Output Change in U.S. Agriculture: An Input-Output Analysis

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Abstract

This paper analyzes output changes in the U.S. agricultural economy from 1972 to 1977 using a 477-sector input-output framework. The empirical model is based on benchmark input-output data from the U.S. Bureau of Economic Analysis for 1972 and 1977. Output changes were decomposed into components attributable to technical change, domestic final demand change, export demand change and import substitution. A major advantage of the decomposition is its ability to identify the output change in a given sector due to general equilibrium effects in all sectors.

Key Words: import substitution, input-output, output change, technical change

Introduction

During the decade of the seventies, various social and economic forces interacted in the United States to significantly reshape the structure of the U.S. economy. The 1972-77 period offers some interesting parallels to the current economic condition. Changing international conditions and new opportunities for international trade were characteristic of the period. The Vietnam War was winding down with a corresponding reduction in military personnel and expenditures for military capital. International trade and international commodity markets emerged into prominence. The shock of increased oil prices and long gasoline lines was coupled with increased opportunities for export of U.S. agricultural commodities. Some manufacturing sectors, such as automobiles, steel and textiles, felt increased competition from international producers while other sectors, such as aircraft, experienced increased sales into international markets.

Agricultural commodities were among the products most affected by these changes. Certain agricultural sectors, such as Oil Bearing Crops and Forestry and Fishery Products, experienced dramatic growth while other sectors, such as Meat Animals (cattle and pork), experienced substantial decline. In this paper the growth and decline of these and other agricultural sectors of the United States economy are analyzed using an input-output decomposition technique. The primary objective of this analysis is to describe the typical patterns of growth and decline in U.S. agriculture in relation to other major sectors of the economy. Special attention is given to the importance of international trade.

The Office of Technology Assessment (OTA) attributes past and present changes in the U.S. economy to the following four major forces (U.S. Congress, 1988):

1. Emergence of new technologies.
2. Growth of international competition and markets.
3. Changes in resource limitations.
4. Changes in consumer values and tastes.

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They predict these will continue to shape the economy beyond the year 2000. Understanding how these forces shaped production in the 1970s lends insight into several aspects of the current economic situation in the United States.

Because of the intangible nature of many of these underlying forces of change and the extreme complexity of the interrelationships involved, it is not possible to identify and measure the individual effects of each force on U.S. economic activity. Instead, in this paper, we attempt to capture their aggregate effects in four distinct, but additive elements of output change according to the identity:

$$\Delta Q = \Delta W + \Delta F + \Delta E + \Delta M$$

where

ΔQ ≡ Real changes in sector (commodity) total output.

ΔW ≡ Changes in sector output attributable directly and indirectly to changes in interindustry demand.

ΔF ≡ Changes in sector output attributable directly and indirectly to changes in domestic final demand.

ΔE ≡ Changes in sector output attributable directly and indirectly to changes in export demand.

ΔM ≡ Changes in sector output attributable directly and indirectly to changes in import usage.

Total output change for any sector i is therefore the sum of its four components of output growth ΔW, ΔF, ΔE and ΔM. Changes in the magnitude and relative importance of these four components of growth between sectors constitutes output change as defined in this study. The intuitive basis for this approach is the observation that consumption drives production in an economy. Goods and services are produced because there exists a demand for them. Intermediate demand consists of the market generated by other domestic producers. Final demand is measured by domestic final consumption and by foreign sales. In an open economy, domestic producers compete with foreign producers for domestic markets. This is represented by the import substitution component of the equation. The input-output accounts provide an economy-wide environment in which to analyze these demand changes.[1]

The research was performed using the benchmark input-output accounts of the U.S. economy compiled by the Bureau of Economic Analysis for the years 1972 and 1977.[2] The period represents great consistency in the benchmark accounting and sectoring scheme. Commodity data were minimally aggregated only to achieve consistent SIC categories between the two time periods. Data from 1977 were deflated to 1972 to provide a consistent accounting of commodity flows over time.[3] The final tables were composed of 477 commodities and 488 industries, which marks a new level of disaggregation in the analysis of U.S. structural change. The advantage of this level of sector detail is that it facilitates the study of high growth and low growth sectors across the economy.

Methodology of Structural Decomposition Using Input-Output Accounts

The use of input-output techniques to analyze output change dates to the very origin of the modern I-O system. Leontief was the first to use the technique to compare patterns of economic growth over time (Leontief, 1951, 1953). His work was followed in turn by Chenery (1960; Chenery and Watanabe, 1988; Chenery et al., 1986), Carter (1970), Almon et al. (1974), Syrquin (1976; Syrquin et al., 1984), Kubo (1980), Feldman et al. (1987), and Holland and Cooke (1989).

The decomposition procedure utilized in this study was developed by Syrquin (1976). The technique was refined by Kubo (1980) and used extensively in a cross-country comparison of industrialization and economic growth (Chenery et al., 1986, Chapter 5). Other applications have involved a study of economic growth and structural change in Austria (Skolka, 1989) and an analysis of structural change in the U.S. economy from 1963 to 1978 (Feldman et al., 1987). The starting point for the structural decomposition procedure is the materials balance equation in commodity terms.[4]

$$(1) \quad Q_{iT} = W_{iT}^{d} + F_{iT}^{d} + E_{iT}$$

$$(2) \quad M_{iT} = W_{iT}^{M} + F_{iT}^{M}$$

where

Q_{iT} ≡ domestic production in sector i in year T,

W_{iT}^{d} ≡ domestic intermediate demand for commodity i in year T,

F_{iT}^{d} ≡ domestic final demand for commodity i in year T,

E_{iT} ≡ export demand for commodity i in year T,

M_{iT} ≡ imports of commodity i in year T,

W_{iT}^{M} ≡ imports for intermediate demand of commodity i in year T, and

F_{iT}^{M} ≡ imports for final demand of commodity i in year T.

The domestic supply ratio for each sector i, (u_{iT} in equation 3), and the domestically produced intermediate input requirements from sector i per unit of output of sector j (a_{ijT}^{d} in equation 4) are given respectively as

$$(3) \quad \hat{u}_{iT} = \frac{F_{iT}^{d} + W_{iT}^{d}}{F_{iT} + W_{iT}} = 1 - \left[\frac{M_{iT}}{F_{iT} + W_{iT}}\right]$$

and

$$(4) \quad a_{ijT}^{d} = \hat{u}_{iT} a_{ijT}$$

Using these identities we relate each sector's intermediate demand for products from sector i to production levels in sector j.

$$(5) \quad Q_{iT} = \hat{u}_{iT}\left(\sum_{j=1}^{n} a_{ijT} Q_{jT}\right) + \hat{u}_{iT} F_{iT} + E_{iT}$$

Solving for Q_{iT} and writing the results in matrix notation, we obtain the sought-after Leontief equation,

$$(6) \quad Q_{T} = R_{T}^{d}(\hat{u}_{T} F_{T} + E_{T}),$$

where $R_{T}^{d} = (I - \hat{u}_{T} A_{T})^{-1}$ denotes the domestic Leontief inverse; A_{T} denotes the matrix of input-output technical coefficients, a_{ijT}; $\hat{u}_{T}$ denotes the 477 x 477 diagonalized matrix of domestic supply ratios.

Equation 6 indicates that domestic sectoral production is a function of growth of domestic final demand, export demand, interindustry demand (expressed as technical coefficients) and domestic supply ratios. For 1972 and 1977, the Leontief equation 6 is written respectively as

$$(7) \quad Q_{72} = R_{72}^{d}(\hat{u}_{72} F_{72} + E_{72}),$$

$$(8) \quad Q_{77} = R_{77}^{d}(\hat{u}_{77} F_{77} + E_{77}).$$

Equation 8 can be rewritten in an equivalent expanded form as

$$(9) \quad Q_{77} = R_{72}^{d}(\hat{u}_{72} F_{77} + E_{77}) + R_{72}^{d}(\hat{u}_{77} - \hat{u}_{72}) F_{77} + (R_{77}^{d} - R_{72}^{d})(\hat{u}_{77} F_{77} + E_{77}).$$

Subtracting equation 7 from equation 9 and simplifying yields the completed decomposition equation for measuring the growth contributions of demand side components (see Appendix).

In terms of the underlying forces promoting output change, domestic final demand primarily captures the effects of changes in tastes and values, and is influenced to a lesser extent by changes in technology. Changes in export demand reflect openings in international markets and competition, as well as changes in resource availability, exchange rates and comparative advantage. Changes in import substitution captures the growth in

international competition, but is also influenced by U.S. policy regarding access to the domestic market. Changes in input-output coefficients primarily reflect the emergence of new technologies, and factor-factor substitution in response to relative price changes.

$$(10) \quad \Delta Q = R_{72}^{d}\hat{u}_{72}\Delta F + R_{72}^{d}\Delta E + R_{72}^{d}\Delta\hat{u}(F_{77} + W_{77}) + R_{72}^{d}\hat{u}_{72}\Delta A\, Q_{77}.$$

where

$R_{72}^{d}\hat{u}_{72}\Delta F$ ≡ Real growth attributable directly and indirectly to changes in domestic final demand,

$R_{72}^{d}\Delta E$ ≡ real growth attributable directly and indirectly to changes in export demand,

$R_{72}^{d}\Delta\hat{u}(F_{77} + W_{77})$ ≡ real growth attributable directly and indirectly to changes in the domestic supply ratio (import substitution),

$R_{72}^{d}\hat{u}_{72}\Delta AQ_{77}$ ≡ real growth attributable directly and indirectly to changes in technical coefficients with fixed intermediate import structure.

The first two terms on the right-hand side of equation 10 provide measures of the change in output of each commodity sector indicated directly and indirectly by the expansion of domestic final demand and export demand, respectively. The third term measures the direct and indirect effects of changes in the import structure, assuming the domestic supply ratios for final and intermediate goods are equal. The last term gives the direct and indirect effects of changes in the matrix of input-output coefficients. Increases in technical coefficients represent a widening and deepening of the interindustry linkages brought about by changes in intermediate input requirements. Changes in intermediate input requirements are in turn brought about by changes in production technology as well as by substitution of one input for another--commonly in response to changes in relative prices.[5]

It should be noted that each term of the decomposition for a given sector is a function of change throughout the economy. For example, the export term for the ith sector is a function of the ith sector's change in export sales and the change in export sales in all other sectors as well. A large export contribution for the ith sector could arise from a combination of no change in export sales from the ith sector, but large changes export sales in sectors in which the ith sector is an important input in the production process.

Patterns of Output Change in U.S. Agriculture Compared to Other Sectors of the U.S. Economy

The 1970s were exceptionally good years for many agricultural sectors. Poor international harvests, increasingly open trade policies, and favorable exchange rates created the enviable combination of high world prices and large new markets. As a result, many U.S. agricultural commodities experienced record exports. While U.S. agriculture grew at a rate only slightly slower than the rest of the United States economy, the pattern of this growth differed markedly from the broader economy. In this section, we discuss some of these differences, including differences in the importance of international trade.

The first column of table 1 shows the sector aggregations that are used to describe the U.S. economy according to the Bureau of Economic Analysis Sectoring Scheme (U.S. Department of Commerce, 1980). Seventeen individual agricultural production sectors are included in the Agricultural aggregation. Real output in Agriculture expanded by 9.43 percent. Most of the expansion was accounted for by the export (EXP) component (7.56 percent of the 9.43 percent). Domestic final demand (DFD) accounted for 3.21 percent followed by import substitution (I-S) 0.69 percent. The technical change (I-O) component was negative accounting for -2.02 percent.

Table 1. Output Growth at the BEA One Digit Aggregation of Sectors Components of Output Growth as a Percentage of Average Total Sector Output

Aggregation	BEA Sectors	Statistic	DFD	EXP	I-S	I-O	Total
Agriculture	10100-30000		3.21	7.56	0.69	-2.02	9.43
		%D[a]	24	29	12	35	
		%N[b]	12	0	59	47	
Mining	50000-100000		6.91	5.16	-28.18	11.42	-0.04
		%D	14	29	14	43	
		%N	29	0	86	57	
Construction	110101-120216		-2.51	0.46	-0.47	3.31	0.79
		%D	80	0	0	20	
		%N	42	2	26	12	
Manufacturing	130100-641200		11.96	5.33	-2.3	-0.80	14.19
		%D	58	6	4	31	
		%N	22	4	77	56	
Trans/Comm	650100-680300		12.85	3.17	-0.26	3.40	19.16
		%D	75	0	8	17	
		%N	8	0	3	50	
Trade	690100-690200		13.57	2 82	-0.4	5.60	21.6
		%D	100	0	0	0	
		%N	0	0	100	0	
Finance	7700100-710200		19.34	1.37	-0 81	-1.74	18 16
		%D	71	0	0	29	
		%N	0	0	71	43	
Services	720100-770900		17.41	1 64	-0.48	0 38	18 95
		%D	84	0	0	16	
		%N	5	5	63	32	
Total	10100-770900		12.45	3.46	-1.06	-0.97	15.37
		%D	59	7	3	30	
		%N	22	4	71	50	

[a]Percent D (%D) refers to the relative dominance of a given component of output growth. For example, for agriculture the (I-O) component accounted for the largest output change for 35 percent of the agricultural sectors.

[b]Percent N (%N) percentage of sectors with negative entries for a given growth component.

For individual agricultural sectors, the technical change component was generally the most important as measured by the percent of dominant sectors (table 1).[6] Technical changes were, however, nearly equally divided between growth and decline so that, in aggregate, the technical change component made a relatively small negative contribution to growth.[7] In contrast, the agricultural export component was consistently positive for the agricultural sectors so that its aggregate effect was larger than the other components of growth.

No agricultural sector was characterized by a negative export component. While 59 percent of the agricultural sectors recorded a negative import-substitution component, the overall contribution of this component for agriculture was also positive. A negative number for this component occurs when the domestic supply ratios become smaller which means the proportion of domestic commodity supply to total commodity supply decreased. It may be thought of as the reverse of import substitution. In contrast to agriculture, the manufacturing sector experienced a negative import substitution component. This indicates that by the mid-1970s, U.S. manufacturing firms were beginning to lose their domestic market share to increased international competition. The result of import substitution was a negative 2.3 percent change in manufacturing output from 1972-77 (table 1).

For Agriculture most of the growth was due to the export demand component, domestic final demand (DFD) was second in aggregate importance, while growth attributable import substitution (I-S) was negligible. In contrast, the broader U.S. economy was characterized by the dominance of domestic final demand (dominant for 60 percent of the sectors and triple the aggregate output change of any other component of growth). Exports (EXP)

were second in aggregate importance followed by import substitution and technical coefficient changes.[8]

These patterns indicate that in comparison to a representative sector of the broader economy, the growth (or decline) of agricultural products was linked much more closely to their use as inputs to downstream industries. This was especially true for the Forest and Fishery Products and Meat Animals sectors. Seventy-two percent of the Forestry and Fishery Products sector's growth was accounted for as sales to other manufacturers. In the same way, 74 percent of the Meat Animal sector's decline in output shows up as changes in the technical coefficients for downstream industries.

This distinct pattern of growth in the agricultural aggregation becomes even more clear when compared to that of the Service and Trade sectors (figure 1). In these two groups of tertiary sectors, DFD was dominant 80 percent and 100 percent of the time respectively (contrast with 24 percent for Agriculture). In general, as we move along the continuum of sectors from primary to secondary to tertiary, the role of changes in domestic final demand becomes increasingly important.[9] Conversely, in the primary sectors, technical change, export and import substitution components of growth are relatively more important.

The patterns of growth summarized in figure 1 reveal somewhat of a paradox for the U.S. economy. With the relative growth of tertiary sectors, these sectors are accounting for an increasing share of jobs and income in the economy. Figure 1 shows that these sectors are mainly dependent on the expansion of domestic demand for output growth. Thus, U.S. economic growth became more dependent on a prosperous domestic economy at the very time of increased international openness and opportunities for sales internationally.

By adding the export and import substitution components of growth, we obtain a full picture of the output gains (or losses) from international trade. More than any other common grouping of sectors, agriculture benefitted from the opening up of world markets in the 1970s. The export component increased real total agricultural output by 7.5 percent. In addition, domestic agricultural producers were able to displace imports to gain a slightly larger portion of the U.S. market. In total, the international trade component accounted for an 8.3 percent increase in real agricultural output from 1972 to 1977. This was more than two and one-half times the growth effect received by any of the other single digit BEA group of sectors (figure 2).

Most other groups of sectors in the economy experienced smaller but positive gains from international trade. The manufacturing aggregation's total output grew by 3 percent from trade despite losses from import substitution, while the total outputs of the services and finance aggregations increased by 1.1 percent and 0.5 percent, respectively.

Agriculture's substantial net gains from international trade are in stark contrast to the enormous losses experienced by mining. Mining sectors (dominated by crude petroleum) suffered a 23 percent decline in total output solely attributable to the substitution of imported production for domestic production.[10]

Patterns of Output Change in the Livestock and Nonlivestock Agricultural Sectors

In spite of agriculture's substantial growth from international trade, agriculture, in aggregate, declined in importance relative to the rest of the economy. This result was anticipated. However, even with the decline in the relative importance of agriculture, 10 of the 17 agricultural sectors actually experienced above national average rates of growth. Four of these sectors were among the 40 most rapidly growing sectors of the economy (Forest and Fishery Products, Oil Bearing Crops, Miscellaneous Livestock and Tree Nuts).

In total, nonlivestock agricultural products experienced more rapid growth than their livestock counterparts. However, the aggregate of the livestock sectors was heavily weighted by the Meat Animals sector. In addition to differences in growth rates, livestock and nonlivestock sectors grew in very different ways (tables 2 and 3). Among the livestock sectors, technical change was dominant for 75 percent of the sectors while final demand was dominant for the other 25 percent. In contrast, for the nonlivestock sectors, technical change was dominant for only 23 percent of the sectors.

Figure 1. BEA Single Digit Sector Aggregations: Patterns of Output Change

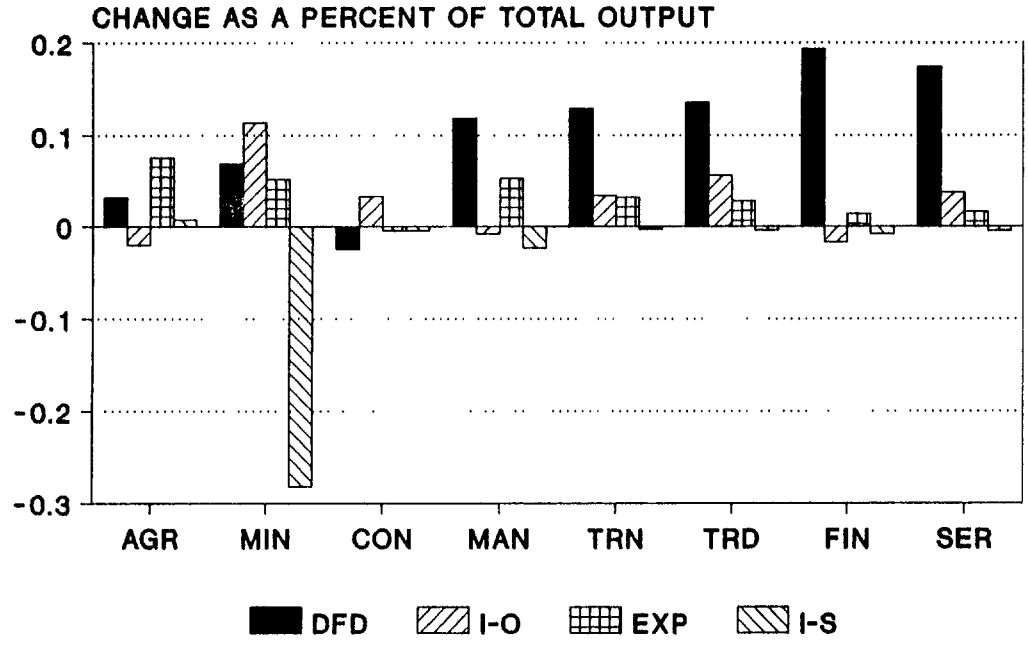

Figure 2. BEA Single Digit Sector Aggregations: Benefits and Losses from International Trade

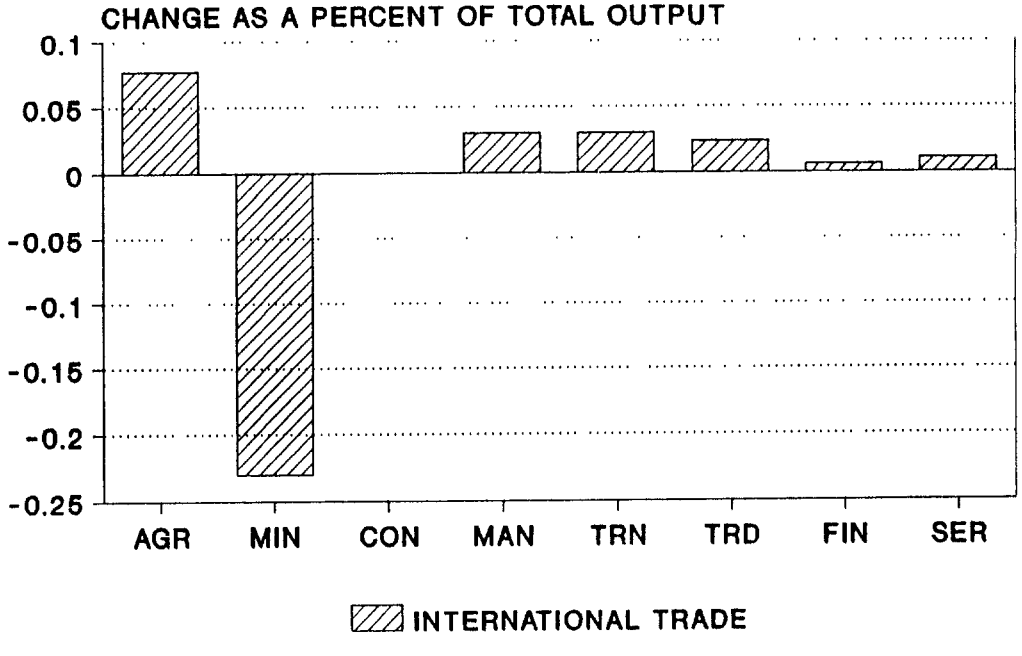

Table 2. The U.S. Livestock Products Sectors: Components of Output Growth as a Percentage of Average Total Sector Output

Description	BEA Sector	TCO 1972	TCO 1977	DFD	EXP	I-S	I-O	Total
Dairy	10100	5631	7415	12.85	0.59	0.37	13.31	27.35
Poultry and Eggs	10200	4236	5540	18.59	3.08	-0.56	5 43	26 67
Meat Animals	10301	30234	22330	-11.28	2.77	0.50	-22.15	-30.07
Misc Livestock	10302	599	981	10.00	6.88	-3.777	34.90	48.31
Mean				-2.96	2 52	0.25	-11.46	-11.65
Percent of Dominant Sectors				25	0	0	75	
Percent of Sectors with Negative Coefficients				25	0	50	25	

NOTE: TCO stands for Total Commodity Output

Table 3. The U.S Nonlivestock Agricultural Products Sectors: Components of Output Growth as a Percentage of Average Total Sector Output

Description	BEA Sector	TCO 1972	TCO 1977	DFD	EXP	I-S	I-O	Total
Cotton	20100	2054	2718	6.39	22.71	-0.30	-0.94	27.83
Food Grains	20201	3523	3764	5.12	12.67	-0.17	-11.27	6.62
Feed Grains	20202	13876	16874	6.12	11.84	0.21	1.17	19.50
Grass Seeds	20203	136	155	6.60	7.83	0.14	-1.72	13.12
Tobacco	20300	1464	1558	-4.86	5.85	-6.41	11.96	6.24
Fruits	20401	2214	2501	11.25	3.74	-1.20	-1.72	12.18
Tree Nuts	20402	248	380	16.36	16.11	28.02	-18.53	42.09
Vegetables	20501	3496	3987	8.71	2.66	-0.39	2.13	13.13
Sugar Crops	20502	746	714	6.70	2 07	-7.02	-6.26	-4.45
Misc Crops	20503	206	297	12.46	0.72	5.89	16.64	36.06
Oil Crops	20600	4756	8322	21.49	24.34	-0 39	8 90	54 53
Nursery Products	20702	1411	1696	23.96	3.97	-3.43	-6.26	18.37
Forest and Fish	30000	2242	5582	0.46	7.99	15.49	61.12	85.38
Mean				8.79	12.12	1.08	6.54	28.53
Percent of Dominant Sectors				23	38	15	23	
Percent of Sectors with Negative Components				8	0	62	54	

These results indicate that changes in downstream interindustry linkages were more important to change (growth and decline) in livestock agriculture than nonlivestock, and that this change was opposite in sign in the two groups (mean for I-O table 2 and table 3). The reason for these differences can be traced to changes in consumer attitudes and the supply cycle of Meat Animals. As the supply of meat animals declined, industries dependent on them as inputs (restaurants, meat packers and prepared foods) began to substitute towards other meat and protein sources. This is reflected in the large negative interindustry growth component of Meat Animals (table 2) and in the large positive interindustry components of the Miscellaneous Livestock and Dairy products sectors. In addition, households weary of fatty meats may have also substituted towards other protein sources. This is reflected in the negative domestic final demand component in Meat Animals and the large domestic positive final demand component in the Poultry, Eggs and Dairy sectors.[11]

International trade is another area of contrast between the livestock and nonlivestock products sectors. Whereas the export component (EXP) accounted for a modest increase in the total sales of livestock products (2.5 percent real growth), it accounted for a very large portion of the growth of the nonlivestock products sectors (12.1 percent real growth). This fivefold difference indicates that for U.S. agriculture, the majority of the benefits of expanding world markets in the 1972-77 period accrued to the nonlivestock agricultural producers. Tree Nuts, Oil Bearing Crops, and Fish and Forestry Products are three sectors which experienced especially large gains from world trade. Only Tobacco and Sugar actually lost net sales as a result of trade changes during this period of time.

One sector, Sugar Crops, experienced a decline in real output between 1972 and 1977. The decline was caused by decreased interindustry demand (I-O) and the substitution of imported sugar for domestically produced sugar (I-S). The decreased interindustry demand can probably be attributed to the increased use of a close substitute, high fructose corn syrup (HFCS). High fructose corn syrup was introduced commercially in 1972 and was substituted for sugar in a wide range of processed food products. The result was to decrease the technical coefficients for sugar crops in the food processing sectors.

Agriculture and the Rise of Producer Services

Throughout the 1980s a major topic in discussions of economic restructuring was the relative growth of service producing sectors relative to goods producing sectors. It is now recognized that an important component of that service growth was accounted for by the increase of producer services. Often these services represented activities that were formerly carried out by firms themselves, but were now found to be more profitable or convenient to purchase from outside suppliers. The decision to "buy rather than make" is described as "out-sourcing" in the input-output literature. Out-sourcing explains much of the expansion of producer services over recent years. Examples of sectors that are recognized as benefiting from out-sourcing are legal services, accounting services, services to buildings, and personnel supply services.

Agricultural Services are defined in the input-output accounts as BEA Sector 4000. Even as early as the 1972-77 period, agricultural services were rapidly expanding. In real terms, average total output for Agricultural Services expanded by 80 percent from 1972 to 1977 (Martin, 1990), making it the twelfth most rapidly expanding sector in the economy. As expected, most of the output change was accounted for by the technical change component (68 percent) which reflects out-sourcing. The domestic final demand component accounted for 25 percent and the export demand component accounted for the remaining 7 percent of output change.[12]

The phenomenon of out-sourcing may explain much of the increased demand for agricultural services the 1970s. Given the seasonality of agricultural work and the increasing complexity of government regulation regarding hired labor, farms increasingly began using the services of labor contractors. Fertilizer application services as well as the commodity itself became sold by the dealer. Harvesting services in the form of custom harvesting became increasingly utilized.

It seems likely that agricultural production processes in the 1970s were being transformed by much of the same out-sourcing phenomenon that

characterized manufacturing in the 1980s as reflected in increase in the intermediate demand for agricultural services. The result, even in the early 1970s, was rapid growth of agricultural producer services as firms in this sector took advantage of increased marketing opportunities to agricultural producers.

Conclusions

The decomposition procedure used in this study permits a different look at the components of output change in the U.S. economy than has characterized previous supply-oriented work. In this approach, demand-side considerations in the form of interindustry, domestic and international markets are featured. A major advantage is that the analysis permits a complete accounting of the gains and losses associated with a given commodity's success in interindustry versus domestic final demand versus international markets. For example, output changes associated with loss of domestic markets to imports can be compared with gains from increased sales to international markets. No other methodology offers such convenient comparison.

In addition, the technique allows given sectors and broader aggregations to be studied in relationship to other sectors and the entire rest of the economy. The disaggregation of the input-output accounts used in this study (477 commodities) and the more detailed decomposition allows greater agricultural detail than has previously been obtained.

Distinctly different patterns of output change were observed between agriculture and other aggregations of the economy. Growth in agriculture was driven, to a much greater degree, by changes in international trade and interindustry linkages (downstream industry demand) than was observed in any other division of the economy. The contrast was especially stark between agriculture and the tertiary sectors. In general, progressing from primary to tertiary sectors, growth became less dependent on trade and technical change and increasingly dependent on domestic final demand. The irony is that at the very time markets were opening internationally the U.S. economy was becoming dominated by tertiary sectors that are driven largely by domestic demand.

In aggregate, agricultural sectors benefitted more from the opening world markets (EXP and I-S) of this time period than did any other BEA single digit aggregation. Yet this was not consistent across all sectors. Two agricultural sectors--Sugar and Tobacco--experienced output declines from international trade and the Livestock Products aggregation experienced only modest benefits. The Nonlivestock Products aggregation on the other hand (fiber, grains and vegetables) experienced exceptionally strong growth from international trade which alone accounted for 13 percent real growth in average total output for these sectors over the 1972-77 period.

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Appendix

The decomposition is completed by subtracting equation 7 from equation 9 to obtain

$$\text{(a)} \qquad \Delta Q = R_{72}^{d}\hat{u}_{72}\Delta F + R_{72}^{d}\Delta E + R_{72}^{d}\Delta\hat{u}F_{77} + \left(R_{77}^{d} - R_{72}^{d}\right)\left(\hat{u}_{77}F_{77} + E_{77}\right).$$

The fourth term in this expression can be rewritten as follows:

$$\text{(b)} \quad \left(R_{77}^{d} - R_{72}^{d}\right)\left(\hat{u}_{77}F_{77} + E_{77}\right) = R_{72}^{d}\left[\left(R_{72}^{d}\right)^{-1} - \left(R_{77}^{d}\right)^{-1}\right]R_{77}^{d}\left(\hat{u}_{77}F_{77} + E_{77}\right)$$
$$= R_{72}^{d}\left[A_{77}^{d} - A_{72}^{d}\right]R_{77}^{d}\left(\hat{u}_{77}F_{77} + E_{77}\right)$$
$$= R_{72}^{d}\left(A_{77}^{d} - A_{72}^{d}\right)Q_{77}.$$

Domestic input-output coefficients can be expressed as the difference between total (domestic and imported) input-output coefficients and import coefficients, $A^d = A - (I - \hat{u})A$, so that equation (b) is rewritten as

$$\text{(c)} \quad R_{72}^{d}\left(A_{77} - A_{72}\right)Q_{77} - R_{72}^{d}\left[\left(I - \hat{u}_{77}\right)A_{77} - \left(I - \hat{u}_{72}\right)A_{72}\right]Q_{77}$$
$$= R_{72}^{d}\left(A_{77} - A_{72}\right)Q_{77} - R_{72}^{d}\left[\left(I - \hat{u}_{77}\right)A_{77} - \left(I - \hat{u}_{72}\right)A_{77} + \left(I - \hat{u}_{72}\right)A_{77} - \left(I - \hat{u}_{72}\right)A_{72}\right]Q_{77}$$
$$= R_{72}^{d}\left(A_{77} - A_{72}\right)Q_{77} + R_{72}^{d}\left(\hat{u}_{77} - \hat{u}_{72}\right)A_{77}Q_{77} - R_{72}^{d}\left[\left(I - \hat{u}_{72}\right)A_{77} - \left(I - \hat{u}_{72}\right)A_{72}\right]Q_{77}$$
$$= R_{72}^{d}\,\Delta A\,Q_{77} + R_{72}^{d}\,\Delta\hat{u}\,W_{77} - R_{72}^{d}\,\Delta A\,Q_{77} + R_{72}^{d}\,\hat{u}_{72}\,\Delta A\,Q_{77}.$$

Combining equations (a) and (c), we obtain the completed expression for measuring changes in output growth.

$$\text{(d)} \quad \Delta Q = R_{72}^{d}\hat{u}_{72}\Delta F + R_{72}^{d}\,\Delta E + R_{72}^{d}\,\Delta\hat{u}\left(F_{77} + W_{77}\right) + R_{72}^{d}\hat{u}_{72}\Delta A\,Q_{77}.$$

Endnotes

1. Other approaches to analyzing output change have followed in the tradition of Solow and Denison using aggregate production functions (Chenery et al., 1986, Chapter 1). More recently, aggregate profit functions and duality theory have been used (Blayney and Mittelhammer, 1990). A common theme characterizing all of this work is its supply-side orientation. Output change is explained as a result of supply changes that result from changing factor intensity, technological change, and improvements in factor quality.

2. At the time of this study, 1990, the 1977 benchmark input-output table was the most recent table available.

3. The input-output accounts were deflated to record flows in real dollars. Price indexes for each sector were obtained by modifying the output price indexes derived for the 528-sector IMPLAN I-O accounting system. The IMPLAN price indexes were produced from the Bureau of Labor Statistics 226-sector index of producer prices. Based on these indexes, a price deflator was constructed for each input-output sector to adjust 1977 dollar flows into real 1972 values. The commodity deflator obtained from this was simply $O_C = \dfrac{P_{72}}{P_{77}}$.

   The industry price deflator was obtained with the following construction: $O_I = \hat{X}_{77}^{-1}\,V_{77}\,O_C$.

   Where $\hat{X}_{77}$ is the 488 x 488 vector of total industry output in 1977 nominal dollars, V_{77} is the 488 x 477 industry by commodity make matrix again in 1977 nominal dollars, and O_C is the 477 x 1 vector of commodity price deflators. This bridge operation normalizes across rows of the make matrix to construct the industry price deflator as a weighted average of the price deflators of all the commodity outputs of the given industry.

Domestic final demand, export demand, imports and interindustry demand in 1977 were all deflated to real 1972 dollars by premultiplying by O_C. Input-output coefficients for 1977 were deflated to real 1972 equivalent form according to the construction $A_{77} = O_C\ B_{77}\ \hat{O}_I^{-1}\ S_{77}$ where B_{77} and S_{77} are respectively the technical coefficient and market shares matrices for 1977.

4. A commodity by commodity model was used in the decomposition to facilitate a consistent accounting of goods and service flows. Industry by commodity, industry by industry, and commodity by industry models can be used in the decomposition only when the I-O accounts do not indicate secondary production. When secondary production is present, it is possible to carry out the decomposition only with the commodity by commodity model.

5. To estimate the relative importance of technology changes and price-induced input substitution in this term, we regressed the price ratio (P_{72}/P_{77}) for the sector against growth induced by the changes in input-output coefficients. The low R^2 (0.014) tends to indicate that most of this change is brought on by changes in production technology of downstream sectors rather than response to own sector price changes.

6. Dominance refers to the growth component accounting for the largest absolute output change. The dominance percentage was computed for each growth component by dividing the number of times the component was dominant by the total number of sectors in a given aggregation.

7. Technical change is usually thought of in terms of changes in the technical coefficients for a given sector as measured down a column of the technical coefficients (A) matrix. The technical change component of this analysis relates to the changes in technical coefficients across the row of the A matrix for a given sector.

8. It should be noted that while technical coefficient changes were last in aggregate importance to the overall U.S. economy, they were second in importance to individual sectors as given by the percent of dominant sectors (30 percent). This emphasizes the importance of the intermediate market.

9. Agriculture and mining are the primary sectors. Services are the tertiary sectors.

10. The Arab oil embargo and formation of OPEC resulted in dramatic increases in crude oil prices. Between 1972 and 1977 the U.S. domestic crude oil price nearly tripled. Yet real crude oil production in the U.S. actually declined. When the output change is decomposed, all of the decrease was accounted for by a decrease in the domestic supply ratio; in other words, by the substitution of imported crude oil for domestic crude oil. In spite of the great incentives for supply increase, domestic crude oil producers were either unable or unwilling to expand domestic production over the 1972-77 period.

11. Also contributing to the negative domestic demand component was negative inventory change for Meat Animals reflecting changes in herd size.

12. The increase in the domestic demand component is probably accounted for by increased purchase of lawn and garden services by households.