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David W. Roland-Holst and Ferran Sancho*

Abstract—The aim of this paper is to develop an intersectoral price model in a Social Accounting Matrix. Traditionally, the emphasis of the Social Accounting methodology has been on quantity oriented models and their income effects. In contrast, we use the Social Accounting Matrix to develop a price model that captures the interdependence among activities, households, and factors and provides a complete set of accounting prices. Furthermore, we use decomposition techniques to trace underlying general equilibrium effects.

Introduction

THE Social Accounting Matrix (SAM) approach has been intensively used to examine the income generating process. Sectors in a SAM are partitioned into two mutually exclusive classes, i.e., endogenous and exogenous, and the income or activity levels of the former are explained by those of the latter through reduced form multipliers. In essence, SAM models are extensions of the input–output model that account for income generation from non-industrial demand sources.

Although the underlying mathematics imposes no restriction on the choice of endogenous and exogenous accounts, economics dictates criteria for sensible partitioning of the SAM. The SAM approach to modeling is a very flexible one and is a basic element in the tool kit of the general equilibrium economist. SAMs have been used to study (i) growth strategies in developing economies (Pyatt and Round (1985), Robinson (1988)), (ii) income distribution (Pyatt and Roe (1977), Adelman & Robinson (1978)) and redistribution (Roland-Holst and Sancho (1992)), (iii) fiscal policy in national or regional settings (Whalley and St. Hillaire (1983, 1987)), and (iv) decomposition of activity multipliers that shed light on the circuits comprising the circular flow of income (Stone (1981), Pyatt and Round (1979), Defourny and Thorbecke (1984), Robinson and Roland-Holst (1988)). SAMs have also been used to provide applied general equilibrium models with consistent calibration data (Ballard et al. (1985)). In fact, as Pyatt (1988) convincingly argues, any disaggregate model has, knowingly or not, an associated Social Accounting Matrix.

Surprisingly, however, SAM-based models have not been used to examine price formation. The aim of this paper is to show how the SAM approach is useful for analyzing price formation and cost transmission mechanisms in economies with institutional rigidities. In these economies factor prices need not conform to the neoclassical paradigm and are implicitly indexed to commodity prices or cost-of-living effects. Of course, no real-world economy is purely neoclassical or purely structural, but by analyzing the structural components in isolation, we gain additional knowledge about the transmission mechanism for prices and its implications for policy and welfare. The next section of the paper develops the dual relationship between standard SAM-based quantity models and SAM-based price models. Section II sets up the basic framework for a linkage decomposition analysis. To illustrate the potential usefulness of the approach, we use in section III the latest available SAM for Spain to proceed to block-decompose a price multiplier matrix, showing how price variations depend upon and interact between the large determinants of price levels. In section IV we contrast this with the path-decomposition of the multiplier matrix to provide a detailed micro analysis of sectoral price linkages. A summary section ends the paper.

I. SAM-based Price Models

A standard SAM offers a disaggregate view of value flows in a given base period, detailing the direct linkages among its component sectors and institutions but also pointing out the scope of the underlying indirect interactions. Inflows from exogenous sectors that stimulate the level of activity of a production sector, for instance, will also induce additional factor incomes that, once distributed among households, will be used to finance new final demand for producer goods and services. Table 1 depicts a partitioned simplified

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TABLE 1.—MACRO SAM

	I	II	III	IV	V
I. Production	T_{11}	O	T_{13}	T_{14}	Y_1
II. Factors	T_{21}	O	O	T_{24}	Y_2
III. Households	O	T_{32}	T_{33}	T_{34}	Y_3
IV. Rest	T_{41}	T_{42}	T_{43}	T_{44}	Y_4
V. Total	Y_1	Y_2	Y_3	Y_4	

macro SAM with four classes or groups of accounts, namely, production, factors, households, and a consolidated account of the remaining sectors (government, capital and foreign accounts). Columns of the SAM indicate payments and rows show receipts. For each group total spending is necessarily equal to total receipts, i.e., column and row totals of the matrix are equal.

A SAM-based quantity model is derived from the table by distinguishing endogenous and exogenous groups and assuming activity levels may vary while prices are fixed. This assumption is justified in the presence of excess capacity and unused resources in production activities. Suppose group 1 is chosen as endogenous and 2, 3 and 4 as exogenous. Let A_{ij} denote the matrix of normalized column coefficients obtained from T_{ij} and let $\bar{Y}_i$ denote that the incomes of groups $i = 2, 3, 4$ are taken as given exogenously. Then the income level of group 1 can be expressed by

$$\begin{aligned} Y_1 &= A_{11}Y_1 + A_{13}\bar{Y}_3 + A_{14}\bar{Y}_4 \\ &= (I - A_{11})^{-1}\left(A_{13}\bar{Y}_3 + A_{14}\bar{Y}_4\right) = M_{11}x \end{aligned} \tag{1}$$

where $M_{11} = (I - A_{11})^{-1}$ is the interindustry Leontief inverse and x is a vector of exogenous income levels. Since (1) implies $\Delta Y_1 = M_{11}\,\Delta x$, matrix M_{11} is also termed the multiplier matrix. Column i of M_{11} shows the global effects on all endogenous activity levels induced by an exogenous unit inflow accruing to i, after allowing for all interdependent feedbacks to run their course.

Consider now the alternate polar case in which prices are responsive to costs but not to activity levels. The justifying assumption here, in addition to the usual excess capacity condition, is generalized homogeneity and fixed coefficients in activities. This is a situation where the classical dichotomy between prices and quantities holds true and prices can be computed independently of activity levels. Let p_i now denote a price index[1] for group i's activity. With the same classification of endogenous and exogenous accounts and identical notational conventions as above, reading down column 1 of the SAM gives us

$$\begin{aligned} p_1 &= p_1 A_{11} + \bar{p}_2 A_{21} + \bar{p}_4 A_{41} \\ &= (\bar{p}_2 A_{21} + \bar{p}_4 A_{41})(I - A_{11})^{-1} = \nu_1 M_{11} \end{aligned} \tag{2}$$

where ν_1 is a row vector of exogenous costs (i.e., factor payments, taxes, import costs) and M_{11} is the same multiplier matrix as in (1). Notice that from (2) we have $\Delta p_1 = \Delta \nu_1\, M_{11}$ and so we can re-interpret the Leontief inverse by reading across rows. Row j of M_{11} displays the effects on prices triggered by a unitary exogenous change in sector j costs. This is a straightforward but seldom used interpretation of Leontief's multiplier matrix.

Starting from equation (1) of the basic linear model, SAM-based quantity models yield extensions to encompass a larger and more complete view of the income generating process. In the same way, SAM-based price models departing from expression (2) may prove to be useful generalizations for evaluating the extensive cost linkages that pervade the relationships among households, factors, and producers. To give content to this approach consider each one of these groups as undertaking an economic activity. Producers pay for raw materials (T_{11}) and factors (T_{21}) which are combined to generate output; factors make use of households' endowments (T_{32}) to provide firms with labor and capital services. Finally, households purchase output (T_{13}) from production to obtain consumption.[2] Additionally, each group is liable to pay taxes or import costs to the consolidated group 4. In terms of taxes, the government collects indirect production taxes from firms, taxes on the use of labor and capital from factors, and indirect consumption taxes and income taxes from households. Thus, each of these activities has an implicit cost or price index which is linked to the rest of price indices through the coefficient submatrices of the SAM. But as it stands, price expression (2) omits these linkages

[1] The notion of price should be taken in the same broad sense that the notion of income of a sector or institution has in a SAM framework.

[2] Transfers among households T_{33} can be thought as distribution cost linked to consumption.

and thus falls short of a satisfactory representation of interdependencies in the economy.

These links can be coherently integrated into a model by considering the three sets of accounts comprising producers, factors and households as endogenous and taking the consolidated account as exogenous. Using the column normalized expenditure coefficients and reading down the SAM columns for endogenous accounts yields

$$\begin{aligned} p_1 &= p_1 A_{11} + p_2 A_{21} + \bar{p}_4 A_{41} \\ p_2 &= p_3 A_{32} + \bar{p}_4 A_{42} \\ p_3 &= p_1 A_{13} + p_3 A_{33} + \bar{p}_4 A_{43}. \end{aligned} \tag{3}$$

Define a matrix A of normalized coefficients:

$$A = \begin{bmatrix} A_{11} & 0 & A_{13} \\ A_{21} & 0 & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix}$$

let $p = (p_1, p_2, p_3)$ be the vector of prices for the endogenous sectors of the SAM, and set the vector of exogenous costs (taxes, import costs) as $\nu = p_4 A_{(4)}$, where $A_{(4)}$ is the submatrix of the SAM composed by column adjoining A_{41}, A_{42} and A_{43}. In matrix notation,

$$p = pA + \nu = \nu(I - A)^{-1} = \nu M \tag{4}$$

where M is the multiplier matrix. For the same classification of endogenous and exogenous accounts, M is also the multiplier matrix of the endogenous income determination model:

$$Y = (I - A)^{-1} x = Mx. \tag{5}$$

The interpretation of M is different, however, depending on whether we read its entries across the rows or down the columns. To clarify this distinction, M will be referred as the (standard) multiplier matrix whereas its transpose M' will be termed the price-transmission matrix.

II. Block-decomposition of the Price Transmission Matrix

In their seminal papers, Stone (1981) and Pyatt-Round (1979) show that the multiplier matrix M can be decomposed into three economically meaningful additive (or multiplicative) components. Firstly, a transfers matrix that picks up the net multiplier effects induced on a given set of accounts by exogenous transfers accruing to the given set; secondly, an open-loop matrix that captures the cross-effects between different groups; and thirdly a closed-loop matrix detailing the multiplier effects of an exogenous inflow on an endogenous group after it has traveled through the rest of endogenous accounts and returned to the original recipient. To decompose the price-transmission matrix M' let us take expression (4) and consider any matrix $\tilde{A}$ satisfying the obvious algebraic requirements.[3] Then it can be checked that

$$\begin{aligned} p &= pA + \nu \\ &= pA + p\tilde{A} - p\tilde{A} + \nu \\ &= p(A - \tilde{A})(I - \tilde{A})^{-1} + \nu(I - \tilde{A})^{-1} \\ &= pA^* + \nu(I - \tilde{A})^{-1} \\ &= \left[pA^* + \nu(I - \tilde{A})^{-1}\right]A^* + \nu(I - \tilde{A})^{-1} \\ &= pA^{*2} + \nu(I - A)^{-1}(I + A^*) \\ &= \left[pA^* + \nu(I - \tilde{A})^{-1}\right]A^{*2} \\ &\qquad + \nu(I - \tilde{A})^{-1}(I + A^*) \\ &= pA^{*3} + \nu(I - \tilde{A})^{-1}(I + A^* + A^{*2}) \\ &= \nu(I - \tilde{A})^{-1}(I + A^* + A^{*2})(I - A^{*3})^{-1} \\ &= \nu M_1 M_2 M_3. \end{aligned} \tag{7}$$

To obtain the corresponding decomposition, $M' = M_3' M_2' M_1'$, we extract from matrix A the blocks A_{11} and A_{33} and take

$$\tilde{A} = \begin{bmatrix} A_{11} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & A_{33} \end{bmatrix}.$$

[3] $\tilde{A}$ must be conformal to A and $(I - \tilde{A})$ must be invertible.

This yields

$$M_1' = \begin{bmatrix} (I - A_{11})^{-1} & 0 & 0 \\ 0 & I & 0 \\ 0 & 0 & (I - A_{33})^{-1} \end{bmatrix}$$

$$M_2' = \begin{bmatrix} I & A_{21}^* & A_{32}^* A_{21}^* \\ A_{13}^* A_{32}^* & I & A_{32}^* \\ A_{13}^* & A_{21}^* A_{13}^* & I \end{bmatrix}$$

$$M_3' = \begin{bmatrix} (I - A_{13}^* A_{32}^* A_{21}^*)^{-1} & 0 & 0 \\ 0 & (I - A_{21}^* A_{13}^* A_{32}^*)^{-1} & 0 \\ 0 & 0 & (I - A_{32}^* A_{21}^* A_{13}^*)^{-1} \end{bmatrix}$$

with $A_{13}^* = A_{13}(I - A_{33})^{-1}$, $A_{21}^* = A_{21}(I - A_{11})^{-1}$, $A_{32}^* = A_{32}$.

The first column of the multiplicative transfers matrix M_1' shows how an exogenous cost increase affecting the production activities multiplies itself through the interindustry cost linkages (Leontief's inverse) but exerts no effects on groups 2 and 3 (respective entries of the column are zero). In contrast, the first column of the open-loop matrix M_2' indicates how the same exogenous cost increase ends up having an impact on factors (second entry, $A_{13}^* A_{32}^*$) after rebounding from households (third entry, A_{13}^*). Finally, the first column of the closed-loop matrix M_3' captures the impact on production prices of the exogenous increase in producers' costs after first affecting households' cost indices (A_{13}^*), then moving onto factors ($A_{13}^* A_{32}^*$) and from these back to producers ($A_{13}^* A_{32}^* A_{21}^*$). The final figure shows the overall impact after this process has converged.

Any given element of the price-transmission matrix M' can be studied using either the multiplicative or additive decomposition, which yield the same information in a different format. In a general disaggregate SAM, $n + m$ individualized sectors are detailed, n being take as endogenous and m exogenous. Let I and J denote the indexing sets for the exogenous and endogenous accounts, respectively. From (4) above and $i \in I$, $j \in J$, the individual impact on price p_j of an exogenous cost change in sector i can be written as

$$\frac{\partial p_j}{\partial v_i} = m_{ji} = 1 + n_{ji}^1 + n_{ji}^2 + n_{ji}^3 \qquad (8)$$

with $m_{ji} \in M'$.

III. Path-decomposition of Price Influence

The previous section shows that the SAM offers a suitable accounting structure for modeling price formation. Prices can be computed and, furthermore, price variations can be decomposed according to three different categories of interdependence which provide us with a detailed view of the extent and magnitude of cost-linkages as they work through the main linkages. To obtain a more comprehensive description of the effect of linkages on prices, however, we need to go one step further and analyze intersectoral linkages between individual accounts of the SAM by identifying the paths through which cost effects travel. The structural path analysis put forth by Lantner (1974) and Gazon (1979) to study abstract linear systems of equations has been used by several authors to examine input–output quantity systems. Realizing the applicability of this technique to extended linear models, Defourny and Thorbecke (1984) showed the rich information structure that could be derived using this approach in a SAM model. The use of path analysis to investigate cost-linkages is a natural extension and a promising way to enrich our understanding of the price formation mechanism. Following the ideas in these authors' contributions, we now reformulate the concepts of structural analysis for the SAM-based price model. Each pair $\langle i, j \rangle$ of indices in the SAM accounts is called an arc. A path is a sequence s of indices $s = \langle i, k, l, \ldots, m_j \rangle$ which can be decomposed into consecutive arcs $\langle i, k \rangle, \langle k, l \rangle, \ldots, \langle m, j \rangle$. A path with non-repeating indices is termed an elementary path. A circuit of influence is a path s such that the first and last index coincide. The influence of account i on account j through a path s will be represented by $(i \to j)_s$. To estimate the cost influence of account i on account j along $\langle i, j \rangle$, notice from (4) above that, prior to any of the ensuing general equilibrium feedbacks, we have

$$\frac{\partial p_j}{\partial p_i} = a_{ji} \tag{9}$$

thus any exogenous price increase affecting p_i gives rise to a direct price increase in j measured by entry (j, i) of the transpose of the column normalized matrix A. Due to the linear structure of the model, the *direct* price influence along an elementary path $s = \langle i, k, \ldots, m, j \rangle$ is the composite effect of the direct influences along the constituent arcs, i.e.,

$$D^P_{(i \to j)s} = a_{ki} \ldots a_{jm}. \tag{10}$$

In any given path s there may exist feedback effects among its indices. Account i influences k but k in turn may influence i, either directly or through other intermediary indices. Accounts influence themselves through loops as well. All of these feedback effects taking place along circuits in the path work to amplify the magnitude of the direct influence being transmitted over the path. The expanded influence will be called *total* price influence, the ratio of total to direct price influence being the price path-multiplier:

$$T^P_{(i \to j)s} = D^P_{(i \to j)s} \mu^P_s. \tag{11}$$

Notice, on the other hand, that more than one elementary path, each one with its respective feedback circuits, may span two indices i, j. Therefore, the total price influence along a path does not capture the full or global price influence in the network of itineraries linking i and j. Let $S = \{s/i, j\}$ be the set of all elementary paths joining i and j. By additivity, the *global* price influence is defined as

$$G^P_{(i \to j)s} = \sum_{s \in S} T^P_{(i \to j)s} = \sum_{s \in S} D^P_{(i \to j)s} \mu^P_s \tag{12}$$

the last equality, where m_{ji} is the (j, i) entry in the price-transmission matrix M', following from the fact that S includes all connecting paths between accounts i and j. Direct, total and global price influence are three distinct but related concepts of influence that supply precise information on the transmission mechanism underlying price formation.

IV. Numerical Results

We now illustrate the price multiplier analysis with an empirical example using recent Spanish data. The version of the 1987 SAM for Spain used in this study includes 23 endogenous accounts. Of these, 12 are production activities, 3 are factors of production and the remaining 8 describe households groups categorized by socioeconomic characteristics (age, income and education). A listing of the accounts and their label abbreviations appear in the appendix below.

The empirical interpretation of any given multiplier element m_{ji} in the matrix M' is quite straightforward if we take into account that benchmark prices are all, by calibration, set to be unitary. Thus, m_{ji} gives us both the absolute and percentage variation of price j when the exogenous cost in sector i increases by one money unit, and the same considerations apply to any of the elements of a given decomposition. The multiplier matrix in itself is of some interest since it yields information on questions such as, for instance, how a one peseta increase in taxes (production, consumption, and factor taxes, as well as tariffs, for instance) will rise producers' prices, factor prices and individual cost-of-living indices, hence providing useful information on the distortionary effects of taxes but also, and equally important, on the welfare effects on individual consumers as measured by changes in their expenditures. Tables 2 and 3 present a selection of the price decomposition results.[4]

A. *Block-decomposition of Price Multipliers*

Table 2 focuses on the additive block-decomposition of the price multiplier matrix and reveals the extent of price effects that can be traced to each of the big circuits of influence. Examples 1 through 6 show the decomposition of a 1 peseta increase in the exogenous cost of production activities and the implied effect on production prices. Example 1 indicates that the price of the Food Industry products would potentially rise by 0.607 pesetas with a 0.496 increase taking place

[4] The complete empirical results are available from the authors.

TABLE 2.—BLOCK-DECOMPOSITION OF PRICE MULTIPLIERS

Cost Increase in sector i	Price Effect in Destination Sector j	Price Multiplier M	Transfers Effects $1 + N_1$ (%)	Open-loop Effects N_2 (%)	Closed-loop Effects N_3 (%)
1. Agriculture	Food Industry	0.607	0.496 (81.7%)	0	0.110 (18.3%)
2. Energy	Construction	0.280	0.119 (42.5%)	0	0.161 (57.5%)
3. Energy	Transportation	0.396	0.229 (57.8%)	0	0.167 (42.2%)
4. Machinery	Automobiles	0.181	0.148 (81.8%)	0	0.033 (18.2%)
5. Automobiles	Machinery	0.018	0.001 (11.1%)	0	0.016 (88.9%)
6. Food Industry	Other Manufacturing	0.187	0.032 (17.7%)	0	0.154 (82.3%)
7. Agriculture	Young-low income	0.203	0	0.111 (54.7%)	0.092 (45.3%)
8. Food Industry	Young-low income	0.301	0	0.166 (55.1%)	0.135 (45.9%)
9. Construction	Young-low income	0.125	0	0.040 (32.0%)	0.085 (68.0%)
10. Agriculture	Unskilled Labor	0.145	0	0.081 (55.9%)	0.064 (44.1%)
11. Construction	Unskilled Labor	0.112	0	0.053 (47.3%)	0.059 (52.7%)
12. Food Industry	Unskilled Labor	0.214	0	0.119 (55.6%)	0.095 44.4%)
13. Construction	Capital	0.148	0	0.084 (56.8%)	0.065 (43.2%)
14. Unskilled Labor	Agriculture	0.545	0	0.241 (44.2%)	0.324 (55.8%)
15. Unskilled Labor	Food Industry	0.581	0	0.295 (50.8%)	0.286 (49.2%)
16. Unskilled Labor	Private Services	0.774	0	0.448 (57.9%)	0.326 (42.1%)
17. Unskilled Labor	Public Administration	1.055	0	0.727 (67.0%)	0.328 (33.0%)
18. Unskilled Labor	Adult-low-unskilled	0.484	0	0.255 (52.7%)	0.229 (47.3%)

due to interindustry interactions (81.7% of the overall effect) and 0.11 (only 18.3% of total) originating in closed-loop price effects. Open-loop effects are zero since origin and destination sectors belong to the same account category. As can be seen from examples 1–6, no general patterns are discernible in the decomposition. Transfer effects can dominate closed-loop effects, as in cases 1 and 4, or the other way around, cases 5 and 6, where closed-loop effects dominate transfer effects. Example 3 shows, on the other hand, a relatively balanced case in which transfer and closed-loop effects are of a similar order of magnitude. These figures help to unveil the nature of the general equilibrium price effects hidden in the multiplier process and provide useful infor-

TABLE 3.—PATH-DECOMPOSITION OF PRICE INFLUENCE

Cost Increase in Sector i	Destination Sector j	Paths	Price Influence Global	Direct	Path	Total	$\%T/G$
1. Agriculture	Food Industry	Ag. → FI	0.607	0.355	1.624	0.577	10.5
2. Energy	Construction	En. → Co	0.280	0.023	2.198	0.051	18.3
		En. → BI → Co		0.017	3.492	0.058	20.8
		En. → Tr → Co		0.003	2.592	0.009	3.1
3. Energy	Transportation	En → Tr	0.396	0.102	2.372	0.242	61.0
		En → ALU → UL → Tr		0.005	3.270	0.016	4.1
		En → ALS → Cap → Tr		0.005	3.437	0.016	3.9
4. Machinery	Automobiles	Ma → Aut	0.181	0.098	1.483	0.146	80.3
5. Automobiles	Machinery	Aut → Ma	0.018	0.001	2.133	0.003	14.3
6. Food Industry	Other Manufacturing	FI → OM	0.187	0.011	1.925	0.022	11.8
		FI → Ag → OM		0.003	2.244	0.008	4.2
		FI → ALU → UL → OM		0.013	2.509	0.031	16.8
7. Agriculture	Young low-income	Ag → YLI	0.203	0.032	1.340	0.043	21.0
		Ag → FI → YLI		0.035	1.633	0.057	28.0
		Ag → FI → Com → YLI		0.010	2.143	0.021	10.3
8. Food Industry	Young low-income	FI → YLI	0.301	0.098	1.396	0.137	45.4
		FI → Ag → YLI		0.004	1.633	0.007	2.4
		FI → Com → YLI		0.027	1.852	0.051	16.9
9. Construction	Young low-income	Con → YLI	0.125	0.012	1.123	0.014	11.0
		Con → Com → YLI		0.004	1.532	0.007	5.4
		Con → PS → YLI		0.013	1.736	0.022	17.6
10. Agriculture	Unskilled labor	Ag → ALU → UL	0.145	0.021	1.856	0.039	26.5
		Ag → FI → ALU → UL		0.022	2.161	0.047	32.5
11. Construction	Unskilled Labor	Con → ALU → UL	0.112	0.021	1.548	0.033	29.6
		Co → AHU → UL		0.011	1.617	0.018	15.7
		Con → PS → ALU → UL		0.007	2.117	0.015	13.1
12. Construction	Capital	Con → ALU → Cap	0.148	0.007	1.833	0.014	9.1
		Con → AHU → Cap		0.033	1.631	0.054	36.2
		Con → AHS → Cap		0.020	1.587	0.032	21.3
13. Unskilled labor	Food Industry	UL → FI	0.581	0.111	1.748	0.194	33.5
		UL → Ag → FI		0.040	2.017	0.194	14.0
		UL → Com → FI		0.009	2.088	0.019	3.2
14. Unskilled labor	Private Services	UL → PS	0.774	0.276	1.930	0.532	68.8
		UL → CON → PS		0.024	1.989	0.048	6.1
15. Unskilled labor	Public Administration	UL → PA	1.055	0.629	1.354	0.861	80.7
		UL → PS → PA		0.016	1.932	0.031	3.0
16. Unskilled labor	Adult-low-unskilled	UL → FI → ALU	0.484	0.012	1.884	0.023	4.7
		UL → Com → ALU		0.052	1.739	0.091	18.7
		UL → PS → ALU		0.042	2.064	0.088	18.1

mation regarding the underlying cost linkages among sectors. A relatively large transfer effect (and correspondingly, a small closed-loop effect) points out to a sector which is highly integrated and has weak forward links to the rest of the economy.

Examples 7 through 9 illustrate the price effects on young low-income households of a cost increase in production activities. Of the 0.203 pesetas increase in the cost-of-living index following a one peseta exogenous cost increase in agricultural production, 0.111 (54.7%) correspond to open-loop effects and 0.092 (45.3%) to closed-loop effects. As a general rule for household types, open-loop effects tend to slightly dominate closed-loop effects. Transfer effects are zero in all these cases since the origin and destination sectors are in different account categories.

The next four examples (10–13) analyze the impact on factors of increasing costs in production activities while the next set of examples (14–17) studies the opposite linkages and captures the induced effect on production prices of exogenous increases in factor prices. The final example relates factors with households and traces the incidence of an increase in the cost of using unskilled labor on the cost-of-living of adult, low-income, unskilled households. Increasing labor costs push up commodity prices which in turn affect households' cost-of-living.

In general, a large open-loop effect between two sectors suggests a high degree of dependence of the destination sector upon the origin sector, but the link need not be symmetrical. In case 10, for instance, the open-loop effect of Agriculture on Unskilled labor is larger than the closed-loop effect, whereas in case 14 the opposite is true when Unskilled labor is the origin sector and Agriculture the receiving one. In examples 12 (Food Industry on Unskilled labor) and 15 (Unskilled labor on Food Industry), however, the open-loop effects are larger than the respective closed-loop effects. Without evaluating the equilibrium linkages revealed by the decomposition, it would be difficult or impossible to assess these detailed price effects by rules of thumb or inspection of the multiplier matrix.

B. *Path Decomposition of Price Multipliers*

The price-transmission matrix M' provides a global summary of the composite cost feedbacks in the economic structure represented by the SAM. As such, it does not unveil the constituent elements corresponding to linkages in the multiplier process. By using the path decomposition technique, we obtain a measure of how sectoral linkages contribute to the global multipliers, thus yielding valuable insights on cost transmission. The decomposition technique has been applied to the SAM for Spain and some of the results appear in table 3. Unless otherwise stated, only those paths contributing 0.003 or more of the direct influence are presented. For a given multiplier or global effect, we report the direct and total price influence, the corresponding price path multiplier, and the proportion of the global price effect explained by the influence being carried along the path.

Effects on production prices of changing production costs: The first set of examples in table 3 reports the effects on production prices of exogenous cost changes in production activities. We know that $m_{ji} \in M'$ measures the price variation in j as a result of a cost change falling on activity i, but we do not know the extent to which the price change is due mainly to a strong dependence of j on i or is the result of a widespread set of cost changes induced in other production sectors. Cases 1, 3 and 4 exemplify the former, whereas cases 2, 5 and 6 illustrate the latter.

In the presence of a unitary exogenous cost change in Agriculture, the price of the Food Industry output would rise by 0.607 pesetas and most of the change can be attributed to the direct link along the arc $\langle Ag, FI \rangle$ connecting these sectors. The direct price influence (0.355) is amplified by the price path multiplier (1.624) to yield a total price influence (0.577) that accounts for 95% of the overall price change in *FI* products. This example confirms the intuition that large price fluctuations in food products are triggered by changes in the production cost of their main input, and provides a numerical estimate of the effect.

When Energy costs vary, however, the direct arc linking Energy with the Construction sector does not transmit the bulk of the global price effect; only 18.3% can be traced back to the arc, whereas 20.8% of the price push is explained by the longer path including Basic Industry (*BI*). Rising energy prices bring about an upsurge in Basic Industry prices and through its input requirements for Construction activity, prices in the Construction sector further escalate. The other significant path goes through the Transportation sector, where 3.1% of the price change can be traced. Unlike the case just discussed, case 3 again shows a cost linkage where most of the effect is carried along the direct arc between two closely related sectors, Energy and Transportation. This is not a surprising result given the strong dependence of Transportation on Energy through fuel demand, but the analysis reveals that no other significant path includes any other production activity. Interestingly, though, about 8% of the price increase can be imputed to two paths including households and factors, via adjustments in factor prices for unskilled labor and capital in response to variations in the cost of living indices for Adult low-income (skilled and unskilled) households.

Cases 4 and 5 in table 3 show that price effects may run asymmetric courses. Automobile prices are quite dependent on Machinery costs (80.3% of global effect) but the bulk of the comparatively small influence transmitted from Automobiles to Machinery (0.018 as opposed to 0.181 along the arc $\langle Ma, Aut \rangle$) follow myriad individually negligible paths. In fact, to quantify the effect along the arc $\langle Aut, Ma \rangle$ the set level of tolerance for detecting relevant paths has to be lowered to 0.001 or more.

Case 6, the last of this set of examples, illustrates some of the points made in the general discussion. The arc between the Food Industry and Other Manufacturing transmits more price influence than any relevant path including other production activities like Agriculture, but less than the path that picks up cost of living adjustments in unskilled labor wages.

Effects on households' welfare of changing production costs: Here we study the impact on consumer welfare of a change in the exogenous costs of production activities. As before, these changes can originate in output taxes or in the prices of imported goods. For each household type, its consumer price index measures the implicit cost of acquiring the benchmark basket of goods. An increase in the index reflects, therefore, the additional income needed to keep purchasing the original basket and as such provides a simple measure of the welfare impact on individuals.

Cases 7 to 9 consider Young low-income households as recipients of price variations arising in three production activities. In the face of rising Agricultural costs, 21% of this household's price index variation can be ascribed to the direct link in the arc $\langle Ag, YLI \rangle$. A larger proportion, however, results from the indirect effects of longer paths that include the Food Industry sector. Fully 28% of the global effect results from consequence of Agricultural prices exerting pressure on Food Industry prices, which in turn affect the cost of the benchmark consumption basket. A further 10.3% of the increase is accounted for by the three step path that starts in Agriculture, moves onto Food Industry and then goes through Commerce before finishing in the destination household. Another example in which cost effects linked to longer paths are larger than those of the direct arc is case 9. Unlike these last two examples, case 8 reports once again an instance in which the main thrust (45.4%) pushing this consumer's price index up is directly exerted by changes in Food Industry prices. The path going through Commerce, however, also accounts for a substantial amount of the overall price index change (16.7%).

Production prices and factor prices: Considerations similar to those outlined above apply to the analysis of the effects of changes in production prices on factors prices (examples 10–12). In these cases the shortest paths necessarily travel through a household account, given the triangular nature of the SAM interdependencies. Rising unskilled labor wages in case 10 can be traced to cost-of-living adjustments in Adult low-income unskilled households to 68% of the overall wage change induced by Agriculture, with the upward pressure on unskilled wages taking place through Food Industry products being higher (32.5%) than that of the shorter connecting path (26.5%). Case 11, on the contrary, illustrates shorter paths carrying stronger price influence.

The high proportion of property income in both types of Adult high-income households helps to explain, in case 12, 57.5% of the change in Capital costs brought about by Construction, a capital-intensive sector, with only 9.1% resulting from adjustments in Adult low-income unskilled households. This effect is related to the fact that this household type includes the largest proportion of consumers, even though each individual of the class is, on average, endowed with a small share of property income.

Now consider how a change in factor prices, like that induced by a payroll tax on labor, affects commodity prices. Cases 13–15 illustrate this possibility. It should be noted that the high multiplier values relative to those of previous examples reflect the high effective tax rates paid by employers for Social Security in Spain. The impact is so prominent that as a general rule shorter paths carry the bulk of the price influence. Case 13 depicts the arc carrying the least influence linking the Unskilled labor factor and production activities, still a substantial 33.5% of the overall price multiplier. On the opposite end, case 15 carries 80.7%.

Effects on households of changing factor prices: The final example in table 3 examines the impact of factor prices on households' cost-of-living. Since factor prices first affect production activities, the decomposition allows one to identify those production sectors most responsive to variations in, for instance, unskilled labor wages, and the ultimate impact on consumers' welfare as this is measured by the spending associated to fixed benchmark baskets.

V. Concluding Remarks

We have explored in this paper the properties of a very simple price formation model built upon the framework of the Social Accounting Matrix. The purpose of this SAM-based price model is to explain price formation in the presence of endogenous factor prices and household cost-of-living adjustments. Despite its limitations vis à vis Walrasian price models with endogenous activity levels, the SAM-based price model has some advantages, including the ability to estimate absolute price variations, thus providing information of immediate use to policy makers. Furthermore, price variations can be decomposed to reveal the underlying patterns of economic interdependence and price transmission. By partitioning the SAM accounts into blocks, and adapting decomposition techniques developed for SAMs, we can distinguish the extent of price effects explained by interindustry linkages, households' consumption expenditures, and factor prices.

The linear structure of the SAM price model also allows us to break down the price-transmission matrix with structural path decomposition techniques. Path analysis discloses in detail the network of transmission paths and produces direct estimates of all the linkages connecting two SAM accounts. The information indicates what sectors are more cost responsive to changes taking place elsewhere in the economy. Not all sectors are equally responsive in magnitude and scope, and by identifying them in detail a more informed tax policy could be designed to minimize undesirable welfare distortions.

The use of a price model of this kind seems more appropriate in economies where price formation is heavily affected by rigidities in factor prices. In Spain, for instance, nation-wide unions negotiate wages to keep purchasing power adjusted for inflation. This kind of behavior appears quite applicable to the structure of the present model.

APPENDIX

Endogenous Accounting Groups in the 1987 SAM for Spain

Activities:
1. Agriculture (Ag)
2. Energy (En)
3. Basic Industry (BI)
4. Machinery (Ma)
5. Automobiles (Aut)
6. Food Industry (FI)
7. Other Manufacturing (OM)
8. Construction (Con)
9. Commerce (Com)
10. Transportation (Tr)
11. Private Services (PS)
12. Public Administration (PA)

Factors:
13. Unskilled Labor (UL)
14. Skilled Labor (SL)
15. Capital (Cap)

Households:
16. Young, low income (YL)
17. Young, high income (YH)
18. Adult, low income, unskilled (ALU)
19. Adult, high income, unskilled (AHU)
20. Adult, low income, skilled (ALS)
21. Adult, high income, skilled (AHS)
22. Retired, low income (RL)
23. Retired, high income (RH)

REFERENCES

Adelman, Irma, and Sherman Robinson, *Income Distribution Policy in Developing Countries: A Case Study of Korea* (Oxford: Oxford University Press, 1978).

Ballard, Charles, Don Fullerton, James Shoven, and John Whalley, *A General Equilibrium Model for Tax Policy Evaluation* (Chicago: The University of Chicago Press, 1985).

Defourny, Jacques, and Erik Thorbecke, "Structural Path Analysis and Multiplier Decomposition within a Social Accounting Matrix," *Economic Journal* 94 (373) (1984), 111–136.

Gazon, Jules, "Une Nouvelle Methodologie: L'approache Structurale de L'influence Économique," *Economie Appliquée* 32 (2-3) (1979), 301–337.

Lantner, Roland, *Theorie de la Dominance Économique* (Paris: Dunod, 1974).

Pyatt, Graham, "A SAM Approach to Modeling," *Journal of Policy Modeling* 10 (Fall 1988), 327–352.

Pyatt, Graham, and Alan Roe, *Social Accounting for Development Planning* (Cambridge: Cambridge University Press, 1977).

Pyatt, Graham, and Jeffrey Round, "Accounting and Fixed Price Multipliers in a Social Accounting Matrix," *Economic Journal* 89 (356) (1979), 850–873.

——— (eds.), *Social Accounting Matrices: A Basis for Planning* (Washington, D.C.: The World Bank and Oxford University Press, 1985).

Robinson, Sherman, "Multisectoral Models of Developing Countries: A Survey," in H. Chenery and T. N. Srinivasan (eds.), *Handbook of Development Economics* (Amsterdam: North-Holland, 1988).

Robinson, Sherman, and David Roland-Holst, "Macroeconomic Structure and Computable General Equilibrium Models," *Journal of Policy Modeling* 10 (Fall 1988), 353–375.

Roland-Holst, David, and Ferran Sancho, "Relative Income Determination in the US: A Social Accounting Perspective," *Review of Income and Wealth* 38 (2) (1992), 311–327.

Whalley, John, and Francis St. Hillaire, "A Microconsistent Data Set for Canada for Use in Tax Policy Analysis," *Review of Income and Wealth* 29 (2) (1983), 175–204.

______, "A Microconsistent Data Set for Canada for Use in Regional General Equilibrium Policy Analysis," *Review of Income and Wealth* 33 (3) (1987), 327–343.

Stone, Richard, "Aspects of Economic and Social Modelling," 126, Librairie Druz, Geneva (1981).