Chapter 8: Interindustry Macroeconomic Modeling and Social Accounting Matrices: An Application to Agriculture

In the quest to integrate interindustry relationships in econometric models of the macroeconomy, two different paths have been followed. One path, described in detail in Chapter 2 and the basis for this thesis, has been called the Interindustry Macroeconomic modeling approach. A second approach, recently made popular by Sherman Robinson, Jamie de Melo and others, is based on a Social Accounting Matrix (SAM). The SAM-based models include simple multiplier models, as well as Computable General Equilibrium (CGE) models.[1] Although IM models and SAM's were conceived with similar goals and approaches in mind, they have evolved into different tools. The following chapter introduces SAM-based models and outlines the differences between the two approaches by comparing the results of an experiment conducted in a SAM framework and in the LIFT model. The scenario considers a change in Agricultural policy that directly affects income in the sector.

SAM Modeling

Developed, in part, to reconcile input-output accounts with

[1] For development of multiplier models, see Stone and Pyatt and Round. CGE's in developing economies are surveyed in Dervis, de Melo and Robinson. For survey of CGE's of developed economies, see Scarf and Shoven.

national income and product accounts, a Social Accounting Matrix (SAM) summarizes the full circular flow of goods and services in the economy. Its cornerstone is a traditional input-output table that captures intersectoral flows of intermediate inputs. In addition, a SAM includes flows from producing activities to factors of production and final demand, and then from factors back to activities.

The foundation of SAM accounting is a square matrix in which each row sum equals the corresponding column sum. It is illustrated by a SAM using 1982 data for the U.S. economy shown in Figure 8.1.[2] The top left-hand corner of the matrix, showing flows from one Activity to another, is the traditional input output table. It illustrates that in 1982, for instance, the Agriculture industry purchased $71 billion of goods from Agriculture-related activities. In addition, the SAM shows income flows from Activities to Value added, in the second block in the first column. For instance, workers in Agriculture-related activities earned $1314 billion in labor income in 1982. The SAM framework also depicts the flow of income in the economy among different Institutions (namely, labor, firms, and government). Total labor income (the sum of Row 4: Labor income) equals $1864 billion. The distribution of that labor income between Labor ($1613) and Government ($251) is shown in Column 4 of the SAM. The SAM further illustrates the flow of total Labor income to

[2] The SAM is reproduced from Adelman and Robinson (1986), and highlights the agriculture sector. The following description of SAM's draws on Adelman and Robinson.

Households, based on the size distribution of income. For instance, the richest 20 percent of Households earned $725 billion in 1982, while the poorest 40 percent earned $145 billion. The SAM includes a block illustrating not only the sources of income for Households, but also the disposition of that income. (In other words, it shows the consumption expenditures of households.) The block containing rows 1-3 and columns 10-12 shows that the Middle 40% of Households spent $692 billion on Agriculture-related activities, while the poorest 40% of Households spent $389 billion. Finally, the SAM shows the sources and disposition of income for three remaining institutions: Capital, Government and Rest of world. The row for the Capital account (13) shows that most of its income comes from Enterprises ($388 billion), while the column shows that most of its

Figure 8.1: Social Accounting Matrix[3]

	Activities			Value added			Institutions								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Activities															
1 Agriculture	50	94	10							5	9	7	-.2	8	19
2 Ag-related	71	1120	443							389	692	634	41	452	97
3 Othr activity	8	453	645							45	102	103	374	190	232
Sum	128	1667	1097							439	803	744	415	651	348
Value added															
4 Labor income	19	1314	531												
5 Capital income	45	701	200												
6 Ind. bus. tax	4	217	38												
Sum	68	2233	769												
Institutions															
7 Labor				1613											
8 Proprietors					112										
9 Enterprises					835									53	
Sum				1613	947									53	
Households															
10 Low 40%							145	10	81					205	-.2
11 Mid 40%							742	34	133					107	-.5
12 High 20%							725	68	225					50	-.5
Sum							1613	112	439					362	- 1
13 Capital accnt									388	-19	57	97		-115	7
14 Government				251		259			61	21	156	227		180	-24
15 Rest of world	5	38	286												
TOTALS	201	3937	2152	1864	947	259	1613	112	888	441	1016	1068	415	1130	329

[3] Data for U.S. economy in 1982, billions of dollars. Source: A&R, page 1197, data provided by Engineering Economics Associates.

purchases are of non-agricultural commodities ($375 billion purchased from Other activities). The expenditure accounts for Households, Capital, Government, and Rest of world are simply the product accounts of the National Income and Product Accounts: Personal consumption expenditures, Investment, Government spending, and Net exports. The SAM summarizes flows between activities (the input-output matrix), as well as income distribution and transfers between institutions (capital account to government, for example).

As shown here, the SAM is not a model in itself, but rather is an accounting framework for depicting the interrelationships in the economy. Its usefulness as a model is developed by computing coefficients and using those coefficients to derive multipliers. The first step is to compute SAM coefficients by dividing each element in a column by the column sum. The result is called the A matrix. Since each row total equals the corresponding column total, a vector of row or column totals can be written

$$x = A\,x \quad (8.1)$$

where

x = vector of row or column totals,
A = matrix of SAM coefficients.

Because equation 8.1 represents a homogenous-equation system, the multipliers for analyzing a change in any column sum are equal to 1.0. In order to calculate more meaningful multipliers, the SAM A-matrix first must be partitioned into endogenous and exogenous columns, with a corresponding interchange of rows. Then, equation 8.1 becomes:

where
y = endogenous column sums,
z = exogenous column sums,
B,C,D,E = partitions of A matrix based on y and z vectors.

The solution for the endogenous column sums can be written as:

The components of $(I - B)^{-1}$ C are then the SAM multipliers, and the following equation for the vector of exogenous column sums is simply ignored:

The multiplier matrix summarizes the relationships among activities, among institutions, and from activities to institutions. One of the important steps in setting up a SAM multiplier matrix is choosing the accounts to make exogenous. Standard practice is to choose some combination of the Capital account, Government, and the Rest of world sector. (p. 1200) The computed multipliers then can be derived to analyze a shock to the model, where the shock is defined as a change in one of the exogenous variables.

Value-added Shock to Agriculture

Recent work by Adelman and Robinson (A&R) points out the importance of analyzing a change to agriculture in a general equilibrium framework. The authors point out that partial equilibrium analysis ignores many important feedbacks between agriculture and the rest of the economy. The Agriculture sector purchases Fertilizers, for example, while the income earned in Agriculture is spent on consumer goods, among other items, and therefore affects non-agricultural sectors of the economy. In analyzing changes in agricultural policy, A&R use a SAM multiplier model to avoid the shortcomings of partial equilibrium analysis, which would ignore Agriculture's links to the rest of the economy. The SAM is based on 1982 data, and the multiplier model is derived by assuming Government and Rest of world are exogenous.[4]

[4] In the A&R paper, it is not clear exactly how the multipliers for an increase in agriculture's value added are computed. The authors state that their model "focuses on the adjustment of the economy to shocks arising from changes in government expenditures and exports" (page 1200). Four shocks are analyzed with the SAM model, including a $10 billion increase in agriculture's value added.

Using a SAM-based multiplier model, A&R show the beneficial effects, to both the agricultural and non-agricultural sectors of the economy, of a ten billion dollar increase in agriculture's value added. It is assumed that the increase in value added does not change agricultural production, but rather is a strict transfer of income.[5] The results of the A&R analysis are summarized in Table 8.1. Non-agricultural value added rises by $19 billion, while agricultural value added rises by $10.4 billion. In addition, non-agricultural production increases by $38 billion, and non-agricultural income increases by $19 billion. The increase in agriculture's value added increases demand in the system, and yields positive leakages to the rest of the economy.

As noted by the authors, the multiplier model is completely demand driven. The multipliers are strictly fixed-price multipliers, and do not consider effects induced by changes in relative prices. Also, the multiplier model gives the comparative static results for a shock to the system, but does not specify the dynamic path taken to achieve the static solution. It may well be that an increase in agricultural value added of $10 billion leads to a $38 billion increase in nonagricultural output, but how and when that increase occurs may be just as important as the amount of the increase.

Table 8.1: Results of Value added Shock to Agriculture
Using SAM Multiplier Model[6]

billions of dollars and percentages

Presumably, the increase results from a transfer from the Government to Agriculture (as a reduction in Indirect business taxes of Agriculture, for example.) Alternatively, SAM multipliers could have been computed by creating a separate, exogenous, row/column for Agriculture, and computing the multipliers using the new exogenous column.

[5] A&R point out that price support programs that keep quantities unchanged, for example, result in direct increases in value added, with no change in input demand. In addition, input subsidies, such as the Farm Credit Program, combined with output controls also result in an effective subsidy to value added. (page 1203)

[6] Adelman and Robinson, page 1204.

	1982 value	Change	% change
Producing activities			
Agriculture	201.43	1.171	0.581
Food & tobacco	310.03	2.114	0.682
Chemicals	464.51	2.657	0.572
Utilities	525.83	3.285	0.625
Wholesale/retail	564.27	4.149	0.735
Finance,insur,re	720.12	5.471	0.760
Services	1352.65	7.240	0.535
Other	2152.19	13.242	0.615
Nonagriculture Sum	6089.61	38.159	0.627
Value added: Agriculture			
Employee compensation	18.79	3.054	16.258
Proprietor income	45.13	7.297	16.168
Indirect business tax	3.64	0.021	0.583
Sum	67.56	10.373	15.353
Value added: Nonagriculture			
Employee compensation	1845.43	11.252	0.610
Proprietor income	901.13	5.971	0.663
Indirect business tax	255.12	1.776	0.696
Sum	3001.69	18.999	0.633

Value-added Shock to Agriculture in LIFT

The accounting framework of a SAM is similar to the accounting framework of an Interindustry Macroeconomic model. As noted in Chapter 2, the cornerstone of an IM model is the A matrix of input-output coefficients, but the model also reconciles input-output data with National Income and Product Account data. The IM model includes the relationships between production activities, factor income, and final demand. Since the IM model is a closed system, like the SAM, all inter-institutional flows in the economy are accounted for.

The IM model differs from a simple SAM multiplier model, however, in three respects important for this analysis. First, the IM model is not based on fixed-prices, but rather includes the response of prices to changes in costs and demand. Second, behavior in the IM model is determined based on estimated parameters that are consistent with historical behavior of producers, consumers, and institutions. In the SAM model, relationships between institutions are determined by fixed coefficients which are based on data for one particular year. In determining the amount of Household income spent on Agriculture-related activities, for example, the SAM model uses a fixed coefficient based on 1982 data. In LIFT, on the other hand, the amount spent by persons (Households) on Agriculture-related activities is determined by the price of Agriculture-related products, the price of those products relative to Other commodities, as well as by the level of personal income. Third, the IM model projects economic variables over time and explicitly allows for lags in response to changes in the economy. The multiplier analysis, on the other hand, gives only the comparative static solution.

In the following exercise, the LIFT model is used to analyze the effects of an increase in value added for Agriculture. Because the model is based on the input-output equations for output and prices, an increase in value added corresponds to an increase in price. A concurrent increase in price and value added can occur in the following manner. Consider an increase in the world price of grain due to a crop failure abroad. An increase in the world price of grain, with no concurrent increase in costs of production for American farmers, implies that the surplus of farmers increases. The income shock introduced to LIFT assumes that agricultural value added is increased by $10 billion, and that the increase corresponds to an increase in agricultural prices. The scenario therefore includes the stimulatory income effects of an increase in value added, as does the A&R multiplier analysis. In addition, however, it includes the negative effects of a price shock, which the fixed-price multiplier model omits.

The macroeconomic effects of the agriculture shock are summarized in Table 8.2. (The shock scenario is compared to the Base forecast described in Chapter 7.) In the shock scenario, agricultural value added was permanently increased by $10 billion, starting in 1992. By 1992, GNP is almost $3 billion lower, or .097%, than it would have been without the shock. Although agriculture's real income is $9.4 billion higher than in the Base forecast, overall labor compensation is $4.4 billion lower than in the Base. Lower income reduces personal consumption expenditures, which are $1.6 billion (.08%) lower due to the shock. Higher inflation also leads to higher interest rates, which, combined with lower output, decreases investment expenditures. Fixed investment is $1.6 billion lower than in the Base forecast in 1992.

In the long run, the positive income effects of the shock help the economy recover almost completely. By 1998, the decrease in GNP is less than $100 million dollars, or just .003%. Employment likewise recovers partially from the shock, with the drop in employment cut in half by 1998. The increase in agricultural income leads to an increase in disposable income, which stimulates consumption expenditures. In addition, fixed investment recovers partially, and is only $400 million lower than in the Base forecast by 1998.

The deleterious short-run effects of the shock are caused by the price shock implied by an increase in value added. Higher prices increase costs throughout the economy. An increase in agricultural prices raises costs for the Food and tobacco industry, for example. Higher costs lead to further price increases and reductions in demand.

Table 8.2: Macroeconomic Effects of Agriculture Value Added Shock in LIFT

	1991	1992			1998		
	base	base	diff	% diff	base	diff	% diff
billions of 1977$ and %							
Gross national product	2810.0	2885.1	-2.8	-0.0971	3211.7	-0.1	-0.0031
Personal consumption	1854.7	1902.1	-1.6	-0.0841	2083.8	2.0	0.0960
Producer durable equipment	255.9	264.5	-1.2	-0.4483	320.0	0.1	0.0347
Structures (Nonresidential)	80.4	87.5	-0.2	-0.2527	97.8	0.3	0.3303
Residential structures	114.9	118.2	-0.2	-0.2038	117.8	-0.8	-0.6432

Inventory change	16.6	17.5	-0.1	-0.7779	16.4	.03	0.1893
Exports	408.1	431.7	-0.0	-0.0088	561.9	-0.6	-0.1125
Imports	450.3	461.6	-0.6	-0.1200	518.0	1.2	0.2239
Disposable income, 1972$	1421.2	1455.0	-0.6	-0.0412	1609.9	1.3	0.0807
Unemployment rate	5.53	4.65	0.06	-	4.64	.03	-
Inflation rate	2.66	3.42	0.10	-	3.60	.06	-
Corporate bond rate	9.27	9.30	0.04	-	10.42	.14	-
Non-Agricultural income, 1992$							
Labor compensation	3410.9	3606.2	-4.40	-0.1220	3885.3	-8.77	-0.2260
Proprietor income	315.7	341.5	-0.34	-0.0980	363.4	-0.62	-0.1710
Agricultural income, 1992$							
Labor compensation	22.35	23.59	-0.00	-0.0190	23.62	-0.12	-0.4920
Proprietor income	86.61	96.29	9.41	9.7670	110.60	17.77	16.0660

Higher prices also imply that real income falls, which further reduces demand.

The effect of the shock on sectoral outputs, summarized in Table 8.3, highlights the contrasting impact of the shock in the short and long run. In the short run, 1992, output falls in almost all producing sectors of the economy. Higher prices induced by the increase in agricultural prices decrease demand. The sectors that use agricultural products as inputs, such as Food and tobacco, Eating and drinking places, and Lumber, suffer some of the largest percentage decreases in output. Likewise, those sectors that supply agriculture, such as Agricultural machinery and Agricultural fertilizers, also see relatively large reductions in output. As the stimulatory effects of increased demand emerge, demand for income-sensitive products increases. In the long-run, output of sectors such as Movies and amusements, Ships and

Table 8.3: Industry Effects of Agricultural Value Added Shock in LIFT

billions of 1977$ and percent

diff = output in Agriculture shock - output in Base Forecast
% diff = diff as percent of output in Base forecast

	1991	1992			1998			base
base	diff	% diff	base	diff	% diff			
	b 77$	b 77$	b 77$	percent	b 77$	b 77$	percent	

Agriculture, forestry, fishery	160.15	164.45	-0.72	-0.4366	183.02	-1.29	-0.7044
Agriculture-linked: buyers	1084.60	1116.73	-2.96	-0.2651	1253.55	-3.45	-0.2751
Food and tobacco	272.69	276.96	-1.45	-0.5239	296.11	-2.67	-0.9031
Eating and drinking places	112.02	114.92	-0.53	-0.4585	127.59	-0.82	-0.6416
Textiles	40.46	42.19	-0.02	-0.0412	48.10	0.01	0.0235
Lumber	53.20	55.75	-0.12	-0.2174	63.01	-0.26	-0.4133
Wholesale trade	321.77	334.18	-0.62	-0.1842	395.29	-0.27	-0.0689
Retail trade	284.45	292.72	-0.23	-0.0782	323.46	0.57	0.1750
Agriculture-linked: suppliers	595.04	614.28	-0.65	-0.1062	684.10	-0.19	-0.0282
Agricultural fertilizers	13.50	13.83	-0.03	-0.2444	15.36	-0.06	-0.4140
Agricultural machinery	9.47	10.20	-0.12	-1.1779	11.64	-0.09	-0.8044
Trucking, highway transp	77.20	79.85	-0.12	-0.1454	91.79	-0.05	-0.0594
Chemicals	156.00	162.38	-0.06	-0.0397	186.60	-0.01	-0.0034
Construction	149.56	154.56	-0.22	-0.1400	168.03	-0.09	-0.0537
Electric utilities	87.03	89.47	-0.06	-0.0672	100.69	0.00	0.0036
Petroleum refining	102.28	103.98	-0.04	-0.0398	110.00	0.11	0.1015
All other industries	3309.87	3413.99	-2.30	-0.0674	3922.97	2.86	0.0729
Mining	81.39	83.31	-0.06	-0.0767	89.43	0.02	0.0263
Nondurables	297.99	307.40	-0.21	-0.0675	350.33	0.10	0.0273
Apparel	46.84	47.97	0.01	0.0117	51.57	0.05	0.0950
Other nondurables	251.14	259.43	-0.21	-0.0821	298.76	0.05	0.0156
Durables	879.87	916.65	-1.33	-0.1448	1103.13	0.77	0.0694
Nonelectric machinery	184.59	193.62	-0.42	-0.2188	255.40	0.00	0.0001
Electrical machinery	164.97	172.54	-0.11	-0.0658	227.97	0.10	0.0420
Transportation equip	201.79	208.36	-0.30	-0.1464	230.14	0.62	0.2687
Other durables	328.52	342.13	-0.49	-0.1418	389.61	0.05	0.0131
Transportation	118.19	122.57	-0.06	-0.0510	148.07	0.03	0.0232
Utilities	202.96	210.99	-0.12	-0.0583	252.76	0.18	0.0704
Services	827.78	856.45	-0.32	-0.0377	993.18	1.28	0.1287
Hotels; non-auto repair	65.17	67.25	0.00	0.0045	74.71	0.22	0.2942
Automobile repairs	76.61	79.29	-0.01	-0.0145	90.88	0.21	0.2321
Movies and amusements	53.39	56.01	-0.06	-0.1021	65.26	0.13	0.2003
Other services	632.61	653.90	-0.26	-0.0394	762.34	0.72	0.0941
Miscellaneous	901.69	916.62	-0.19	-0.0210	986.07	0.48	0.0490

boats, and Other services benefit from the income effects of the shock.

The analysis of an agricultural value added shock in LIFT contrasts with the results from the SAM multiplier analysis in several respects. Interestingly, in the SAM analysis, a $10 billion increase in agriculture value added has a positive multiplier on its own income, and value added increases by an additional $.4 billion dollars. In the LIFT analysis, the $10 billion increase corresponds to an increase in price, which reduces demand for agricultural products, and the net effect on agricultural income is slightly less than the original $10 billion increase. The largest difference between the SAM analysis and the LIFT results centers on the price effects of an increase in value added. In the fixed-price analysis, an injection of income to agriculture has uniformly positive leakages on the rest of the economy. In LIFT, the initial effect of the shock is uniformly negative, in response to higher inflation and lower real income. Eventually, as the effects of higher income for agricultural workers and proprietorships affect aggregate income, there are some positive leakages to other sectors of the economy. Unlike in the multiplier analysis, however, the effects are not unanimous. Some industries are more affected by the price effects, even in the long run, than by the positive income effects. In addition, industries where there are positive long-run effects of the change generally have a smaller increase from the shock in the LIFT model than in the SAM multiplier analysis. For instance, the long-run percentage increase for Services in the LIFT analysis is .129%, while in the SAM multiplier analysis it is .535%.

Conclusions

Two conclusions on the effect of an agricultural value added shock are evident from the analysis with the LIFT model. First, LIFT highlights not only the stimulatory income effects of the shock, but also the deleterious effects of the implied price shock. These results contrast strongly with the results of a similar experiment with a SAM multiplier model that illustrates only the stimulatory income effects of the shock. The two experiments can best be seen as representing two extreme types of changes in agriculture. It is possible to define an income shock to agriculture that would have little or no effect on agricultural prices, as implied by the SAM analysis. It is highly unlikely, however, that such an initial change would not eventually affect prices in the rest of the economy. The fixed-price analysis is only appropriate, therefore, for quantifying one aspect of an income shock. As defined in this experiment, the income shock in the IM model corresponds to an equivalent price shock. Although the experiment may overstate the price effects of the agriculture shock, it provides a more complete picture of the income change because it includes price changes for the rest of the economy as well.

Analysis with the IM model also highlights the importance of the timing of the different effects of the change in value added. The negative effects of the price shock are felt immediately, while the offsetting stimulus from the change in income occurs with a lag. The SAM-based multiplier model gives no such insight into the dynamic effects of an income shock to agriculture. In analyzing a policy decision that involves a change in Agricultural income, the IM analysis shows that the time-horizon chosen to analyze the shock is crucial in evaluating the its overall impact. The ability to specify the dynamics of a policy change makes the IM model preferable to SAM multiplier models as a tool for policy analysis, when the timing of the effects of the policy change are important.