Changes in the Structure of the Washington State Economy, 1963-72: An Input-Output Analysis

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This analysis examines structural change in the State of Washington economy through an input-output analysis. The results indicate that significant changes in interindustry demand occurred between 1963 and 1972. For the Agricultural sector, the interindustry demand in 1972 was more than in 1963. In contrast, the Energy sector used more interindustry demand in 1963 than in 1972. For the Trade and Finance, Insurance, and Real Estate sector, there was also more interindustry demand in 1963 than in 1972. The empirical analysis leads to similar conclusions when interindustry demand is calculated using alternative methods.

The primary objective of this analysis is to examine changes in the structure of the Washington State economy through an input-output (I/O) model. More specifically, structural changes are examined by a direct comparison of the change in factor inputs in an industry's production process over time. Changes during 1963-72 in the demand for intermediate uses by each industry (hereafter call interindustry demand) are evaluated by examination of I/O tables for the Washington State economy for 1963 and 1972. Every regional economy has a unique internal structure. Each sector's economic activity is determined by its relationships to other sectors for its inputs and outputs. An I/O analysis allows such structural interaction to be identified and evaluated.

It is important to examine the patterns of structural changes in a regional economy even though such studies are done periodically at the national level. In many instances the structure of a regional economy, in this case, the Washington State economy, is different from the national economy. Washington State has large hydro-electric power resources whereas most of the rest of the nation has few such resources. The State uses little coal for energy whereas most other areas of the U.S. use large amounts of coal. Industries as well as households in the State reflect the dependence on hydro-electric power as a primary energy resource. On the output side, the aerospace industry was the single most important industry in the State in 1967[1] while the trade sector (retail and wholesale) was the most important sector of the economy in both 1963 and 1972. Furthermore, since I/O tables are available for the State, it is useful to examine patterns of structural changes through an I/O model.

Structural changes in a regional economy occur as a result of such factors as technological change, a resource supply deficiency, or changes in the composition of final demand. Technological advances may improve raw material utilization and/or machinery for a particular industry, which then leads to a changing relative input mix within that industry. These new production processes may

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[1]This analysis focuses on changes occurring between 1963 and 1972 as evidenced by changes in I/O tables for 1963 and 1972. The 1967 I/O table for the State of Washington was also available and reflected the importance of the aerospace industry at that time.

require a different combination of inputs as producers substitute less expensive inputs for more expensive ones. Sometimes a limited supply of resources will result in price induced substitution among the different production processes in the economy. Finally, changes in the composition of final demand may also require changes in industry output requirements, which in turn cause adjustments in interindustry demand. All these changes require time, the amount depending on the nature of changes in technology, relative prices, and the composition of final demand.

There are published I/O tables for Washington State for different time periods, but no empirical study has been done to examine changes in the structures of the State economy through an I/O model. Thus, if two tables (reflecting different time periods) are consistent in their structural framework, it is possible to discern declining as well as growing elements of the changing process mix.

A secondary objective of this paper is to determine whether different methods of estimating interindustry demand lead to different conclusions concerning changes in the structure of a state economy. More specifically, the "current dollar" interindustry demand is compared with "constant dollar" interindustry demand. Also, the "backcasting" method, which predicts earlier year interindustry demand based on later year I/O coefficients, is used in the analysis.

Methodology

The fundamental strength of I/O analysis is its prediction power of total (sector) output requirements under a given technology and final demand for goods and services. Thus, one might question the concern over changes in interindustry demand rather than changes in total output requirements. Each sector's total output includes both interindustry demand and final demand. But, final demand is given exogenously. Therefore, the actual I/O prediction is not the total output requirement, but only the portion of total output that is used as inputs by industries. The reason for predicting interindustry demand rather than total output requirements can further be explained through empirical observation. For the State of Washington, the total "net" output of the Business and Personnel Services sector (sector 35) in 1972 was \$2.6 billion, of which \$1.9 billion (73 percent) was final demand and the remaining \$0.7 billion (27 percent) was interindustry demand.[2] The aerospace industry (sector 24) had only \$4 million for interindustry demand (0.2 percent) compared with \$1,841.8 million final demand (more than 99 percent) in 1972. Thus, in the case of the aerospace industry it would be misleading to say that the total output requirement is the object of the prediction since 99 percent of it is determined exogenously. Predicting only interindustry demand gives a more realistic picture of the accuracy of the prediction.

In matrix terminology, let the structure of the Washington I/O economy be a standard static-open system which can be presented as follows:

X = a 35 by 1 vector of sector output
A = a 35 by 35 technological matrix
F = a 35 by 1 final demand vector
I = a 35 by 35 identity matrix

then the Washington State economy can be written as:

$$(1) \quad AX + F = X$$

[2]Total "net" output means gross output minus the amounts consumed by the same industry. Thus, if the interindustry flow of good and service are denoted as X_{ij}, meaning i-th good and service to j-th sector, the "net" output implies that $I_{ij} = 0$ when $i = j$. In his original publication Leontief (p. 205) assumes that an industry does not use any of its own products as inputs in production itself. Dorfman, *et al.* (p. 203) indicate that this is not a harmful convention in the static economic model. Since primary interest is to examine changes in interindustry demand, not "intra" industry demand, all calculations in the empirical section are based on the "net" concept.

and the interindustry demand can be calculated as:

$$(2) \quad AX = X - F, \text{ or}$$

$$(3) \quad = (I - A)^{-1} F - F = [(I - A)^{-1} - I] F; \text{ since}$$

$X = (I - A)^{-1}F$. If we denote the 35 by 1 vector AX as D, the i-th element of the vector D will show how much i-th sector output is used to satisfy the given set of final demand in the economy.

Based on the published I/O tables for both 1963 and 1972 the following estimations can be made. First, in equation (3), the technological matrix "A" and final demand vector "F" can be expressed in 1972 "current" dollar basis and this vector is compared with a vector derived by using the 1963 "A" matrix with the 1972 final demand vector. The latter vector, then can be written as:

$$(4) \qquad AX = [(I - A_t)^{-1} - I] F_{t+1}$$

where t = 1963 and t+1 = 1972. This vector will be a "forecasted" vector under the assumption that 1972 technology is similar to that of 1963. Conversely, the 1963 interindustry demand can also be "backcasted" by using 1972 technology with 1963 final demand. In this case, the matrix "A" is in 1972 dollars while the vector "F" is in 1963 dollars.

Another method is to use the base year "A" matrix with a future year's final demand but on the basis of constant prices. This is known as the "constant dollar" method which requires deflating final demand by the base year prices [Tilanus and Rey].

To use input coefficients in constant prices, the standard I/O coefficients (a_{ij}'s) are replaced by $(p_j/p_i)\ a_{ij}$ where p_i and p_j are product prices of i-th and j-th sector output, respectively. The (p_j/p_i) is the (i,j)-th element of the matrix $P^{-1}A\ P$ where P is a diagonal matrix whose (i,j)-th element is P_i. Then the role of $[I - A_t]^{-1}$ can be written as

$$[I - P_t^{-1} A_t P_t]^{-1} = [P_t^{-1} P_t - P_t^{-1} A_t P_t]^{-1}$$

$$= [P_t^{-1} (I - A_t) P_t]^{-1} = [P_t^{-1} (I - A_t)^{-1} P_t]$$

and, $[P_t^{-1} (I - A_t)^{-1} P_t - I] = P_t^{-1} [(I - A_t)^{-1} - I] P_t$. Now the final demand vector "F_{t+1}" in equation (4) can be expressed in constant prices by the vector $P_{t+1}^{-1}\ F_{t+1}$, where $P_{t+1}^{-1}$is a similar matrix as P_t^{-1}, but with new prices. Thus, the "constant" dollar interindustry demand equation becomes:

$$(5) \qquad P_t^{-1} (I - A_t)^{-1} - I] P_t P_{t+1}^{-1} F_{t+1}$$

If year t is the base for price indices, so that $P_t = P_t^{-1} = I$, equation (5) will show the interindustry demand in the price of t (1963 in the empirical analysis for the State.)[3]

Empirical Analysis

For the empirical analysis the original 51 sector Washington I/O tables by Bourque and others (1969 and 1976) were condensed to 35 sectors. Table 1 identifies the 35 sectors used in this study and gives sector descriptions. Because of difficulty in getting producers' prices at the State level for the 35 sectors classified, the Wholesale Prices and Price Index published by BLS, U.S. Department of Labor is used. This assumes that the State's price movements during 1963-72 are the same as national price movements.

To analyze how structural change has affected the input requirement for different type of products, certain sectors of the Washington State economy are grouped under three headings: Agriculture, Energy, and Trade and Services. Sectors 1 through 4 in table 1 are grouped as Agriculture; sectors

[3]For a detailed analysis of current versus constant dollar forecasting methods, see Bezdek and Wendling or Tilanus and Rey. Similar analysis for the Washington economy can be found in Lee *et al.*

TABLE 1. Classification of Washington Industries for Input-Output Analysis, 1963 and 1972

Input-Output Sector	Sector Description	I/O Sector
1.	Field and seed crops	1
2.	Vegetables, fruits, and nuts	2
3.	Livestock and livestock products	3
4.	Other agricultural products	4
5.	Forestry and fishing	5, 15
6.	Mining	14
7.	Meat and dairy products	6, 7
8.	Canning and preserving	8
9.	Grain mills	9
10.	Beverage industries and other food	10, 11
11.	Textile products and apparel	12, 13
12.	Lumber and wood	16, 17
13.	Veneer and plywood	18, 19
14.	Paper and allied products	21-23
15.	Printing and publishing	24
16.	Industrial chemicals and allied products	25, 26
17.	Petroleum and related industries	27
18.	Glass, stone, cement, and clay	28, 29
19.	Iron and steel	30
20.	Nonferrous metals	31
21.	Aluminum	32
22.	Fabricated metal products	33, 34
23.	Machine, equipment	35-38
24.	Aerospace	39
25.	Other transportation equipment	40, 41
26.	Other manufacturing	20, 42
27.	Construction	48
28.	Transportation services	43
29.	Communications	47
30.	Electric systems and services	44
31.	Gas systems and services	45
32.	Water, sanitary, and irrigation	46
33.	Trade (wholesale and retail)	49
34.	Finance, insurance, and real estate	50
35.	Business and personal services	51

17, 30, and 31 as Energy; and sectors 33, 34 and 35 as Trade and Services.

Tables 2 through 5 summarize the results obtained for current and constant dollar forecasts and backcasts. Current dollar values of interindustry demand for 1963 and 1972 are listed in column 2. This is compared with column 3, which shows interindustry demand for 1972 under 1963 technology with 1972 final demand. Column 4 lists values for 1972 interindustry demand in 1963 constant dollars. Column 5 shows backcasting for 1963 interindustry demand with 1972 technology.

Comparisons between 1972 values in columns 2 and 3 show the change in interindustry output demand between 1963 and 1972 attributable solely to changes in input-output coefficients. Comparisons of values in columns 2 and 4 show changes in interindustry output demand caused by both changes in I/O coefficients and real final demand. Finally, comparison of 1963 values in columns 2 and 5 gives estimates of how regional products of different industries are affected over time when 1963 interindustry demand is backcasted by using 1972 I/O coefficients with 1963 final demand.

TABLE 2. Changes in Interindustry Demand For Agricultural Products, 1963-72

(1)	(2)		(3)	(4)	(5)
	Current dollar		1963 tech with 1972 final demand	Deflated by 1963 prices	1972 tech with 1963 final demand
Agriculture	1963	1972			
			Million dollars		
Field and seed crops	55.1	111.4	88.5	69.2	67.2
Vegetables, fruits, and nuts	56.1	143.3	103.4	83.6	81.3
Livestock and livestock products	176.1	217.3	254.3	181.7	150.3
Other agricultural products	3.4	4.3	7.4	5.1	2.0
Subtotal	290.7	476.3	453.6	339.6	300.8

TABLE 3. Changes in Interindustry Demand For Energy Products, 1963-72

(1)	(2)		(3)	(4)	(5)
	Current dollar		1963 tech with 1972 final demand	Deflated by 1963 prices	1972 tech with 1963 final demand
Energy	1963	1972			
			Million dollars		
Petroleum and petroleum products	86.6	130.5	138.2	132.4	64.3
Electricity services	100.1	214.9	228.1	163.9	95.9
Natural gas	105.4	195.1	214.8	166.6	94.7
Subtotal	292.1	575.2	630.1	465.4	254.9

TABLE 4. Changes in Interindustry Demand For Trade, Finance, Insurance, Real Estate, and Services, 1963-72

(1)	(2)		(3)	(4)	(5)
	Current dollar		1963 tech with 1972 final demand	Deflated by 1963 prices	1972 tech with 1963 final demand
Trade, Finance, Insurance and Real Estate & Services	1963	1972			
			Million dollars		
Trade	210.5	436.2	446.5	296.2	202.2
Finance, insurance, real estate	173.1	184.8	385.6	283.3	83.2
Business and personal service	204.3	712.3	446.8	324.7	339.6
Subtotal	587.9	2,333.3	1,278.9	859.2	615.0
Total for all 35 sectors	2,399.4	4,510.0	4,944.2	3,532.3	2,239.6

TABLE 5. Washington Aggregate Inputs in 1963 and 1972

Inputs	1963		1972	
	Million dollars	Percent	Million dollars	Percent
Washington State's inter-industry demand	2,940.7	23.5	5,907.3	22.8
Value added	7,135.4	57.1	14,949.1	57.7
Wages	4,043.8	56.6	7,404.7	49.5
Residual[1]	3,901.6	43.4	7,544.4	50.5
Imported intermediate inputs	2,424.2	19.4	5,037.7	19.5
From U.S.	2,139.9		4,106.0	
From Foreign	284.3		931.7	
Total gross input	12,503.3	100.0	25,894.1	100.0

[1]Residual income includes returns to fixed capital, owner-operator labor, and entrepreneurship.

Comparison of columns 2 and 3 in table 2 shows that the actual interindustry demand for 1972 agricultural products was $476.3 million while it was $453.6 million when 1963 technology was assumed. Thus, some degree of specialization of production processes occurred so that more farm products were used in 1972 than in 1963. This argument can also be tested by the backcasting method. Column 5 shows that using 1972 I/O technology, $300.8 million in agricultural products could be used to satisfy 1963 final demand. Comparing this with 1963 current dollar interindustry use ($290.7 million in column 2) reveals that the 1972 I/O coefficients utilize more agricultural products. Among the four agricultural products, more field and seed crops and vegetables, fruits, and nuts were demanded with 1972 technology than 1963, while the reverse was true for the other two agricultural sectors (livestock and livestock products, and other agricultural products).

Comparisons between columns 2 and 4 show that when the matrix is deflated by 1963 prices, the real interindustry demand for agricultural products increased in 1972 ($339.6 in 1972 versus $290.7 million in 1963). Increased demand for agricultural products in 1972 was caused by changes in relative prices which affected the input mix and by higher real final demand in 1972 than in 1963.

The interindustry demand for energy products is shown in table 3. A comparison of 1972 values in column 2 with those in column 3 indicates that there were substantial changes in I/O coefficients between 1963 and 1972. These changes indicate that either energy-saving technologies were applied in 1972 or changes in relative prices caused substition of energy inputs. Column 3 shows that use of 1963 I/O coefficients to satisfy 1972 final demand, would require $630.1 million of energy products compared to the actual $575.2 million (column 2) used with 1972 I/O coefficients. Thus, technology in 1972 was almost 10 percent more energy-saving than in 1963. Backcasting the 1963 interindustry demand using 1972 I/O coefficients indicates use of $254.9 million of energy resources compared with $292.1 million using 1963 technology. Table 3 also shows that all three energy sectors developed energy-saving technology by 1972.

When the I/O coefficients matrix and final demand vector are deflated by 1963 prices (column 4), $465.4 million of interindustry output was demanded in 1972 compared to $292.1 million in 1963. This is a 60 percent increase over the decade, which is substantial considering the energy-saving technology in 1972. This large increase in interindustry demand is primarily due to a higher real final demand. For example, the final demand for petroleum and petroleum products in 1972,

when deflated by 1963 prices, was $389.7 million compared with $176.1 million in 1963. This was an increase of 121.3 percent between 1963 and 1972. Final demand for the electricity sector was $149.1 million in 1963; but it increased to $205.7 million in real terms in 1972, a 40-percent increase. Likewise, the final demand for gas products increased 84 percent (from $27.8 million in 1963 to $51.1 million in 1972). Thus, the substantial increase in the interindustry demand for energy resources in 1972 was mainly due to increases in overall final demand.

Interindustry demand for the Trade and Services subsector is shown in table 4. Total interindustry demand for all 35 sectors is also given in the last row of the table. Comparing columns 2 and 3 reveals that the Trade and Finance, Insurance, and Real Estate sectors have higher interindustry demand when 1963 I/O coefficients are used than with 1972 I/O coefficients. The trade sector would use $446.5 million with 1963 technology compared to $436.2 million with 1972 technology. The Finance, Insurance, and Real Estate sector shows substantial differences between 1963 an 1972. For example, the interindustry demand for this sector's service was $184.8 million based on the 1972 input-output coefficients with 1972 final demand. However, when 1963 I/O coefficients are used, the value increased more than 100 percent to $385.6 million. When the 1963 interindustry demand is backcasted using 1972 I/O coefficients and 1963 final demand, the last column shows that the value declines to $83.2 million from $173.1 million. Thus, there was a substantial decrease in the interindustry demand for the sector's service. Because 1972 was a year of slow growth after a period of substantial decline in the State's economy, this phenomenon was probably due to slow economic activities, particularly in the housing industry.

Considering that 1972 was a slow growth year, it is difficult to explain the situation in the Business and Personal Service sector. In 1972 the interindustry demand for the sector's output was $712.3 million (column 2) but if 1963 I/O coefficients are used, the value decreases to $446.8 (column 3). Thus, substantially more interindustry demand for these services was apparent in 1972.

The last row shows that overall $2,399.4 million of total interindustry demand was required to satisfy the total final demand of $9,581.9 million in 1963. On the other hand, state production processes used $4,510.0 million of interindustry output to generate the gross state product (total final demand) of $19,998.3 million in 1972.

Comparing values in columns 2 and 3 reveals that had 1963 I/O coefficients been used, a total of $4,944.2 million in interindustry output would have been required. Thus, 1963 technology uses $434.2 million (about 10 percent) more interindustry demand than 1972 technology. In fact, the 1963 I/O coefficients utilize more interindustry output for only 11 sectors. Industries experiencing the highest gain in the interindustry demand were Other Manufacturing (sector 26) which gained 196 percent, Business and Personal Services (sector 35) which gained 59 percent, and Gas Systems and Services (sector 31) which gained 49 percent. Industries experiencing the largest loss in interindustry demand were Construction (sector 27), down 55 percent; Finance, Insurance, and Real Estate (sector 34), down 52 percent; and, Other Agricultural Products (sector 4), down 42 percent.

Column 4 shows that when the 1972 I/O coefficient matrix and final demand vector are deflated by 1963 prices, the overall interindustry demand was $3,532.3 million compared with $2,399.4 million in 1963. Thus, there was a 47-percent increase in the demand from 1963 to 1972. However, since the 1972 values in column 2 are smaller than the values in column 3, the increases in column 4 are primarily due to the higher real final demand in 1972.

Comparisons between 1972 current dollar values in column 2 and 1963 I/O coefficients with 1972 final demand in column 3 in all three tables (tables 2-4) imply that projecting

1972 interindustry demand by using 1963 I/O coefficient results in different interindustry demand from the published ones. In table 2, for example, the Field and Seed Crops sector interindustry demand was 20 percent less than the 1972 current dollar interindustry demand when 1963 I/O coefficients are used ($111.4 million compared to $88.5 million). Overall industry demand for all 35 sectors (the last row in table 4) show a 9.6 percent over-estimation by the 1963 I/O coefficient method compared with 1972 current dollar estimates ($4,944.2 versus $4,510.0 million).

Because of the "openness" of its economy, Washington State I/O coefficients may be affected by the region's external trading patterns. Different resource endowments among regions as well as different regional production capacity will require changes in the interindustry demand on imports (represented by an import coefficient matrix) as regional economic activity adjusts to the impulses of growth and decline. Thus, examining the regional interindustry demand is complicated by having to consider varying trade patterns and not having an import matrix from foreign countries in the Washington I/O tables.

Table 5 shows that the region did not rely on imported intermediate inputs any more in 1972 than it did in 1963. In both periods, about 19 percent of total aggregate inputs were imported. The first row of the table shows that 1972 interindustry demand was a slightly smaller percent of the total than 1963 (0.7 percent) while the reverse is true for value-added. This is similar to Humphrey's findings at the national level that between 1947 and 1958 there was very little price-induced substitution among intermediate inputs alone, but substantial substitution between intermediate inputs and value-added. Specifically in Washington State, larger residual income was earned in 1972 than in 1963 (from 43.4 in 1963 to 50.5 percent in 1972 of the total value-added) while returns to wage earners declined from 56.6 percent in 1963 to 49.5 percent in 1972.

Summary and Conclusion

From the preceding discussion, it is clear that between 1963 and 1972, there were significant changes in the interindustry demand. Some of them were large, while others were small. This paper examined the changes in interindustry demand under alternative methods.

For the agricultural subsector, interindustry demand in 1972 was less using 1963 technology than when using 1972 technology. This suggests that changes occurred in the technology of production processes in agriculture. This argument is also confirmed by backcasting 1963 interindustry demand using 1972 technology. In contrast to the Agricultural subsector, the Energy subsector used more interindustry demand when 1963 technology rather than 1972 technology is used to satisfy the same final demand of 1972. This argument is again supported by the backcasting method. For the Trade and Finance, Insurance, and Real Estate sectors, there was more interindustry demand when 1963 technology was used than when 1972 technology was used. Surprisingly, however, substantially more interindustry demand for service sector output was apparent in 1972. The empirical examination leads to similar conclusions where interindustry demand is calculated with different methods. In other words, when the 1972 current dollar demand is compared with the constant technology matrix and current final demand vector by base year price index, similar patterns of interindustry demand result. When 1963 interindustry demand is backcasted using the 1972 "A" matrix, results similar to the 1963 current dollar estimation are obtained.

It is apparent that there were definite changes in technology in the production processes during the decade which resulted in greater demand for interindustry output for 11 sectors, including Business and Personal Services and Agricultural Products. On the other hand, changes in relative prices caused input substitutions such that fewer energy resources were used in 1972 than in

1963 when measured by the 1963 and 1972 input-output coefficients for 1972 final demand.

The deflated measure of the interindustry demand shows that in real terms, there was more interindustry demand in 1972. This is primarily due to increases in real final demand. This is not surprising since there was definite economic growth during the decade. Increases in real final demand had a strong effect on the increased interindustry demand.

The results of this analysis have one strong implication for the use of I/O techniques for projection purposes. Using current final demand estimates with a dated I/O coefficient matrix will likely result in inaccurate predictions of interindustry demand and hence sector output. Thus, using the 1972 I/O coefficients to predict, say 1980 interindustry demand or sector output would likely lead to unreliable projections.

In this paper the major objective was to examine changes in the flow of interindustry demand over time. However, this method also can be used to analyze changes in the I/O coefficients over time by comparing "A" matrices in different time periods under the different methods.

Results presented here should be interpreted with some caution. First, no specific inquiry is made relative to the effects of changing trade patterns on the regional I/O matrix. Thus the assumption of constant imports could lead to misinterpretation of the changes in interindustry demand. Second, the use of a national Wholesale Price Index (WPI) may not be appropriate for some industries. For example, the price of electricity in the state is among the lowest in the nation. By using the WPI, the price of electricity may be higher.

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