Input-Output Models and Technological Change: Some Explorations in Methodology

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The 1963 input-output table is aggregated into a 20-sector table and additional sectors for flue-cured and burley tobacco are developed using different sources of data. Farm budget data are used to develop input vectors for flue-cured tobacco production at eight different levels of technology. Total requirements per $1 of change in final demand are calculated for each level of technology. The output multipliers for these technology levels are also calculated.

Keywords: Tobacco, technology, input-output.

The U.S. tobacco economy is faced with several potential technological innovations. An earlier ERS study outlined the complex nature of the problem and pointed the need for additional research to determine the magnitude and characteristics of the problem (*14*). The harvesting and curing of flue-cured tobacco are being mechanized at an increasing rate. A recent ERS survey of the major producing areas showed that in 1972 about 50 percent of the flue-cured tobacco was harvested with the use of tying machines, 36 percent was harvested with the use of priming aides, and about 8 percent was cured in bulk barns (*6*).

This paper was originally written to study the interaction of the various systems of technology in flue-cured tobacco production with the rest of the economy. Input-output analysis was adopted for analyzing these relationships because it takes into account the interdependence of various sectors. Several methodological issues arose in the use of the input-output table compiled by the U.S. Department of Commerce (*15*). The 85-industry table does not have enough details (*7, 9*). Although the 367-industry table is too big to be manageable, it aggregates tobacco into one industry. In the present study the main focus was on flue-cured tobacco production and this required the use of other sources of data. To study the interaction of flue-cured tobacco with other industries, alternative vectors of costs representing eight different systems of technology were developed, using data from a budget study. These eight vectors were then included in the transaction matrix, one at a time, and a solution was obtained. Although 1967 input-output data became available after the present research was completed, the paper, based on 1963 input-output tables, is being published because of its methodological significance. Moreover, the analysis of 1963 data facilitates comparison with other studies, using other approaches. The methodological issues dealt with are (1) extending an existing industry into new industries which are compatible with the original vector, (2) using farm budgets to construct input columns for different systems of technology, and (3) obtaining alternate solutions for different technologies.

Derivation of Aggregated Input-Output Table

The transaction matrix for 367 industries was aggregated into 20 industries for this study. The definitions of these industries and their relation to those of the Department of Commerce are shown in table 1. Industries 1 and 2 were derived according to procedures explained later. Industries 3, 5, 6, 10, 11, 13, and 15-18 were included as separate industries in the model because they are major providers of inputs to the tobacco production industries. The farm machinery industry was included since it occupies a central role in the analysis. Industries 7 and 8 were included as separate industries because they are major consumers of the output of the tobacco industries, and industries 4, 9, 12, and 19 because they are major suppliers of inputs to these industries. All remaining industries of the 367-industry table were aggregated together since they were not directly related to industries of interest in the analysis. The aggregated transaction flows for the 20-industry matrix are given in table 2. Each row in the table shows the distribution to each industry of the output of goods and services of a given industry. The columns show the value of each industry's use of raw materials and services. The aggregation process affected mostly industry 20; all other industries can be identified directly with the entries in the Commerce tables.[1]

[1] To be very precise adjustment should have been made for secondary production. As this was not done, there may be a slight bias in the entries for industry 20.

Table 1. Definitions of industries used in this study and by the U.S. Department of Commerce

Industry number and title used in this study		Department of Commerce industry number and title[a]	
Number	Title	Number	Title
1	Tobacco—burley	---	Not defined
2	Tobacco—flue-cured	---	Not defined
3	Agriculture—livestock	1.01-1.03	Livestock and Livestock products
4	Agriculture—crops	2.01-2.02 and 2.04-2.07	Other agricultural products[b]
5	Agricultural services	4.00	Agricultural, forestry and fishery services
6	Maintenance and repair construction	12.02	Maintenance and repair construction, all other
7	Cigarettes, cigars, etc.	15.01	Cigarettes, cigars, etc.
8	Tobacco stemming and redrying	15.02	Tobacco stemming and redrying
9	Commercial printing	26.05	Commercial printing
10	Fertilizers	27.02	Fertilizers
11	Agricultural chemicals	27.03	Agricultural chemicals, n.e.c.
12	Plastic materials and resins	28.01	Plastic materials and resins
13	Petroleum refining	31.01	Petroleum refining and related products
14	Farm machinery	44.00	Farm machinery
15	Wholesale trade	69.01	Wholesale trade
16	Retail trade	69.02	Retail trade
17	Insurance carriers	70.04	Insurance carriers
18	Real estate	71.02	Real estate
19	Advertising	73.02	Advertising
20	All others	(c)	(c)

[a]Source - (*15*).

[b]Less tobacco.

[c]Includes all industries defined by the U.S. Department of Commerce for the 1963 Input-Output Structure of the U.S. Economy which are not included in the previous 19 industries.

Derivation of Burley and Flue-Cured Tobacco Production Industries

The input-output table compiled by the Department of Commerce has only one tobacco production sector, which represents the production of all types of tobacco. Since in this study interest is focused on flue-cured tobacco production, it was necessary to define sectors which represent the production of flue-cured and burley tobacco as separate industries. The procedure followed was to divide the original aggregate tobacco sector into three subsectors: (a) burley tobacco production, (b) flue-cured tobacco production, and (c) "other" tobacco production representing all other types of tobacco. The "other" tobacco production sector was aggregated into agricultural crops (industry 4).

To disaggregate tobacco into flue-cured, burley, and other tobacco, the elements in the column of the original transaction matrix were multiplied by the ratio of the value of each type of tobacco to the total value of tobacco produced in 1963, and by adjustment factors to reflect the differences in input expenditures by types of tobacco. A further adjustment was made to make the new columns consistent with the old one.

The equation for deriving the adjusted elements may be written as

$$(1)\quad f_{it} = f_i p_t c_{it} + b_{it}$$

where:

f_{it} = modified flow element for input i of tobacco sector t.

t = 1, burley; t = 2, flue cured; and t = 3, other tobacco.

f_i = flow element for input i of the original tobacco sector. This value was taken directly from the 1963 input-output transaction matrix.

p_t = ratio of the value of type t tobacco produced to total value of tobacco (source, *13*).

c_{it} = adjustment coefficient for input i of tobacco sector t as defined below.

b_{it} = an adjustment factor, positive or negative, determined so as to satisfy the two conditions defined in equations (2) and (3).

Table 2. Interindustry transactions, 1963

(In millions of dollars at producers' prices)

Industry number and title	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. Tobacco—burley	1.1	---	---	---	4.2	---	3.4	324.9	---	---
2. Tobacco—flue-cured	---	2.7	---	---	9.2	---	7.4	712.2	---	---
3. Agriculture—livestock	30.9	79.0	4,749.8	1,709.6	191.8	---	---	---	---	---
4. Agriculture—crops	---	---	7,897.4	764.8	536.6	.3	1.0	75.7	---	---
5. Agricultural services	5.4	13.9	444.8	1,033.9	---	---	---	---	---	---
6. Maintenance and repair construction	6.3	18.4	200.1	341.9	---	4.7	4.5	2.8	7.1	6.9
7. Cigarettes, cigars, etc.	---	---	---	---	---	---	1.0	5.6	---	---
8. Tobacco, stemming & redrying	---	---	---	---	---	---	1,205.7	556.8	---	---
9. Commercial printing	---	---	---	---	---	---	57.2	---	1.7	---
10. Fertilizers	11.3	26.2	---	746.7	.6	.3	---	---	1.6	136.1
11. Agricultural chemicals	3.7	14.7	20.6	263.6	.3	.6	---	---	---	3.3
12. Plastic material & resins	---	---	---	---	---	---	88.9	.2	33.0	.3
13. Petroleum refining	5.5	41.6	169.8	906.8	3.4	116.2	1.3	.7	19.3	4.8
14. Farm machinery	.4	2.0	5.4	226.5	---	.6	---	---	---	---
15. Wholesale trade	5.5	15.2	612.4	504.2	36.2	400.0	24.8	26.5	101.2	54.4
16. Retail trade	3.4	9.5	257.5	304.8	6.0	471.6	13.2	.9	29.8	5.8
17. Insurance carriers	4.7	13.9	93.1	194.8	---	79.8	3.2	.6	8.9	2.7
18. Real estate	30.0	82.9	288.8	1,906.8	41.2	89.5	6.1	7.0	86.6	4.7
19. Advertising	---	---	1.3	13.4	---	7.3	292.8	2.2	32.9	14.6
20. All others	22.4	58.1	5,077.3	2,789.5	360.6	4,034.9	294.5	37.4	2,493.3	796.4

See note at end of table.

Continued

Table 2. Interindustry transactions, 1963—Continued

(In millions of dollars at producers' prices)

Industry number and title	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1. Tobacco-burley	---	---	---	---	---	---	---	12.8	---	14.6
2. Tobacco—flue-cured	---	---	---	---	---	---	---	28.1	---	32.0
3. Agriculture—livestock	---	---	---	---	---	---	---	162.3	---	17,570.9
4. Agriculture—crops	.1	---	---	---	---	---	---	682.2	---	9,826.9
5. Agricultural services	---	---	---	---	169.5	---	---	17.1	---	43.5
6. Maintenance and repair construction	1.0	17.5	345.2	3.3	84.0	312.8	21.3	819.4	3.4	8,735.7
7. Cigarettes, cigars, etc.	---	---	---	---	.7	---	---	4.5	---	168.1
8. Tobacco, stemming & redrying	---	---	.1	---	3.4	---	---	2.2	---	7.7
9. Commercial printing	---	---	---	---	93.1	54.5	47.5	10.9	2,081.5	2,677.9
10. Fertilizers	21.8	---	.1	.1	30.7	.1	---	29.6	---	295.6
11. Agricultural chemicals	.4	3.8	.1	.2	15.0	.1	---	13.9	---	136.0
12. Plastic material & resins	11.5	97.5	.3	---	6.9	35.0	---	15.6	---	2,661.8
13. Petroleum refining	19.5	45.5	1,413.2	6.9	762.5	583.1	32.8	488.2	7.0	6,211.3
14. Farm machinery	.1	---	---	146.5	17.6	---	---	6.4	---	407.6
15. Wholesale trade	18.9	80.3	288.1	104.5	992.7	511.8	81.9	417.6	15.6	18,507.0
16. Retail trade	1.4	9.2	33.7	13.2	457.8	196.6	92.6	678.1	23.1	6,766.7
17. Insurance carriers	.8	3.3	53.4	6.5	473.4	386.2	8.5	856.6	2.1	3,327.1
18. Real estate	1.8	22.9	413.3	12.5	1,802.9	4,613.2	608.1	2,555.4	104.8	15,443.1
19. Advertising	8.6	47.2	266.1	49.3	1,543.3	2,124.7	149.7	494.5	20.9	7,475.0
20. All others	342.4	1,856.9	12,479.9	1,592.6	9,246.5	7,647.2	6,807.4	8,106.7	9,255.5	294,977.7

For the distribution of the output of an industry, read the row for that industry. For the composition of inputs to the industry, read the column for that industry.

(2) $f_i = \sum_t f_{it}$

(3) $F_t = \sum_t f_{it}$ (See below for definition of F_t.)

This adjustment assures that the elements in the new columns sum to the elements in the old input column. The adjustment coefficients c_{ij} are derived from tobacco production budget expenditures by reweighting the expenditure items.

$$c_{it} = F_t g_t f_i p_t e_{it} / \sum_i f_i p_t e_{it}$$

where:

e_{it} = tobacco budget expenditure for i type inputs for tobacco sector t. These values were obtained from tobacco production budgets (*10*) which represent production practices on an average size farm in 1963.

g_t = an adjustment factor designed to modify the budget expenditure items to correspond to the total value of tobacco produced in 1963 defined as the ratio of average yield in the budget (*10*) to the actual yield in 1963 (*13*).

F_t = column total of tobacco sector t; defined as:

$$= \sum_i f_i p_t$$

Note that F_t is obtained simply by multiplying the total of the old tobacco column by the proportion of the value of all tobacco produced by type-p's.

Due to lack of information, all c_{it} adjustment coefficients were assumed to be 1 and all b_{it} adjustment factors 0 for the "other" tobacco sector. This sector was a catchall sector designed to aggregate the leftovers, as adequate information was not available to characterize the sector.

The new row elements were derived by multiplying the values in the old row by the ratio of the value of each type of tobacco produced to the total value of tobacco according to equation (4).

(4) $k_{tj} = k_j p_t$

where:

k_{tj} = modified flow element for new tobacco row t of sector j.

k_j = original tobacco row flow element of sector j.

p_t = proportions of the value of all type t tobacco produced in 1963.

In summary, the above procedure disaggregates the original tobacco sector so that the distribution of output of the new tobacco sectors is proportional to the value of that type of tobacco produced in 1963, but the columns are adjusted for differences in the production functions underlying the production of different types of tobacco. Also, for any row the procedure leaves the sum of the row elements of the three new tobacco sectors equal to the row element of the original tobacco sector. Moreover, for each of the new industries, the column sum of the flow elements is proportional to the value of that type of tobacco produced in 1963. The burley and flue-cured production are presented as industries 1 and 2, respectively, in table 2. The other tobacco sectors have been added to industry 4, agriculture—crops.

Other methods of setting up the columns and rows in an input-output matrix have been recommended (*5,11*). The technique adopted here makes the new columns and rows compatible with the original Commerce table.

Input Vectors for Flue-Cured Tobacco Production for Different Technologies

Underlying an industry's transaction flows in an input-output table is a particular system of technologies. Likewise, a particular system of technology implies a specific combination of inputs. Thus, a relationship exists between an industry's transaction flows and the combination of inputs which are used to produce the industry's output. The procedure for adjusting the transaction flows of the flue-cured tobacco production industry is to specify the combination of inputs associated with different technological systems.

Davis and Chappel (*4*) have specified in detail the combinations of inputs associated with eight different technological systems. These are:[2]

A. Conventional curing system
   (1) Hand harvesting
   (2) Automatic tying machines
   (3) Priming aide and tying machines
   (4) Priming aide
   (5) Self-propelled priming aide

B. Bulk curing system
   (6) Hand harvesting
   (7) Priming aide
   (8) Mechanical harvester

Using data from the Davis-Chappel study, adjustment factors for selected classes of inputs were estimated. These were the ratios of input expenditures for different systems of tobacco production. The flows of the flue-cured tobacco production industry in table 2 were

[2] For a detailed discussion of this classification, see (*4*). The methodology developed in this study can be used with other classifications.

then multiplied by the adjustment coefficients to obtain the transaction flows associated with the different technological systems.

The derivation of the adjustment factors is based upon the assumption that the Davis and Chappel hand system, using hand harvesting, hand curing, and a conventional curing barn, corresponds to the transaction flows of the flue-cured tobacco production (in 1963) as given in table 2. Thus, all of the adjustment factors for this system are 1. For the other technological systems the adjustment factors for a particular class of inputs (flows) will be less than 1 if the system uses less of these inputs and greater than 1 if it uses more of these inputs. That is, the adjustment factors for each technological system are derived by comparing each system with the basic hand system, hand harvesting, hand barning, and a conventional barn.

The adjustment factors for different types of transaction flows were calculated from production expenditures. For the maintenance and repair construction industry, the annual ownership costs of the tobacco curing barn were used to derive the adjustment factors. In this case only two types of barns are considered and consequently the adjustment factors take on only two values. For the petroleum refining industry, expenditures on fuels and lubricants were used to determine the adjustment factors. Since there is very little difference between technological systems in the expenditures on fuels and lubricants, all of the adjustment factors were very near 1. The adjustment factors for the farm machinery industry were relatively large and varied widely. These are based on the annual ownership costs of all equipment used, which represent repair and maintenance expenditures. Since mechanized systems use much more equipment than the hand system, and some substantially more, the adjustment factors were relatively large and varied considerably. For the insurance carriers the adjustment factors were derived from expenditures on crop, equipment, and barn insurance. Since expenditures on crop insurance dominate, these factors vary little by type of technological system.

The adjustment factors for wholesale and retail trade reflect the increased trade associated with the purchase of nonfarm inputs associated with mechanized systems. The adjustment factor is equal to the ratio of the sum of adjusted elements for other industries (that is, excluding wholesale and retail trade) to a similar sum for the hand system.

It was judged that seven purchased inputs of the flue-cured tobacco production industry are not affected by the type of technological system used in the industry. Hence, the adjustment factors for these industries are 1.

The adjustment factors were multiplied by the corresponding flows of the basic hand system to obtain adjusted transaction flows for each of the technological systems. In further analysis, it was assumed that value added is a residual which absorbs the gains and losses from the adoption of a given technological system. The adjusted transactions columns are given in table 3.

Table 3. Adjusted flue-cured tobacco column by level of technology

(Million dollars)

Industry	(1) Hand	(2) Tying	(3) Aide tying	(4) Aide	(5) S.P. aide	(6) Hand bulk	(7) Aide bulk	(8) Mecha-nized
1. Tobacco, burley								
2. Tobacco, flue-cured	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
3. Agriculture, livestock	79.0	79.0	79.0	79.0	79.0	79.0	79.0	79.0
4. Agriculture, crops								
5. Agricultural services	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
6. Maintenance, repair, and construction	18.4	18.4	18.4	18.4	18.4	53.4	53.4	53.4
7. Cigarettes, cigars, etc.								
8. Tobacco, stemming and redrying								
9. Commercial printing								
10. Fertilizer	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2
11. Agricultural chemicals	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
12. Plastic material and resins								
13. Petroleum refining	41.6	41.6	42.0	42.0	40.4	41.2	42.0	42.0
14. Farm machinery	2.0	10.8	13.1	5.0	13.6	2.0	10.6	60.3
15. Wholesale trade	15.2	15.7	15.8	15.4	15.8	16.7	17.2	19.8
16. Retail trade	9.5	9.8	9.9	9.6	9.9	10.5	10.7	12.4
17. Insurance	13.9	15.2	16.5	14.6	16.8	17.0	19.3	30.0
18. Real estate	82.9	82.9	82.9	82.9	82.9	82.9	82.9	82.9
19. Advertising								
20. All others	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1

Direct and Total Requirements

The matrices of direct and total (direct plus indirect) requirements were calculated using eight different input columns for flue-cured tobacco.[3] That is, each of the eight technology vectors in table 3 was used to replace column 2 in table 2 and then eight different solutions were obtained. The direct requirements show the inputs required by an industry from each of the other industries to produce $1 of its output. The total requirements matrix takes into account both the direct and indirect requirements of an industry. A matrix of total requirements shows the total requirements by each industry from each of the other industries per $1 increase in final demand. The massive amount of information in the total requirements matrices is summarized by summing the total requirements of each industry. These sums, called output multipliers, measure the sum of direct and indirect requirements from all industries needed to deliver an additional $1 of output of a particular industry to final demand (*12*). The output multipliers for eight systems of technology are given in table 4.

The output multipliers increase as we move from technology 1 (hand harvesting with conventional curing) to technology 8 (mechanized harvesting with bulk curing). For example, for flue-cured tobacco production, the multiplier is 1.86 for level 1 and 2.12 for level 8. For stemming and redrying, the multiplier is 2.77 for level 1 and 2.89 for level 8. The biggest increase is in flue-cured tobacco production (industry 2). The increase in stemming and redrying (industry 8) reflects the impact of mechanization on increased derived demand for processing. Industry 14, farm machinery, shows very little change. This needs further study at a regional level, concentrating attention on areas where tobacco is produced and processed.

[3] The standard procedure for obtaining the total requirements is discussed in (*3*) and (*8*). For a similar application see (*1*). The tables for direct and total requirements are not reproduced here.

Summary and Conclusions

The research reported in this paper was undertaken to determine the interaction of the adoption of the different systems of technology in tobacco production with the rest of the economy. It was discovered that the differences in output multipliers for different systems of technology were very small. A closer look at the data showed that tobacco is a very small sector of the U.S. economy. In 1973, 1.8 percent of cash receipts from farming in the United States were from tobacco. When working with national magnitudes, the tobacco activities, being very small fractions of the total economy, get lost in large numbers. The production, processing, and manufacturing of flue-cured tobacco are regional activities concentrated in North Carolina, South Carolina, Virginia, and Georgia. Therefore, it is recommended that further work should be done on a regional basis.

However, several other lessons about input-output analysis were learned which are worth noting. In using the 1963 input-output table for analysis of the tobacco sector, some peculiar facts were discovered. The table shows that the tobacco industry purchased inputs valued

Table 4. Output multipliers for 8 levels of technology

Industry	(1) Hand	(2) Tying	(3) Aide tying	(4) Aide	(5) S.P. aide	(6) Hand bulk	(7) Aide bulk	(8) Mecha-nized
1. Tobacco—burley	1.64067	1.64068	1.64068	1.64068	1.64068	1.64069	1.64069	1.64072
2. Tobacco—flue-cured	1.85903	1.88505	1.89510	1.86962	1.89269	1.93486	1.96466	2.11887
3. Agriculture—livestock	2.56669	2.56670	2.56670	2.56669	2.56670	2.56671	2.56672	2.56676
4. Agriculture—crops	1.95766	1.95767	1.95767	1.95767	1.95767	1.95769	1.95770	1.95775
5. Agricultural services	2.36529	2.36543	2.36548	2.36534	2.36547	2.36569	2.36586	2.36668
6. Maintenance and rep. construction	1.74927	1.74927	1.74927	1.74927	1.74927	1.74928	1.74928	1.74929
7. Cigarettes, cigar, etc.	1.98116	1.98396	1.98504	1.98230	1.98478	1.98933	1.99254	2.00914
8. Tobacco stemming & redrying	2.76777	2.77984	2.78450	2.77268	2.78338	2.80293	2.81676	2.88827
9. Commercial printing	2.03412	2.03412	2.03412	2.03412	2.03412	2.03412	2.03412	2.03414
10. Fertilizers	2.49670	2.49671	2.49671	2.49670	2.49671	2.49671	2.49671	2.49673
11. Agricultural chemicals	2.49075	2.49075	2.49076	2.49075	2.49075	2.49076	2.49076	2.49078
12. Plastic material & resins	2.34104	2.34104	2.34105	2.34104	2.34105	2.34105	2.34105	2.34107
13. Petroleum refining	2.52091	2.52091	2.52091	2.52091	2.52091	2.52092	2.52092	2.52094
14. Farm machinery	2.30142	2.30142	2.30142	2.30142	2.30142	2.30142	2.30143	2.30144
15. Wholesale trade	1.65036	1.65037	1.65037	1.65036	1.65037	1.65037	1.65038	1.65039
16. Retail trade	1.45258	1.45258	1.45258	1.45258	1.45258	1.45259	1.45259	1.45260
17. Insurance carriers	2.11911	2.11911	2.11911	2.11911	2.11911	2.11912	2.11912	2.11914
18. Real estate	1.65704	1.65706	1.65706	1.65705	1.65706	1.65709	1.65712	1.65723
19. Advertising	2.78320	2.78320	2.78320	2.78320	2.78320	2.78321	2.78321	2.78323
20. All other	1.95463	1.95464	1.95464	1.95464	1.95465	1.95465	1.95465	1.95467

at $117.9 million from the livestock industry. This value represents draft animals and serves as an imputed value for manure used. A discussion with experts led to the conclusion that this is an overestimate and needs adjustment. In input-output analysis, commodities are shown as if moving directly from producer to user, bypassing trade. The output of trade and transportation measures margins, i.e., profits plus operating expenses (*2*). Tobacco is considered to pass directly to stemming and redrying and from the latter to cigarette and cigar manufacturing. However, tobacco has to be aged for about 3 years before being used for manufacturing. A special procedure to allow for this service for storage should be developed.

The use of budget and cost data to extend the input-output table points to a source of data which need to be investigated in greater detail. The Commerce Department table aggregates the agricultural sector into fairly broad categories. For applied policy analysis, an input-output table showing several crops and livestock activities as separate industries is needed. The budget and cost data can be used in setting up such a table.[4] Other suggested uses for budget data are updating the input-output tables, and constructing regional input-output tables.

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[4] Other attempts at extending the input-output table (*5,11*) may also be noted.