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LINKAGES BETWEEN AGRICULTURE AND THE U.S.  
NATIONAL INCOME AND PRODUCT ACCOUNTS

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The role played by agriculture in a developed urban-oriented economy such as the U.S. differs quite markedly from the heavy reliance upon agriculture which one observes in less developed nations. As an economy goes through the various stages of development, the contribution of agriculture to gross national product usually declines in relative importance. Concurrently, an increasingly complex marketing system for agricultural products develops. As transportation, trade, and other marketing services become increasingly specialized and prevalent, the interrelationships between agriculture and the rest of the economy become more numerous and increasingly complex.

Identifying the size and nature of these interrelationships between agriculture and the rest of the economy is an aid in understanding the role of the agricultural sector in a developed economy. The relationships which will be explored in this paper are identified as linkages between measures of the contribution of agriculture to gross national product (gross farm product) and selected components of the national income and product accounts. Knowledge of the magnitude of these linkages allow the economic researcher to trace the estimates of income generated in agriculture to its impetus in final consumption activity. These linkages, when expressed in terms of income generated in agriculture per dollar of expenditures in a given component of final consumption, can be used to evaluate the implications for agriculture of any change in size or structure of the economy as represented in a set of national income and product accounts.

The Estimation Procedure

One procedure for identifying and quantifying the linkages between measures of output of the agricultural sectors and the national income and product accounts involves the utilization of a total requirement matrix of a national input-output table and a final demand matrix with vectors consistent with selected components of the national income and product accounts.



The methodology of this procedure is rather straightforward:

If we let

- $X$  = an  $n \times 1$  vector of gross sector outputs
- $Y$  = an  $n \times 1$  vector of final demands
- $(I-A)^{-1}$  = an  $n \times n$  matrix of total requirements coefficients
- $V$  = an  $n \times n$  diagonal matrix with value-added coefficients on the diagonal

then the vector of gross outputs in each sector,  $X$ , which would have to be produced to satisfy the final demands specified in the final demand vector,  $Y$ , given the structure of the economy expressed in the total requirements matrix can be obtained from the product of the total requirements matrix and the final demand vector, i.e.,  $X = (I-A)^{-1}Y$ .

If the total requirements matrix is premultiplied by the diagonal matrix,  $V$ , the interpretation of the individual coefficients of the transformed matrix,  $V(I-A)^{-1}$ , is changed from dollars of gross output generated per dollar of final demand as in the initial matrix to value added or income generated by exogenous factors of productions per dollar of final demand. Thus the total gross national product generated within each endogenous sector by a given vector of final demands is given by the product of this new matrix and the final demand vector, i.e.,  $GNP = V(I-A)^{-1}Y$ .

If we disaggregate the final demand vector into a matrix of  $m$  separate vectors so that  $Y$  is now an  $n \times m$  matrix with elements  $Y_{ik}$   $i = 1 \dots n$ ,  $k = 1 \dots m$ , it is possible to solve for a corresponding  $n \times m$  matrix of more detailed estimates of the impetus of gross national products generated in the sectors of the economy. The  $ik$ th element of this matrix would be the gross national product generated in the  $i$ th sector by total expenditures in final demand category  $k$ . This is the nature of the estimates presented in table 1. The components of the national income and product accounts are specified as twenty-two final demand vectors which are premultiplied times a transformed  $10 \times 363$  submatrix of the total requirements table from the Office of Business Economics input-output table of the 1963 United States economy.[2] Table 1 presents the value estimates of gross national product generated in the ten commodity sectors and all agriculture by expenditures in these twenty-two selected components of the national income and product accounts in 1963.

Under the assumption of a constant product mix within each vector of the final demand matrix, we can solve for an  $n \times m$  matrix of income generation coefficients by dividing each  $ik$ th elements of the previous matrix by the sum of total final demand in the  $k$ th final demand category. We shall denote these income generation coefficients as  $Z_{ik}$ 's. Each coefficient,  $Z_{ik}$ , is the gross national product generated in the  $i$ th sector per dollar of final demand expenditure in the  $k$ th final demand category. These coefficients which correspond to the income estimates in table 1 are presented in table 2. The gross national product generated within a given sector  $i$  is now given by the sum of the products of the individual  $Z_{ik}$  term with the total expenditures for final demand included in each of the  $m$  final demand categories. Thus these income generation coefficients can be applied to any set of constant dollar national income and product

Table 1.  
Value added generated in commodity sectors and in all agriculture by selected components  
of final demand, 1963 dollars, \$1,000

Item	Dairy farm prod.	Poultry and eggs	Meat animals and misc. livestock	Cotton	Food, feed: grains, and grass seeds	To- bacco
1. Autos and parts (PCE)	3,526	1,374	12,146	18,692	22,932	4,526
2. Furn. & household equip. (PCE)	3,002	1,128	11,185	21,280	19,531	1,125
3. Other durables (PCE)	2,780	1,088	15,592	42,534	21,732	985
4. Food pur. for off-premise consumption (PCE)	1,233,950	438,352	2,514,293	112,726	3,646,258	7,829
5. Purchased meals and beverages (PCE)	226,522	76,104	498,914	19,921	676,541	1,894
6. Other PCE food	101,967	32,863	159,471	5,839	225,929	423
7. Shoes and other footwear (PCE)	805	336	3,497	10,557	5,769	294
8. Clothing (PCE)	7,036	3,713	64,594	401,529	75,139	2,074
9. Gasoline and oil (PCE)	4,484	1,272	9,017	4,011	22,366	1,478
10. Tobacco products (PCE)	7,917	1,368	18,639	2,312	24,361	491,994
11. Other nondurables (PCE)	8,160	3,988	39,075	93,342	64,421	2,489
12. Housing services (PCE)	76,864	23,740	220,499	81,473	564,359	42,081
13. Household operation serv. (PCE)	1,651	687	5,603	3,222	12,637	915
14. Transportation services (PCE)	2,292	791	6,293	3,357	12,114	843
15. Other services (PCE)	21,806	8,204	108,672	23,731	142,725	6,949
16. Producers durable equipment	7,168	2,551	21,253	17,753	44,335	2,735
17. Structure investment	8,424	3,371	30,461	16,037	55,860	3,068
18. Change in farm inventories	5,755	1,197	143,445	-35,651	219,500	147,207
19. Change in nonfarm inventories	3,919	3,699	46,877	15,516	55,870	1,083
20. Gross exports	61,340	17,190	184,368	330,416	1,267,245	193,017
21. Fed. govt. pur. of goods & serv.	25,825	5,826	34,927	232,914	-159,403	2,913
22. S&L govt. pur. of goods & serv.	33,586	6,545	59,445	13,127	111,391	2,064
TOTAL	1,848,779	635,387	4,208,266	1,434,638	7,131,612	917,986

Continued--



Table 1.--Continued  
Value added generated in commodity sectors and in all agriculture by selected components  
of final demand, 1963 dollars, \$1,000

Item	Fruit and Tree nuts	Veg., sugar and misc. crops	Oil- bearing crops	Greenhouse and nursery	All Agric.
1. Autos and parts (PCE)	2,795	4,531	5,108	5,146	80,776
2. Furn. & household equip. (PCE)	2,334	3,356	4,109	11,498	78,548
3. Other durables (PCE)	2,262	3,198	3,455	4,979	98,605
4. Food pur. for off-premise consumption (PCE)	969,634	1,143,682	457,127	54,721	10,578,572
5. Purchased meals and beverages (PCE)	90,440	266,452	66,149	7,520	1,930,457
6. Other PCE food	64,021	197,917	22,222	2,351	813,003
7. Shoes and other footwear (PCE)	625	968	1,172	1,135	25,158
8. Clothing (PCE)	5,904	7,130	7,892	9,736	584,747
9. Gasoline and oil (PCE)	2,536	3,751	4,244	2,028	55,187
10. Tobacco products (PCE)	1,559	1,888	2,534	1,522	554,094
11. Other nondurables (PCE)	6,094	20,049	16,884	315,419	569,921
12. Housing services (PCE)	49,066	77,951	70,659	43,094	1,249,786
13. Household operation serv. (PCE)	1,611	2,211	1,871	2,293	32,701
14. Transportation services (PCE)	1,968	2,652	2,258	1,470	34,038
15. Other services (PCE)	23,628	35,313	16,819	9,189	397,036
16. Producers durable equipment	5,565	8,005	8,385	9,029	126,779
17. Structure investment	6,644	14,591	13,798	268,955	421,209
18. Change in farm inventories	36,676	-11,786	100,987	511	607,841
19. Change in nonfarm inventories	4,626	21,136	17,597	5,565	175,888
20. Gross exports	74,507	103,981	373,962	31,252	2,637,278
21. Fed. govt. pur. of goods & serv.	10,409	16,185	-29,091	6,617	147,122
22. S&L govt. pur. of goods & serv.	18,107	30,128	12,508	36,371	323,272
TOTAL	1,381,011	1,953,289	1,180,649	930,401	21,522,018

Table 2.  
Gross farm product generated per dollar of expenditure in selected components of the national  
income and product accounts, 1963 dollars

Item	Dairy farm prod.	Poultry and eggs	Meat animals and misc. livestock	Cotton	Food, feed: grains, and grass seeds	To- bacco
1. Autos and parts (PCE)	.00014	.00005	.00048	.00074	.00091	.00018
2. Furniture and household equipment (PCE)	.00019	.00007	.00070	.00134	.00123	.00007
3. Other durables (PCE)	.00024	.00009	.00133	.00364	.00186	.00008
4. Food pur. for off-premise consumption (PCE)	.01873	.00665	.03817	.00171	.05535	.00012
5. Purchased meals and beverages (PCE)	.01151	.00387	.02535	.00101	.03437	.00010
6. Food furn. govt. and commercial employees and consumed in farm households (PCE)	.04426	.01427	.06922	.00253	.09807	.00018
7. Shoes and other footwear (PCE)	.00017	.00007	.00073	.00220	.00120	.00006
8. Clothing (PCE)	.00028	.00015	.00261	.01624	.00304	.00008
9. Gasoline and oil (PCE)	.00033	.00009	.00066	.00029	.00163	.00011
10. Tobacco products (PCE)	.00106	.00018	.00249	.00031	.00325	.06565
11. Other nondurables (PCE)	.00029	.00014	.00137	.00327	.00226	.00009
12. Housing services (PCE)	.00138	.00043	.00397	.00147	.01015	.00076
13. Household operation services (PCE)	.00007	.00003	.00024	.00014	.00054	.00004
14. Transportation services (PCE)	.00018	.00006	.00050	.00027	.00096	.00007
15. Other services (PCE)	.00035	.00013	.00172	.00038	.00226	.00011
16. Producers durable equipment	.00021	.00007	.00062	.00052	.00129	.00008
17. Structure investment	.00018	.00007	.00066	.00035	.00121	.00007
18. Change in farm inventories	.00600	.00125	.14964	-.03719	.22898	.15356
19. Change in nonfarm inventories	.00090	.00085	.01073	.00355	.01278	.00025
20. Gross exports	.00189	.00053	.00568	.01018	.03905	.00230
21. Fed. govt. purchases of goods and services	.00040	.00009	.00054	.00363	-.00249	.00005
22. S & L govt. purchases of goods and services	.00057	.00011	.00101	.00022	.00189	.00003
TOTAL	.00314	.00108	.00714	.00243	.01210	.00156

Continued--



Table 2.--Continued  
Gross farm product generated per dollar of expenditure in selected components of the national  
income and product accounts, 1963 dollars

Item	Fruit and Tree nuts	Veg., sugar and misc. crops	Oil- bearing crops	Greenhouse and nursery	All Agricult.
1. Autos and parts (PCE)	.00011	.00018	.00020	.00020	.00319
2. Furniture and household equipment (PCE)	.00015	.00021	.00026	.00072	.00494
3. Other durables (PCE)	.00019	.00027	.00030	.00043	.00844
4. Food pur. for off-premise consumption (PCE)	.01472	.01736	.00694	.00083	.16058
5. Purchased meals and beverages (PCE)	.00460	.01354	.00336	.00038	.09808
6. Food furn. govt. and commercial employees and consumed in farm households (PCE)	.02779	.08591	.00965	.00102	.35292
7. Shoes and other footwear (PCE)	.00013	.00020	.00024	.00024	.00525
8. Clothing (PCE)	.00024	.00029	.00032	.00039	.02366
9. Gasoline and oil (PCE)	.00019	.00027	.00031	.00015	.00403
10. Tobacco products (PCE)	.00021	.00025	.00034	.00021	.07394
11. Other nondurables (PCE)	.00021	.00070	.00059	.01106	.01999
12. Housing services (PCE)	.00088	.00140	.00127	.00078	.02248
13. Household operation services (PCE)	.00007	.00009	.00008	.00010	.00140
14. Transportation services (PCE)	.00016	.00021	.00018	.00012	.00269
15. Other services (PCE)	.00037	.00056	.00027	.00015	.00629
16. Producers durable equipment	.00016	.00023	.00024	.00026	.00369
17. Structure investment	.00014	.00032	.00030	.00583	.00913
18. Change in farm inventories	.03826	-.01230	.10535	.00053	.63409
19. Change in nonfarm inventories	.00106	.00484	.00403	.00127	.04025
20. Gross exports	.00230	.00320	.01152	.00096	.08127
21. Fed. govt. purchases of goods and services	.00016	.00025	-.00045	.00010	.00229
22. S & L govt. purchases of goods and services	.00031	.00051	.00021	.00062	.00547
TOTAL	.00234	.00331	.00200	.00141	.03651



accounts to evaluate the implications for income generated in agriculture.

This is the essence of the procedure employed in this paper to make quantitative estimates of the linkages between a measure of agricultural output, gross national product generated in agriculture or gross farm product, and the national income and product accounts.

#### Size of Linkages

Many of the results expressed in table 1 are not surprising. A primary function of agriculture is food production and thus not surprisingly over sixty-one percent of the gross national product generated in agriculture can be traced to personal consumption expenditures for food and beverages. Secondly, agriculture has cultivated an active foreign market for its output, and in 1963 gross exports were the impetus for another twelve percent of gross farm product. The gross rental value of farm dwellings is considered one component of gross farm income. This transaction results in a relatively strong linkage between the PCE component, housing services, and the agricultural sector. Over \$1.2 billion or about five percent of total gross farm product in 1963 can be traced through this linkage. With an additional five percent being generated in the PCE categories, clothing and tobacco products a total of over eighty-three percent of gross farm product can be traced to "expected" sources. However, some linkages exist for all components of the national income and product accounts, and even personal consumption expenditures for such nonagricultural products as gasoline and oil generated \$55.2 million of 1963 gross farm product.

The length and size of these linkages have important influences upon income generated in agriculture. In 1963 personal consumption expenditures for clothing were \$24.7 billion and for tobacco products were \$7.5 billion. In contrast to this rather large difference in consumer expenditures, the impact of these expenditures upon gross farm product was essentially equal, \$585 million vs. \$554 million. A brief examination of some of the reasons for this result may help in understanding the tables.

Two important relationships which influence the size of the linkages between agriculture and the rest of the economy are the proportion of the value of output of a commodity sector which is retained as income for factor payments and the number of handling stages the raw agricultural commodity must pass between the producer and consumer.

The commodity sector which is influenced most strongly by PCE expenditures for tobacco is tobacco. For clothing expenditures the analogous sector is cotton. From the direct requirements table of the 1963 OBE input-output study, we can obtain the value added coefficients for these two sectors.[2] They are tobacco, 0.616, and cotton, 0.464. Thus each dollar of output generated in the tobacco sector generated \$.152 more than a dollar of output in the cotton sector. This "income" generated is returns to employee compensation, net interest, indirect business

taxes, capital consumption allowances, and total net farm income. Thus it is net of intermediate operating expenses of production and consequently lower than a "farmer's share" type of concept which measures the proportion of the final sale price of a consumption item that is represented by the price for the basic commodity at the farm gate. Therefore, on the first measure of comparison, one would expect a larger linkage between PCE tobacco expenditures and tobacco production than between clothing expenditures and cotton production simply because a larger share of the tobacco production dollar is retained by the tobacco producer.

In addition tobacco goes through fewer intermediate steps between tobacco producer and tobacco products consumer than exists between the cotton lint producer and the clothing consumer and the direct linkages in these intermediate steps are larger for tobacco so there is less opportunities for leakages of output generation effects to other sectors. Consequently a dollar increase in PCE expenditures for tobacco products also generates more output in the tobacco production sector than an additional dollar of PCE expenditures for clothing generates in the cotton production sector.

Varying characteristics of the individual commodity sectors are illustrated by examining several unique features of the columns of table 1. Nearly eighty percent of the income generated in the livestock sectors can be traced to PCE expenditures for food and only three to five percent attributable to gross exports. In contrast over thirty percent of the income generated in the oil crop sector can be traced to expenditures for gross exports.

The forest products, greenhouse and nursery products sector exhibits a quite different distribution of the sources of its income generated. Consumer expenditures for "other nondurables", which includes cut flowers, and structures investment, which includes landscaping costs for new construction, contribute over thirty-eight percent of the basis for income generated in this sector.

#### An Historical Evaluation

Under the conditions of a stable structure of an economy, it should be possible to apply the coefficients presented in table 2 to any set of national income and product accounts to estimate an implied gross national product originating in agriculture. With the recent proliferations of econometric models of the United States economy which often have their results presented in terms of a projected set of national income and product accounts, it would appear the coefficients in table 2 would be a useful tool for the agricultural economist to utilize in evaluating the implications for agriculture of the results of these various econometric models. Figure one presents comparison of the historical performance of such an effort to estimate gross farm product in constant dollars. It is apparent this technique is inadequate to reflect the expected declining relative importance of agriculture in a developing economy. It underestimates the contribution of agriculture to gross national product prior



to 1963 and overstates its contribution after this year.

Three possible forces which could be causing this unresponsiveness could be a shift in relative prices within the economy, a change in production techniques, and the normal influences of economic growth of the economy. An adjustment equation with proxies for these three influences was grafted onto the estimation model. The results of this adjustment is presented in the "adjusted model" line on figure 1. It is apparent the adjustment equation offsets the tendency of the prediction error of the unadjusted estimation model to get increasingly large as one moves away from 1963, and does a reasonable job of estimating agriculture's contribution to gross national product.

The adjustment equation used for each year was:

$$\text{ADJ} = 41.97297 - 0.12718 P + 0.13976 G - 0.73525 T$$

(5.8)                      (4.4)                      (16.6)

$$R^2 = .98 \text{ Durbin-Watson} = 1.64$$

Where...

ADJ = Adjustment in gross farm product estimate, billion of 1958 dollars

P = Parity ratio, a proxy for changes in relative prices

G = Index of output per unit of input, a proxy of changes in production techniques

T = Time, a proxy for economic growth

A lack of historical data on gross farm product by commodity group precludes the application of this adjustment equation approach to refining the individual commodity prediction equation represented by the columns of table 2. Thus it would be expected that estimates using these coefficients of individual columns of table 2 to predict gross farm product generated in individual commodity sectors would be too low prior to 1963 and too high post 1963.

#### Summary

A method for estimating the linkages between measures of agricultural output and the components of the national income and product accounts has been presented. The method which utilizes input-output analysis and "bridge tables" linking the 1963 national income and product accounts and the final demand vector of the Office of Business Economics, [1] "Input-output Structure of the U.S. Economy: 1963", was used to develop estimates of income generated by selected components of the national income and product accounts within ten commodity sectors and all of agriculture. These estimates are of interest as quantitative measures of the strength of various linkages and as a demonstration of the complex interrelationships which exist between agriculture and the rest of the U.S. economy. The application of the estimated 1963 linkage to historic data was found to be an inadequate procedure to predict the historic contribution of

agriculture to gross national product, but rather strikingly illustrated that even in a developed economy the relative contribution of agriculture to GNP continues to decline. An adjustment equation was fit onto the prediction errors and substantially improved the performance of the estimation procedure.

- [1] U.S. Dept. of Commerce "Industrial Composition of Personal Consumption Expenditures, by PCE Category, in Producers and Purchasers Prices, 1963", Reprint of 363 sector detail available from Bureau of Economic Analysis, U.S. Dept. of Commerce, 1971.
- [2] U.S. Dept. of Commerce "Input-output Structure of the U.S. Economy: 1963 Vol. 2 Direct Requirements for Detail Industries" and Vol. 3 "Total Requirements for Detailed Industries". A Supplement to the Survey of Current Business, 1969.



Figure 1

