.42
26	Paper and Allied Products	6.5	49.0	.13
27	Printing, Publishing and Allied Industries	- .8	16.5	- .05
28	Chemicals and Allied Products	3.9	52.4	.07
29	Petroleum Refining and Related Industries	7.7	14.2	.54
30	Rubber and Miscellaneous Products	9.8	35.5	.28
31	Leather and Products	- 1.5	36.2	-.04
32	Stone, Clay and Glass Products	7.3	21.6	.34
33	Primary Metal Industries	14.3	15.4	.93
34	Fabricated Metal Products	14.3	46.1	.31
35	Machinery, except Electrical	13.2	44.6	.30
36	Electrical Machinery	- 6.5	49.7	- .13
37	Transportation Equipment	5.9	35.7	.17
19, 38 & 39	Ordinance, Instruments and Miscellaneous	4.6	25.4	.18
131	Crude Petroleum	15.9	27.0	.59
131A	Natural Gas	9.2	10.1	.91
132	Natural Gas Liquids	13.7	35.2	.39
491	Electric Companies & Systems	14.8	10.2	1.45
492	Gas Companies & Systems	12.1	12.1	1.00

negative cell loading on factor two were free of cyclical movements. However, a negative cell loading on factor two does indicate that the industry associated with this partial correlation coefficient is "counter-cyclical" or else is out of phase with the business cycle as it is reflected in the movements of the other industries comprising the set of data.

If part or all of the variation of a particular industry is not associated with movement of other industries, the variance of the industry would be classified as specific variance and would be highly loaded on a factor which contained low or zero cell loadings where other industries are concerned. Since such variation must be specific and non-complementary, such a factor would be dropped from the analysis. Such a factor would be of no use as a partial explanation of the complementarity between a particular variable and the other variables in the analysis. That is, this part of the variance of a particular variable is unassociated, or unlinked, with the movements of other variables comprising the set of data being analyzed.

The brief discussion of the linkage relations of the above two industry groups, SIC 131 and 35, particularly the former, is not meant to imply that these areas of production will be unimportant to the future growth of the Texas economy or that these industries have not been instrumental in the development of the Texas economy. Neither does this argument imply that important input-output relations do not currently exist between the crude-oil, petroleum refining, and petrochemical industries in Texas.[22] What the analysis indicates is that changes in the levels of industrial production of two important industry groups--machinery and crude petroleum--are only weakly associated with changes in the industrial segment of the state's economy over the study period.

A more conventional view of the complementarity relations arises from the analysis when the first differences of the time series are factor analyzed. This prodedure, by emphasizing the inter-relations of incremental changes in the production indexes, largely eliminates the effect of trend on the variables. With trend largely washed out of the analysis, the resulting problem is one of attempting to partition the cycle and erratic movements in the series into independent factors. (See Table 3A and 3B)

The result of this "first differences" analysis is a set of linkage indexes for the state that are considerably lower than were previously developed; however, a marked increase in the linkage index of the crude petroleum industry was recorded. (See Table 4) This industry now shows, after trend has largely been eliminated, an IL of 15.9--the highest value of any index in the state. In contrast, electrical machinery (primary electronic components) shows an IL of -6.5, indicating the lack of concomitant movement in this series and the other series of the set. Again as might be expected, the national linkage indexes were much higher than their state counterparts. However, now the linkage indexes must be interpreted as indicating the linkages existing because of effects other than those associated with trend. Since this argument is centered around evaluating industries with regard to their complementarity in a developmental context, it would seem desirable to work with the raw data rather than with first difference data.

Index of Dissimilarity

The linkage index shows the concomitant movements over time of a group of industries or economic activities within a given geographic area. However, it would also be desirable to develop a related though subordinate measure: an index of dissimiliarity (ID).[23] The ID may be defined

6) $$ID = \sum_{f=1}^{m} \left[\left(r_{in}^2 - r_{is}^2 \right) \sigma_f \right] 100,$$ where the sign of the partial correlation,

r, is retained and σ_f refers to the weight defined in equation (3), however, the weight has now been derived from pooled data. The subscripts, i, n, and s, refer to the industry, state, and nation, respectively. The ID is based on a factor analysis of pooled state and national data.

Table 5

INDEXES COMPUTED FOR INDUSTRIAL PRODUCTION
CATEGORIES FOR TEXAS AND THE NATION 1956-1966

SIC Code	Industry	Index of Dissimilarity*
14	Mining and quarying, non-metalic, except fuel	30.4
20	Food and Kindred Products	6.3
22	Textile Mill Products	20.9
23	Apparel	1.1
24	Lumber and Wood Products	5.3
25	Furniture and Fixtures	16.1
26	Paper and Allied Products	4.4
27	Printing, Publishing and Allied Industries	0.9
28	Chemicals and Allied Products	0.4
29	Petroleum, Refining and Related Industries	8.8
30	Rubber and Misc. Plastic Products	0.0
31	Leather Products	76.7
32	Stone, Clay and Glass Products	5.7
33	Primary Metal Industries	37.6
34	Fabricated Metal Products	10.5
35	Machinery, except Electrical	33.8
36	Electrical Machinery, Equipment and Supplies	1.4
37	Transportation Equipment	29.0
19,38, & 39	Ordinance, Instruments and Miscellaneous	12.1
131	Crude Petroleum	72.4
131A	Natural Gas	0.1
132	Natural Gas Liquids	1.6
491	Electric Companies & Systems	1.5
492	Gas Companies and Systems	0.1

*This index was obtained from a factor analysis of the pooled data of the State and National Production Indexes

The ID shows the overall amount of variation in that portion of an industry within a state or region that is associated with changes in the output of the same industry in the nation. An index value of zero would indicate that the changes in industry activity over time in the nation and state have been very closely related. Conversely, the higher the value of the index, the greater the degree of heterogeneity of the two series. A low value for the ID reflects several possibilities: 1) the national industry is largely located within the confines of the state or region, 2) the production and trading relationships are very similar for the same industry in both the state and nation, or 3) the product mix of a particular industry is similar for both the state and the nation. Conversely, if the ID registered a very high value--approaching 100--the movements of the two industrial series (reflecting the same activity in the state and nation) are quite different; that is, the series are heterogeneous. (See Table 5). The analytical value of the ID arises from the fact that a low ID associated with a high IL, for the same regional industry, eliminates some of the problems of interpretation of the meaning of the IL statistic. Where ID approaches zero and where the IL approaches 100, we do not have to worry whether or not the complementarity evidenced by the high IL is due to regional complementarity or from forces emanating from the national level--the effects are the same.

It must be emphasized that in this analysis a high ID does not mean that the state industry is an export industry. The analysis does show that the state industry's reaction to underlying economic movements is different from that of the national industry. In other words, the underlying institutional and technological structure of the economy affects the state (or region) and national industry in a different manner. This may arise from the geographic incidence of industrial mix and competitive effects as they make themselves felt through the trend and cyclical movements of the economy.

Conclusion

In conclusion, it may be said that the measure of industrial linkage is summary in nature; that is, it indicates how industries have been related to one another over time and can be looked upon as a measure of complementarity. This characteristic makes the index a complement to the usual measures of industrial structure. The IL takes into account the relationship between the movements of one industry and the other industries of the regional economy. It is not suggested that the measure comprehensively explains all the characteristics of a regional economy. However, the measure does fill a gap in regional analysis by showing the historical association between the level of industrial activity in one industry and that of the other industries of the region--in this example it shows the linkage between quarterly changes in industrial production. Since the linkage index is based on correlation coefficients, it is not possible to attribute direct casual relationships between the time series used in the analysis. However, the analysis does show the concomitant movements between one industry and all other industries in the set. Thus, the analytical framework of the analysis is sufficient to establish a measure of industrial linkage[24] (or association). A summary measure of the industrial linkages of a particular region would be an important addition to the measures already developed to study the region's export base, factor markets, and industrial structure.

The primary advantage of the IL statistic as a measure of economic activity for a set of industries within a region (and for all the regions comprising the national economy) is that the analysis deals with historical changes; and the data required for the analysis is readily available and is capable of presenting the researcher with a meaningful measure of complementarity which can be obtained at low cost.

[1]The author gratefully acknowledges the comments and criticisms of Leo Fishman and William Miernyk; also the computational assistance of John Milliken.

[2]George H. Borts, Regional Cycles of Manufacturing Employment in the United States, 1914-1953, National Bureau of Economic Research, Inc., Occasional Paper 73; R. Vining, "Regional Variation in Cyclical Fluctuation Viewed as a Frequency Distribution," XIII, Econometrica (July, 1945), and several articles in Vol. XIV of Econometrica; Douglass C. North, "Location Theory and Regional Economic Growth," LXIII, Journal of Political Economy (June, 1955), pp. 243-258; Richard B. Andrews, a series of articles dealing with the theory and technical problems associated with economic base studies in Land Economics, Vols, 29 to 31.

[3]Harvey Perloff and Lowdon Wingo, Jr., "Natural Resource Endowment and Regional Economic Growth," Natural Resources and Economic Growth, (Joseph J. Spengler, ed.) (Washington: Resources for the Future), 1961, pp. 191-212; William H. Miernyk, The Elements of Input-Output Analysis (New York: Random House), 1965, pp. 64-77.

[4]William H. Nicholls, "Southern Traditions and Regional Economic Progress," XXVI, Southern Economic Journal (January, 1960), pp. 187-98; Gunnar Myrdal, An American Dilemma, Vol. I (New York: McGraw-Hill Book Co.), 1964, pp. 386-92; and F. Ray Marshall, "Racial Factors Influencing Entry into the Skilled Trades," Human Resources in the Urban Economy, ed. Mark Perlman (Baltimore: The John Hopkins Press), 1963, pp. 23-54; James G. Maddox, et al, The Advancing South: Manpower Prospects and Problems (New York: The Twentieth Century Fund), 1967.

[5]Francois Perroux, "Economic Space: Theory and Applications," Quarterly Journal of Economics, Vol. 64 (February, 1950), pp. 89-104.

[6]For a discussion of the mathematical and conceptual differences between factor analysis and the related technique of principal components analysis see: Donald F. Morrison, Multivariate Statistical Methods (New York: McGraw-Hill Book Company), 1967, pp. 221-223, and pp. 259-260.

[7]For detailed discussions of principal component and factor analysis see: M. G. Kendall, A Course In Multivariate Analysis (London: Charles Griffin & Company Limited), 1961; Donald F. Morrison, Multivariate Statistical Methods (New York: McGraw-Hill Book Company), 1967, Chapters 7 and 8.

[8]J. Marcus Fleming, "External Economies and the Doctrine of Balanced Growth," The Economic Journal (December, 1955); Tibor Scitorsky, "Two Concepts of External Economies," The Journal of Political Economy (April, 1954).

[9]Benjamin Higgins, Economic Development, Revised Edition (New York: W. W. Norton & Company, Inc.), 1968, p. 347.

[10]For a discussion of these two indexes see: Edward A. Manookian, Industrial Production 1957-59 Base (Washington: Board of Governors of the Federal Reserve System); Carl W. Hale, "Methodology of the Texas Industrial Production Index," 1966 Revision (Mimeographed), Federal Reserve Bank of Dallas (July, 1966).

[11]Instead of a full-pledged production index, man-hours indexes or electrical power cosumption indexes (for specific industries) might be used as measures of industrial structure. Man-hours indexes for major industrial groups can be computed at the regional level by using Bureau of Employment Security survey data. The Board of Governors of the Federal Reserve System along with the regional banks are in the process of completing a monthly series of industrial electrical power consumption which would or could yield state power consumption indexes by industry.

For a recent critique of shift analysis see: David B. Houston, "The Shift and Share Analysis of Regional Growth: A Critique," XXXIII, Southern Economic Journal (April, 1967), pp. 577-581.

[12]Raymond B. Cattell and Marvin Adelson, "The Dimension of Social Change in The U.S.A. as determined by P-Technique," XX, Social Forces (December, 1951), pp. 190-201.

[13]For a discussion of some of the factors leading to instability of regional trading patterns see: Leon N. Moses, "The Stability of Interregional Trading Patterns and Input-Output Analysis," XLV, American Economic Review (December, 1955), pp. 810-812.

[14]It is possible that the latent structure of the set of variables under consideration is not orthogonal. For a discussion see: Benjamin Fruchter, Introduction to Factor Analysis (Princeton: D. Van Nostrand Company, Inc.), 1954, pp. 194-196; Harry H. Harman, Modern Factor Analysis (Chicago: The University of Chicago Press), 1960, pp. 261-262.

[15]Robert Ferber and P. J. Verdoorn, Research Methods in Economics and Business (New York: The MacMillan Company), 1962, p. 105.

[16]Robert Ferber, op. cit., pp. 103-105; Benjamin Fruchter, op. cit., Chapter 2 and Chapter 4.

[17]For a discussion of this problem see: J. Johnston, Econometric Methods (New York: McGraw-Hill), 1963, pp. 95-100.

[18]The measure of linkage advocated here is roughly analogous to Albert Hirshman's "forward and backward linkages." However, while the linkages derived from the factor analysis show interdependence with respect to specific factors, they do not have the same theoretical significance that Hirshman's forward and backward linkages have. Hirshman concludes that spread effects that are induced in an economy are a reflection of shortages developing out of industrial links with rapidly growing industries. This reflects the fact that Hirshman's linkage analysis is based on input-output coefficients developed at a particular point in time. The linkage index referred to in this analysis, however, indicates the historical pattern of interdependence of the data and confounds the effects of the forward and backward linkage measures into a summary statistic--the IL. For a discussion of linkages as they relate to input-output analysis see: Albert O. Hirshman, The Strategy of Economic Development (New Haven, Yale University Press), 1958, pp. 98-119.

[19]For a discussion of the computation and use of the Key industries measure see: Norregard Rasmussen, Studies in Inter-Sectoral Relations (Amsterdam: North-Holland Publishing Company), 1956, pp. 133-149; op. cit. Albert Hirshman, p. 108.

[20]op. cit., William H. Miernyk, pp. 42-55.

[21]James E. Jensen, "Texas: Balance Wheel in Control of Crude Oil Supply," XLI, Land Economics (August, 1965), pp. 271-275.

[22]It can be argued with some force that factor analysis does not show causation but is only a first step in determining the nature of the structure of a set of variables. For a concise discussion see: Charles K. Ramond, "Factor Analysis: When to Use It," Scientific Decision Making in Business, Abe Shuchman, ed. (New York: Holt, Rinehart and Winston, Inc.), pp. 238-239.

[23]C. D. Kirksey, An Interindustry Study of the Sabine-Neches Area of Texas (Austin, Texas: Bureau of Business Research, the University of Texas), Research Monograph No. 20, 1959.

[24]Several measures of economic differentiation are available, but unfortunately they measure the distribution of variables either at one point of time or the changes in the variables between the two points in time. For instance see: Eiji C. Amemiya, "Measurement of Economic Differentiation," V, Journal of Regional Science (1963), pp. 85-87; G. Hilderbrand and A. Mace, "The Employment Multiplier in an Expanding Industrial Market: Los Angeles County, 1940-47," XXXII, Review

of Economics and Statistics (August, 1950); Phillip Neff and Robert M. Williams, "Identification and Measurement of an Industrial Area's Export Employment in Manufacturing," _Proceedings of the Western Committee on Regional Analysis_, 1952.