Combining Input-Output and Regression Analysis in Projection Models: An Application to Agriculture

By Gerald Schluter

Grafting an adjustment equation onto an input-output based projection model improves the predictive performance of the unadjusted model and results in a relatively sensitive estimator of both the level of and changes in nominal and real gross farm product.

Keywords: Input-output analysis, farm income, projection, models.

Despite the logical appeal of the "consistent" forecasts[1] which result from input-output models, this technique remains largely unexploited by agricultural economists in their projection work. This disregard has not occurred without reason. Input-output (I/O) based projection models often overestimate the output of agricultural sectors. Many input-output tables are, to varying degrees, out of date by the time they are constructed, and the adequate specification of a final demand vector for the target year is a formidable task in itself. These are all serious problems, but if several variations are made in the usual I/O projection procedures, an I/O based model can do a reasonably good job of predicting agriculture's contribution to U.S. gross national product.

Projection with an input-output model is mechanically simple. A projected final demand vector (Y) is premultiplied by an $(I\text{-}A)^{-1}$ or total requirement matrix to yield a vector of gross outputs by sector, i.e.,

$$(1)\ X = (I\text{-}A)^{-1} Y$$

The gross output calculated from equation (1) involves varying degrees of multiple counting. Actual gross national product generated in the individual sectors can be calculated by premultiplying the gross output vector (X) by a diagonal matrix with the individual value-added coefficients on the diagonal.

$$(2)\ GNP = VX = V(I\text{-}A)^{-1} Y$$

Difficulties arise in trying to specify an adequate representation of the total requirement matrix and final demand vector. If one is willing to assume a stable relative price, product mix, and technological structure from the year the latest input-output matrix was constructed until the target year, one may simply use the corresponding total requirement matrix in the projection model. When these assumptions are not appropriate or there exists empirical evidence of changes in one of these conditions, the performance of the projection model may be improved by updating the input-output matrix to incorporate these changes.[2]

Several attributes of final demand vectors complicate their accurate specification. Final demand vectors are usually specified in terms of producer's value, that is, that part of their final value not represented by trade or transportation margins. This is a difficult estimation problem which is usually dealt with product by product in the construction of an input-output matrix. The failure to devote equivalent attention to this problem in specifying a projected final demand vector is a possible source of estimating errors in input-output projection models.

A second characteristic of final demand vectors which complicates their accurate specification is the necessity of specifying projections of consumer and Government spending, foreign trade transactions, and inventory and private investment expenditures in terms of specific sector or industry categories. This is time consuming and

[1] Consistency means that the sum of all the estimates of individual sector incomes is equal to the total income in the economy.

[2] Schaffer (2) provides a good discussion of the relative merits of various techniques for updating an input-output matrix.

unfortunately the lack of proper data sources often dictates arbitrary classification decisions.

A Simplified I/O Projection Technique

With the simplifying assumptions of (1) stable input-output coefficients during the projection period and (2) a regular and systematic division of demand from final demand among producing sectors, a projection model was built based on the 363-sector input-output model of the 1963 U.S. economy (*4*). This model avoids the work and problems associated with specifying a detailed final demand vector and the cumbersome problem of handling a 363-sector inverse.

The computational procedure for calculating the model coefficients implicitly views each component of the Nation's income and product accounts as a separate final demand sector. In equation (1) an $n \times 1$ vector of gross outputs is calculated by premultiplying a vector of final demands by the total requirements matrix. Let us expand this analysis so there are m final demand sectors as well as the n producing sectors. Denote by Y_t the n-component column vector of deliveries to final demand at time t, organized by producing sector of origin. Let Z_t be the m-component vector of deliveries to final demand at time t, organized by final demand sector. The sum of the components of each vector is the same, since each represents a different way of expressing total final demand. Thus, if h_k denotes a k-component row vector of unit elements,

$$(3)\ h_n Y_t = h_m Z_t$$

By assumption 2 above we can express the relationship between Y_t and Z_t as

$$(4)\ Y_t = BZ_t + u_t$$

where B is an $n \times m$ constant matrix parameter and u_t is an n-component disturbance vector. Since each column of B represents the distribution of a particular component of final demand over consuming sectors and since each such component must be exactly distributed, each column of B must sum to unity. Thus:

$$(5)\ h_n B = h_m$$

and, in view of equations (3) and (4),

$$(6)\ h_n u_t = h_n (Y_t - BZ_t) = h_n Y_t - h_m Z_t = 0$$

Thus the disturbances sum to zero across all equations.

The data for estimating a B matrix for 1963 are available from published U.S. Department of Commerce sources. The personal consumption expenditures data are available for up to 82 components from (*5*) and detail for the rest of the final demand sector is available from supplements to (*4*).

From equations (2), (4), and (6),

$$(7)\ GNP = V(I - A)^{-1} BZ_t$$

for the whole economy. By assumptions 1 and 2 the matrices V, $(I - A)^{-1}$, and B are all constant so their $n \times m$ matrix product will also be constant.

$$(8)\ C = V(I - A)^{-1} B$$

Element c_{ij} of matrix C is interpreted as the gross national product generated in producing sector i per dollar of expenditure in final demand sector j. This type of computation was performed for the 10 agricultural production sectors of the 363-sector I/O table and for 22 final demand components. The aggregated results of this computation expressed in 1958 dollars are presented in table 1.[3]

The cumulative multiplication of the coefficients in table 1 times the corresponding components of the national income and product accounts for a given year yields an estimate of gross national product originating in farming for that year.[4] This statistic is commonly referred

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[3] If the 10 agricultural production rows of C were aggregated to one row, then the coefficients in table 1 (expressed in 1963 dollars) would be the agricultural production row of the new 354×22 C matrix. For the interested reader the 10×22 C matrix for agricultural production is published in (*3*, table 2).

[4] Actual national income and product account data in constant dollars were used. This approach, equivalent to assuming that a method exists for projecting GNP and its components with no error, makes it possible to evaluate the relative merits of the different projection methods independent of errors associated with GNP projections. In fact, the most useful application of the models investigated in this paper may be to analyze the implications for the farming sector of economic projections of the larger econometric models, such as the Brookings model.

Table 1. Gross farm product generated per dollar of expenditure in selected components of the national income and product accounts, 1963
(In 1958 dollars)

Item	Value[a]
1. Autos and parts (PCE)[b]	.00339
2. Furniture and household equipment (PCE)	.00519
3. Other durables (PCE)	.00912
4. Food purchased for off-premise consumption (PCE)	.17311
5. Purchased meals and beverages (PCE)	.11573
6. Food furnished Government and commercial employees and consumed in farm households (PCE)	.35534
7. Shoes and other footwear (PCE)	.00613
8. Clothing (PCE)	.02607
9. Gasoline and oil (PCE)	.00441
10. Tobacco products (PCE)	.08644
11. Other nondurables (PCE)	.02149
12. Housing services (PCE)	.02542
13. Household operation services (PCE)	.00161
14. Transportation services (PCE)	.00314
15. Other services (PCE)	.00768
16. Producers durable equipment	.00399
17. Structure investment	.01051
18. Change in farm inventories	.67023
19. Change in nonfarm inventories	.04254
20. Gross exports	.08639
21. Federal Government purchases of goods and services	.00262
22. State and local government purchases of goods and services	.00672

[a]Derived from U.S. Department of Commerce data.
[b]PCE = personal consumption expenditures.

to as gross farm product. Estimated gross farm product in current and constant dollars is reported each year in the National Income issue of *Survey of Current Business* (6). It is calculated as the sum of gross farm income and some minor adjustments, less value of intermediate products consumed and gross rents paid to nonfarm operator landlords. The official constant dollar gross farm product series and the I/O based model predictions are presented in table 2 and figure 1 for 1949-72. Table 2 and figure 2 present the annual changes in gross farm product and the I/O based model estimates of changes in this statistic.

The obvious weakness of this type of model is its basis on the economic relationships existing in only one year, 1963. If in fact there were continuing changes in relative prices, relative growth rates in productivity, and other normal characteristics of a dynamic economy, or if some economic situation were unique to the base year, the former are ignored and the latter is considered. One would expect that the further one gets from the base year, the poorer the results would be. A comparison of the actual and I/O based model prediction lines in figure 1 and table 2 provides evidence of this influence in the present model also. This model consistently overestimates gross farm product since 1964. Figure 2 and table 2 show that the I/O based model also is inadequate as a predictor of year-to-year changes in constant dollar gross farm product. This model predicted none of the eight decreases in this statistic during 1949-72 and erroneously predicted a decrease during 1951-53. With a calculated Theil's U^2 statistic[5] of 1.38, this model is inferior to even the naive "no-change" prediction procedure ($U^2 = 1.0$)

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[5] $$U^2 = \frac{\sum_{i=1}^{n}(P_i - A_i)^2}{\sum_{i=1}^{n} A_i^2}$$

where (P_i, A_i) are a pair of predicted and observed changes in an economic series.

as a predictor of yearly changes in constant dollar gross farm product.

The deficiencies of this I/O based model as a predictor of both the level and the changes in gross farm product are obvious. It is also obvious that the estimation procedures presented thus far, while simpler to implement than traditional input-output estimation procedures, have contributed little to improving the quality of the predictions. An attempt to deal with this problem is explored in the next section.

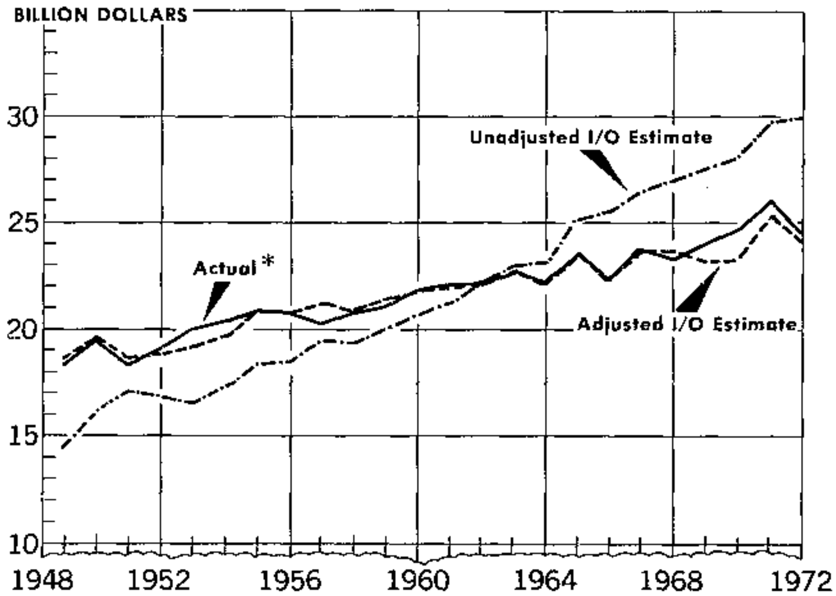
Table 2. Constant dollar gross farm product: Actual series, I/O model estimates, and adjusted I/O model estimates, level and annual changes, 1949-72

(In billions of dollars)

Year	Level			Changes		
	Actual[a]	Unadjusted I/O-based Model	Adjusted I/O-based Model	Actual	Unadjusted I/O-based Model	Adjusted I/O-based Model
1949	18.4	14.5	18.6			
1950	19.4	16.2	19.6	1.0	1.7	1.0
1951	18.4	17.1	18.7	−1.0	.9	−.9
1952	19.0	16.9	18.9	.6	−.2	.2
1953	20.0	16.5	19.1	1.0	−.4	.2
1954	20.4	17.3	19.7	.4	.8	.6
1955	20.9	18.4	20.9	.5	1.1	1.2
1956	20.8	18.5	20.8	−.1	.1	−.1
1957	20.3	19.5	21.3	−.5	1.0	.5
1958	20.8	19.4	20.9	.5	−.1	−.4
1959	21.1	20.0	21.4	.3	.6	.5
1960	21.9	20.7	21.9	.8	.7	.5
1961	22.2	21.3	21.9	.3	.6	0
1962	22.1	22.2	22.2	−.1	.9	.3
1963	22.8	22.9	22.8	.7	.7	.6
1964	22.3	23.2	22.2	−.5	.3	−.6
1965	23.7	25.2	23.6	1.4	2.0	1.4
1966	22.4	25.6	22.4	−1.3	.4	−1.2
1967	23.9	26.5	23.7	1.5	.9	1.3
1968	23.4	27.1	23.6	−.5	.6	−.1
1969	24.1	27.5	23.2	.7	.4	−.4
1970	24.8	28.3	23.4	.7	.8	.2
1971	26.0	29.8	25.4	1.2	1.5	2.0
1972	24.6	30.0	24.3	−1.4	.2	−1.1
RMSPE:						
1949-68		2.29	.37		.93	.44
1969-72		4.11	.90		.83	.74
U^2:						
1949-68					1.38	.31
1969-72					.63	.50

[a]Source: U.S. Department of Commerce, *Survey of Current Business*, various issues.

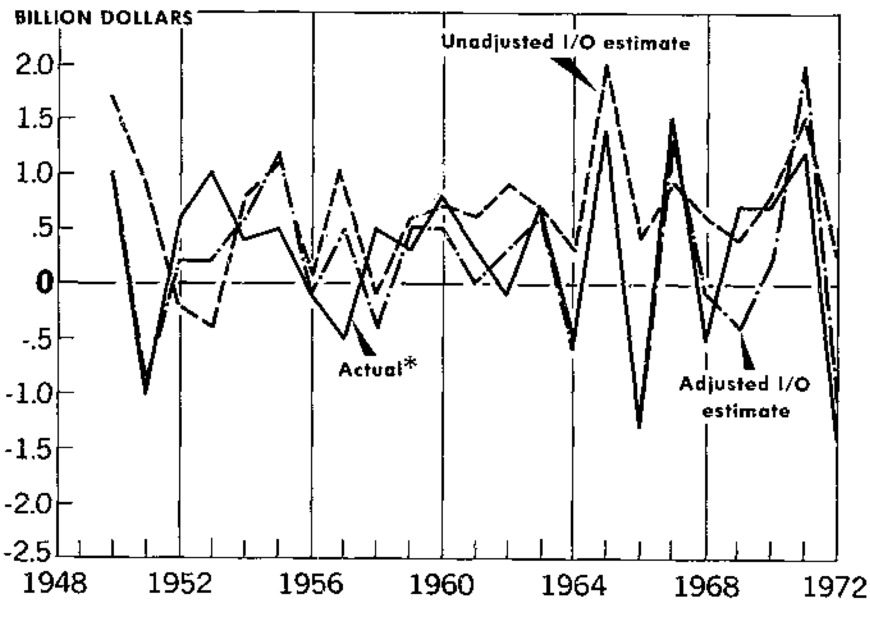
GROSS FARM PRODUCT, 1958 DOLLARS
Actual and Two Input-Output Estimates



*SOURCE: U.S. DEPARTMENT OF COMMERCE, SURVEY OF CURRENT BUSINESS, VARIOUS ISSUES.

Figure 1

CHANGES IN GROSS FARM PRODUCT, 1958 DOLLARS
Actual and Two Input-Output Estimates



*SOURCE: U.S. DEPARTMENT OF COMMERCE, SURVEY OF CURRENT BUSINESS, VARIOUS ISSUES.

Figure 2

"Adjusted" Input-Output Based Model

Several alternatives could be explored to deal with this characteristic "exploding" deviation pattern, which seriously limits its usefulness in a projection system. An attempt could be made to update the input-output matrix or reexamine the national income and product accounts for evidence of changes in product mixes within the various categories. The alternative chosen here involves less detailed adjustments. The technique chosen is the grafting of a regression equation onto the input-output based model as a means of compensating for the exploding deviation pattern.

The logic behind an adjustment equation on an input-output based model is basically that one knows certain structural coefficients are changing but, lacking sufficient data to specify individual coefficient changes, one attempts to estimate a gross adjustment. Sources of error in input-output projection models often arise in the violation of the assumption of a stable technology matrix which implies stable relative prices, stable production techniques, and a constant product mix within and between the sectors.

The adjustment equation proposed for the model attempts to reflect the influence of three forces upon the interrelationships between the agricultural sector and the rest of the economy. These forces are the influence of changes in relative prices, the impact of changing production technology and the resulting changing farm input mix, and the stage of development of the economy. The combination of the ratio of the implicit price deflator for gross farm product to the deflator for gross national product as a proxy for relative price effects, the index of farm output per unit of farm input as a proxy for the effect of changing technology, and a simple time trend as a proxy for stage of development provided the most effective adjustment for the deficiencies of the I/O based model. The adjustment equation for the constant dollar gross farm product prediction model (t-value in parentheses) is:

$$(GFP - \hat{GFP}) = \underset{}{38.06249} - \underset{(6.1)}{0.06203}\frac{PGFP}{PGNP} + \underset{(2.9)}{0.15013\, INDEX} - \underset{(8.9)}{0.75284T}$$

$R^2 = 0.97$ Durbin-Watson $= 1.36$

where

GFP = gross farm product in 1958 dollars
$\hat{GFP}$ = I/O based model estimate of GFP
$PGFP$ = implicit price deflator for gross farm product
$PGNP$ = implicit price deflator for gross national product
$INDEX$ = the index of farm output per unit of farm input
T = time, last two digits of year

Other variables considered were the parity ratio as a proxy for relative prices, the index of nonpurchased inputs as a proxy for changing production technology, and disposable per capita personal income (in 1958 dollars) as a proxy for stage of development.

The influence of shifts in relative prices and changing production technology would cause a violation of the assumption of fixed production coefficients and thus are forces which should be accounted for in the adjustment equation. Likewise, it is a natural consequence of the development of an economy for natural resource based sectors such as agriculture to diminish in relative proportion to the rest of the economy. This is an important force to consider in any adjustment procedure to an I/O based prediction model. In an economy experiencing a relatively stable rate of growth, a simple time trend may be a suitable proxy for rate of development and as a variable in the adjustment equation its performance is superior to the real per capita disposable income.

The adjustment equation was fitted on 1949-68 data to permit a 4-year period, 1969-72, for evaluation of the predictive ability of this model outside its period of fit. The results of the adjusted I/O model are presented in figure 1 and table 2. The adjustment equation has improved the predictive ability of the unadjusted model. The tendency for the model to overestimate gross farm product, apparent in figure 1, has been eliminated. This results in a dramatic drop in the root mean square predictive error,

$$\left[\frac{1}{20}\sum_{i=1}^{20}(P_i - A_i)^2\right]^{.5},$$

from 2.29 to 0.37 during 1949-68 and from 4.11 to 0.90 during the 1969-72 period of validation.

For short-term forecasting purposes, it is important for a model to predict changes as well as absolute levels of economic activity. Figure 2 and table 2 compare actual changes in constant dollar gross farm product with the predictions of the I/O based model and the adjusted I/O based model. The adjustment equation has improved the predictive ability of the I/O based model. It correctly predicted five of the seven decreases in GFP during the 1949-68 period of fit and the 1972 decrease during the validation period. It did erroneously predict a decrease from 1957 to 1958 within the period of fit and a 1968-69 decrease within the validation period. The root mean square prediction error (RMSPE) of the models' predictions of GFP changes was reduced from 0.93 to 0.44 during 1949-68 by the adjustment equation. The Theil U^2 statistic during this period was reduced from 1.38 to 0.31 with the adjustment equation. This low U^2 statistic indicates a superior predictive ability relative to the naive no-change hypothesis.

During the 1969-72 period of validation the adjusted I/O model was not as clearly superior to the performance of the unadjusted I/O model as a predictor of changes in the level of constant dollar gross farm product. The root mean square prediction errors during this period for the two models were 0.74 and 0.83, respectively, and they both had a turning point error during the period. With U^2 statistics of 0.50 and 0.63, both were better predictors than the naive no-change prediction.

Grafting an adjustment equation onto the I/O based model does improve the predictive performance of the unadjusted model. However, it compromises the inherent attribute of consistency of income estimates from an input-output model. Unless the analyst constructs similar adjustment equations for the rest of the economy and the net adjustment for the entire economy is zero, he can no longer be assured that the consistency of the individual sector estimates has been maintained. Therefore, one further comparison which must be made is the predictive performance of this adjusted I/O based model relative to a more direct estimation procedure for an estimator for gross farm product. Direct regression estimates fitted on the same data for 1949-68 did in fact do an equally good job of estimating actual gross farm product during the 1949-68 period of fit. However, during the 1969-72 validation period, the direct regression estimates consistently underestimated actual real gross farm product, and had three turning point errors, a root mean square prediction error of 1.64 on the estimates of the level of gross farm product, and a Theil U^2 statistic of 1.15 on the changes in the level. With RMSPE and U^2 statistics for the same period of 0.74 and 0.50, the adjusted I/O model exhibited a superior performance relative to the more direct approach.

Current Dollar Prediction Models

Although the level of real gross farm product is of interest to a limited number of economic analysts, projection estimates in nominal or current dollar terms are likely to be familiar to a broader audience. Input-output based estimates are by their nature real or constant dollar estimates, so current dollar projection estimates are not directly available from I/O based models. Two alternatives were explored to obtain current dollar estimates from the I/O based model. The first method utilized the adjustment equation approach to make the conversion to current dollars as well as to correct the tendency of the I/O based model to produce larger and larger deviations from actual levels as the period of time from the base year increases. The second approach was to estimate an equation which would predict the gross farm product implicit price deflator and apply this estimate to the adjusted I/O based model estimate of constant dollar gross farm product.

The adjustment equation used in the first approach was:

$$(GFP - \hat{GFP}) = 3.40752 - \underset{(8.4)}{0.11104}\,\frac{PGFP}{PGNP} - \underset{(1.1)}{0.07397}\,INDEX + \underset{(2.1)}{0.23398}T$$

$$R^2 = 0.96 \qquad \text{Durbin-Watson} = 1.26$$

The variables are the same as in the adjustment equation for the constant dollar estimates. The addition of this adjustment equation to the I/O based model estimates yields the series of estimates labeled "direct adjustment" in table 3 and figure 3.

The second approach required the estimation of an equation for the implicit price deflator for gross farm product. The equation used was:

$$PGFP = -34.30686 + \underset{(28.2)}{0.50562\,PR} + \underset{(2.1)}{0.02468\,PP}$$

$R^2 = 0.98$ Durbin-Watson = 1.21

where

$PGFF$ = implicit price deflator for gross farm product
PR = index of prices received by farmers, 1910-14 = 100
PP = index of prices paid by farmers for all items including interest, taxes, and wages, 1910-14 = 100.[6]

This estimated price deflator was applied to the previously discussed adjusted I/O based model estimates of real gross farm product to yield the current dollar gross farm product series labeled "deflated adjustment" in table 3 and figure 3.

The results of the application of these two estimation procedures for current dollar gross farm product, together with the official U.S. Department of Commerce estimates, are shown in figures 3 and 4 and in table 3. During the period of fit for the equations (1949-68), both procedures performed similarly and did an adequate job of estimating the actual series. This graphical impression is borne out by selected analytical statistics. The root mean square prediction errors for the separate deflator procedure and the direct adjustment equation procedure were 0.4522 and 0.5015, respectively, for the level of activity and 0.5795 and 0.5781 for the annual changes. The Theil U^2 statistics were 0.1781 and 0.1773.

As would be expected, neither procedure did as well in predicting the level of change in this measure of economic activity outside the period of fit. During the validation period, 1969-72, the direct adjustment equation approach failed to predict the steady growth in gross farm product experienced during this period. In 1972, predictions using this procedure were $6 billion low and only $1.4 billion of the $4.0 billion increase between 1971 and 1972 had been predicted. The separate deflator procedure did better. After underestimating the 1968-69 change, it exactly predicted the 1969-70 change, overestimated the 1970-71 change by an offsetting amount to the 1968-69 change, and predicted $3.1 of the $4.0 billion jump in gross farm product from 1971 to 1972. As a result, during the last 2 years of the validation period, this procedure gave estimates very close to the actual levels. On the basis of its overall performance, the separate deflator procedure appears to be superior to the direct adjustment equation approach and an acceptable short-run forecaster of current dollar gross farm product.

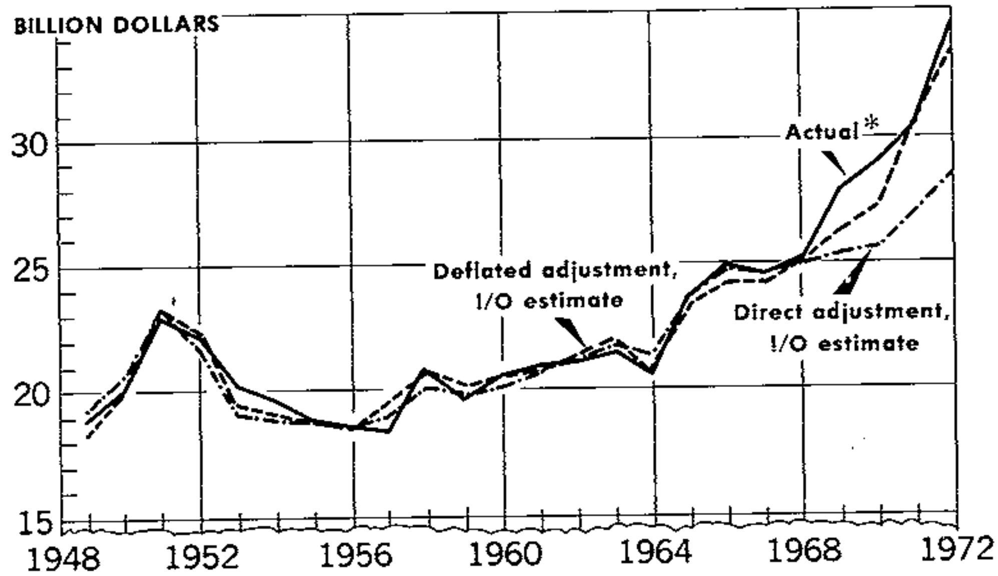
Conclusion

Neglect by the agricultural economics profession of the use of input-output analysis as more than a descriptive tool appears to have been an unfortunate oversight. With several modifications in usual input-output projections procedures, an input-output based model can be an acceptable short-range forecaster of economic activity. In addition, the modification allows one to avoid the massive data manipulation problems associated with the traditional I/O projection techniques with detailed tables, without sacrificing the utilization of the vast information available from these tables.

Gross farm product both in real terms and in constant dollar terms was a volatile component of the U.S. national income and product accounts during 1949-72. Such an economic series provides a rigorous test of the capabilities of an economic forecasting model. It was demonstrated that an input-output model with an adjustment equation to allow for forces which violate the static assumption underlying input-output models could be used as a short-term forecasting model for constant dollar gross farm product. Independently estimating an implicit price deflator for gross farm product

[6] Since the statistic for which the implicit price deflator is being estimated is the difference between gross farm income and intermediate products consumed in farm production, the index of prices paid by farmers for all production items would be the logical prices paid index to use in this equation. However, for the period of fit, the coefficient on this variable was not significant. Thus, the above alternative prices paid series was used.

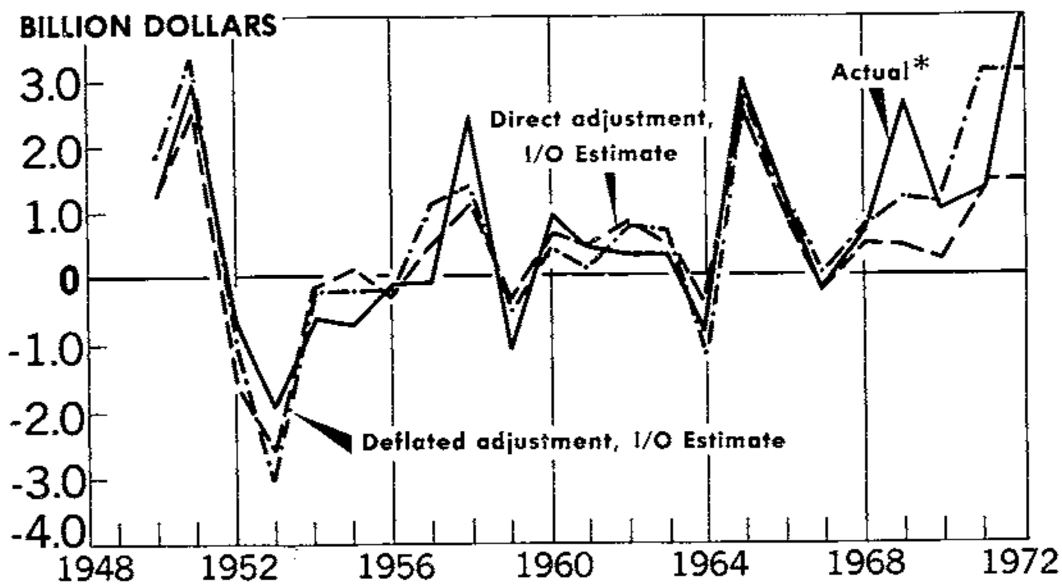
GROSS FARM PRODUCT, CURRENT DOLLARS
Actual and Two Input-Output Estimates



*SOURCE: U.S. DEPARTMENT OF COMMERCE, SURVEY OF CURRENT BUSINESS, VARIOUS ISSUES.

Figure 3

CHANGES IN GROSS FARM PRODUCT, CURRENT DOLLARS
Actual and Two Input-Output Estimates



*SOURCE: U.S. DEPARTMENT OF COMMERCE, SURVEY OF CURRENT BUSINESS, VARIOUS ISSUES.

Figure 4

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Table 3. Current dollar gross farm product: Actual series and two alternative estimation procedures, level and annual changes, 1949-72

(In billions of dollars)

Year	Level			Changes		
	Actual[a]	Direct adjustment	Deflated adjustment	Actual	Direct adjustment	Deflated adjustment
1949	18.8	19.3	18.3			
1950	20.0	20.7	20.1	1.2	1.4	1.8
1951	22.9	23.3	23.4	2.9	2.6	3.3
1952	22.2	21.7	22.4	−.7	−1.6	−1.0
1953	20.3	19.1	19.4	−1.9	−2.6	−3.0
1954	19.6	18.9	19.1	−.7	−.2	−.3
1955	18.8	19.0	18.8	−.8	.1	−.3
1956	18.6	18.6	18.5	−.2	−.4	−.3
1957	18.4	19.0	19.5	−.2	.4	1.0
1958	20.8	20.1	20.8	2.4	1.1	1.3
1959	19.6	19.7	20.2	−1.2	−.4	−.6
1960	20.5	20.2	20.6	.9	.5	.4
1961	20.9	20.6	20.7	.4	.4	.1
1962	21.2	21.4	21.4	.3	.8	.7
1963	21.5	21.8	22.0	.3	.4	.6
1964	20.6	21.4	20.7	−.9	−.4	−1.3
1965	23.7	23.9	23.4	3.1	2.5	2.7
1966	24.9	24.8	24.3	1.2	.9	.9
1967	24.6	24.5	24.3	−.3	−.3	0
1968	25.2	25.0	25.1	.6	.5	.8
1969	27.9	25.4	26.3	2.7	.4	1.2
1970	29.0	25.6	27.4	1.1	.2	1.1
1971	30.4	27.0	30.5	1.4	1.4	3.1
1972	34.4	28.4	33.6	4.0	1.4	3.1
RMSPE:						
1949-68		.50	.45		.58	.58
1969-72		4.01	1.20		1.79	1.22
U^2:						
1949-68					.18	.18
1969-72					.49	.22

[a]Source: U.S. Department of Commerce, *Survey of Current Business*, various issues.

and applying this estimate to the constant dollar gross farm product estimates allows estimates of current dollar gross farm product to be made.

The model was fitted on 1947-68 data to allow several years of data to be used as a validation period for the models. This validation period provided a particularly rigorous test for the model. Between 1971 and 1972, constant dollar gross farm product fell $1.4 billion while current dollar gross farm product rose $4.0 billion. The models accurately predicted the direction of each of these changes and predicted $1.1 and $3.1 billion, respectively, as their magnitude.

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