REGIONAL ECONOMIC ISSUES

Working Paper Series

Forecasting Structural Change with a Regional Econometric Input-Output Model

Philip R. Israilevich, Geoffrey J.D. Hewings,
Michael Sonis and Graham R. Schindler

FEDERAL RESERVE BANK
OF CHICAGO

WP - 1996 / 2

Forecasting Structural Change with a Regional Econometric Input-Output Model[1]

Philip R. Israilevich, Geoffrey J.D. Hewings, Michael Sonis and Graham R. Schindler

Abstract

The sophistication of regional economic models has been demonstrated in several ways, most recently in the form of linking several modeling systems or in the expansion in the number of equations that can be manipulated successfully to produce impact analyses or forecasts. In this paper, an alternative perspective is employed. What do regional macro-level forecasts indicate about the process of structural change? A new methodology is illustrated that enables analysts to make forecasts of detailed structural change in the interindustry relations in an economy. Using a regional econometric-input-output model developed for the Chicago Metropolitan region, derived input-output tables are extracted for the period 1975-2016. These tables are then analyzed to determine the forecasted direction of structural changes for the region. The innovation illustrated here is based on a model that exploits the general equilibrium spirit of computable general equilibrium models through the adjustment of input coefficients to clear markets.

Introduction

Prior work (Israilevich and Mahidhara, 1991) has demonstrated that the Chicago metropolitan economy underwent some significant structural changes over the period 1970-1990. Perhaps the most significant change was the transformation of the employment profile from one dominated by manufacturing to one dominated by services. However, this perspective offers little insight into the changes that might have occurred in the structure of the economy in terms of the interdependence between sectors. Did the Chicago economy exhibit evidence of the *hollowing out* process that Okazaki (1989) found in Japan, in which interdependence declined as Japanese producers sought lower cost production sites in other countries? Can the procedures that were used to estimate the changes in interdependence in the past be used to generate forecasts of structural changes? This paper provides a description of the methodology that is used to extract input-output tables from an econometric-input-output model for the period 1970-2018 for the Chicago region. The system in which the input-output tables are embedded provides an example of the changing nature of regional model construction in the last two decades (see Hewings and Jensen, 1988 for more extended commentary along these lines), with greater focus on integrating input-output tables in more extensive or economy-wide models and with explicit focus on the problems of error and sensitivity analysis (see, for example, Jackson and West, 1989; Sonis and Hewings, 1989, 1992; and Israilevich *et al.* 1995).

The methodology presented in this paper offers an innovative approach to the forecasts of structural change in the context of interindustry linkages through the use of a economy-wide model that achieves balance between supply and demand in the commodity market for all commodities through the annual adjustment of input coefficients. In contrast, many other attempts to estimate changes in input-output coefficients have often operated over short time horizons, focused on only a small set of sectors or used rather more mechanical procedures for which economic interpretation of the resulting changes has proven to be difficult.

The analysis presented here examines input-output in a broader system-wide context by exploiting the potential for introducing endogenously-generated coefficient change within a macro-economic forecasting environment. The methodology is illustrated by reference to a model for the six-county Chicago Metropolitan Region. In the next section, a review of input-output based approaches to structural change are reviewed. Section 3 provides a discussion of the modeling system and the procedure for the extraction of the annual input-output tables from the model. In section 4, attention is focused on some of the major changes; while a few specific sectors will be highlighted, the majority of the attention will be directed to a 3-sector version of the findings. The final section will reflect upon the exercise and provide some sense of the opportunities for further analysis in this direction.

The Legacy

Input-output analysts have long been aware of the problems that are associated with the use of a methodology that is based upon an assumption of constant production relationships over time, especially if this time horizon stretches over a period of more than a decade. At the regional level, the issues are further complicated by the potential for change in trading relationships and problems that may arise if input-output components are nested inside larger modeling systems (such as computable general equilibrium models) or linked or integrated with other models (such as demo-economic models). In this section, a brief review will be provided of some of the issues and approaches that have been proposed to handle the problem of structural change as manifested in changes in input coefficients.

There have been many different approaches to the problem of updating input-output tables; for the most part, the techniques that have been used have handled changes in input coefficients separately from other changes in the economy. One may point to the work of Stone (1961), Bacharach (1970), Lecomber (1969) and others who have grappled with the problem of finding the most efficient ways of updating the U.K. models; attention was devoted to the problem of forecasting the values of r and s in the RAS procedure of the following kind:

$$A(t+1) = \hat{r}A(t)\hat{s} \tag{1}$$

Here, $\hat{r}$ and $\hat{s}$ may be considered as multipliers that implicitly transform a prior matrix to new one and ensure that the row and column sums of the new matrix accord with their observed or forecast values. The economic interpretation of the $\hat{r}$ and $\hat{s}$ has proven to be contentious and analysts have tended to frown on mechanical methods for adjustment - while, at the same time, unable to offer something more attractive.

Fisher (1975) and Tiebout (1970) took different approaches from the macro adjustment procedures implied by the RAS technique. Fisher surveyed experts in different sectors of the economy to develop what he referred to as *ex ante* input coefficients; these ex ante coefficients were then incorporated into new input-output tables. Adjustments would have to be made and this process depended very heavily on the weight attached to the various expert opinions. In addition, there was no guarantee that each expert was basing his/her judgment on a consistent view of the prospects for the macro economy. Almon (1967) has provided one of the earliest, most comprehensive surveys of methods that have been used to forecast changes in input coefficients. He has summarized these as (i) technical projections, (ii) judicious extrapolation and (iii) product mix adjustments. All three were used by Almon in making his forecasts of the United States economy.

Tiebout (1970) adopted an equally novel approach; he assumed that regional economies might reasonably be expected to evolve in similar trajectories. To this end, he sought guidance for forecasting the future of the Puget Sound region's (Seattle) economy through a careful analysis of the San Francisco economy for which an input-output table was available. The idea here was to use the input coefficients from San Francisco at time period t as the basis for change in the structure of the Puget Sound region between t and $t+n$; furthermore, Almon's (1967) national-level forecasts were used to guide overall structural change.

Miernyk's (1970) West Virginia model forecasts were based on a derivative of Tiebout's idea; instead of using input coefficients from another region, he proposed identifying best practice technology within the region. Borrowing from the work of Carter (1970), Miernyk assumed (i) that coefficient change was a moving average process and (ii) that the technology embodied in the best practice firms would become the prevailing average technology ten or fifteen years hence. The approaches of Fisher, Tiebout, Almon and Miernyk all examine individual coefficients but with different degrees of dependence on the macro economy for purposes of ensuring consistency.

A third major initiative in this venture of forecasting input coefficients was initiated by Hudson and Jorgenson (1974) and subsequently, more extensively, by Nakamura (1984). Using a neoclassical general equilibrium approach, they developed a macro model of the economy (in which an input-output system was embedded) and then ran the model to examine how changes in relative prices would effect the growth and development of the economy. All input coefficients were endogenously determined, changes being made in response to changes in relative prices. The translog production functions employed worked well when the model contained just a few sectors but became more intractable when more detailed sectoring schemes were employed, requiring consideration of assumptions of strong and weak separability in the production function specifications.

As Israilevich (1991) has shown, the procedure adopted here might be considered as a columns-only adjustment process, since the only restriction was that column sum to unity (value added was included in the estimation procedure). The procedure was not monoproportional (in the sense of Bacharach's definition) since the effects of relative prices changes would likely produce a different adjustment to each column entry. However, no effort was made to balance across rows.

Wrigley (1970) has provided one of the few thorough analyses of the time trends of input-output coefficients, drawing on some detailed work for the United Kingdom; one of the important innovations in this paper is his attempt to relate the findings to an input-output based production function. The present paper provides a description of data that may provide opportunities for testing some of the ideas in Wrigley's paper. Barker (1985) developed a methodology that, in spirit, is not unlike the one used for Chicago; his method essentially conjoins the detail of an input-output tables with projections of macro variables (such as outputs, final demands, imports and exports). His findings, using the Cambridge model of the British economy, pointed to rather small changes in the input coefficients; however, the methodology does admit the possibility for the inclusion of expert opinion or for partial information on changes in subsets of coefficients.

Finally, there have been sets of approaches to the problem that have attempted to identify analytically important coefficients (West 1981; Jensen, 1980; Hewings, 1984; Israilevich, 1991; Bullard and Sebald, 1977, 1988 and Kop Jansen, 1994); however, the tests adopted here have been varied and there has not been a concerted effort to apply these techniques in a long-run forecasting context. The notion that perhaps only a small set of coefficients might be important sources of change is intuitively appealing; however, all the analysis to date has been of an *ex post* variety and, as Hewings (1984) has shown, what is analytically important may change over time and with the specification of the framework in which the input-output accounts are placed.

In the next section, the approach adopted for the Chicago forecasts will be illustrated; first, a brief description of the regional econometric-input-output model will be provided. Thereafter, the specific methodology used to forecast and extract the input coefficients will be revealed.

The Chicago Model and the Input-Output Extraction Method

Brief Description of the Chicago Model

General Structure

The Chicago Region Econometric Input-output Model [CREIM] generates forecasts of the Chicago economy on an annual basis, with the forecast horizon extending up to 25 years. The model is comprised of two major components, an input-output module and an econometric module. The modeling system is one designed and implemented for the state of Washington by Conway (1990, 1991); the reader is referred to Conway's papers for more complete descriptions of the model. Figure 1 summarizes the main structure of the model and Table 1 describes the main variables. The model is a system of linear and nonlinear equations formulated to predict the behavior of 151 endogenous variables, and consists of 123 behavioral equations, 28 accounting identities, and 68 exogenous variables. CREIM identifies 36 industries and three government sectors. For each industry, there are projections of output, employment, and earnings. Thus, out of 150 equations, only 36 relate to the linear input-output components. Many of the non input-output equations are

Figure 1
Structure of the Chicago Econometric Input-Output Model

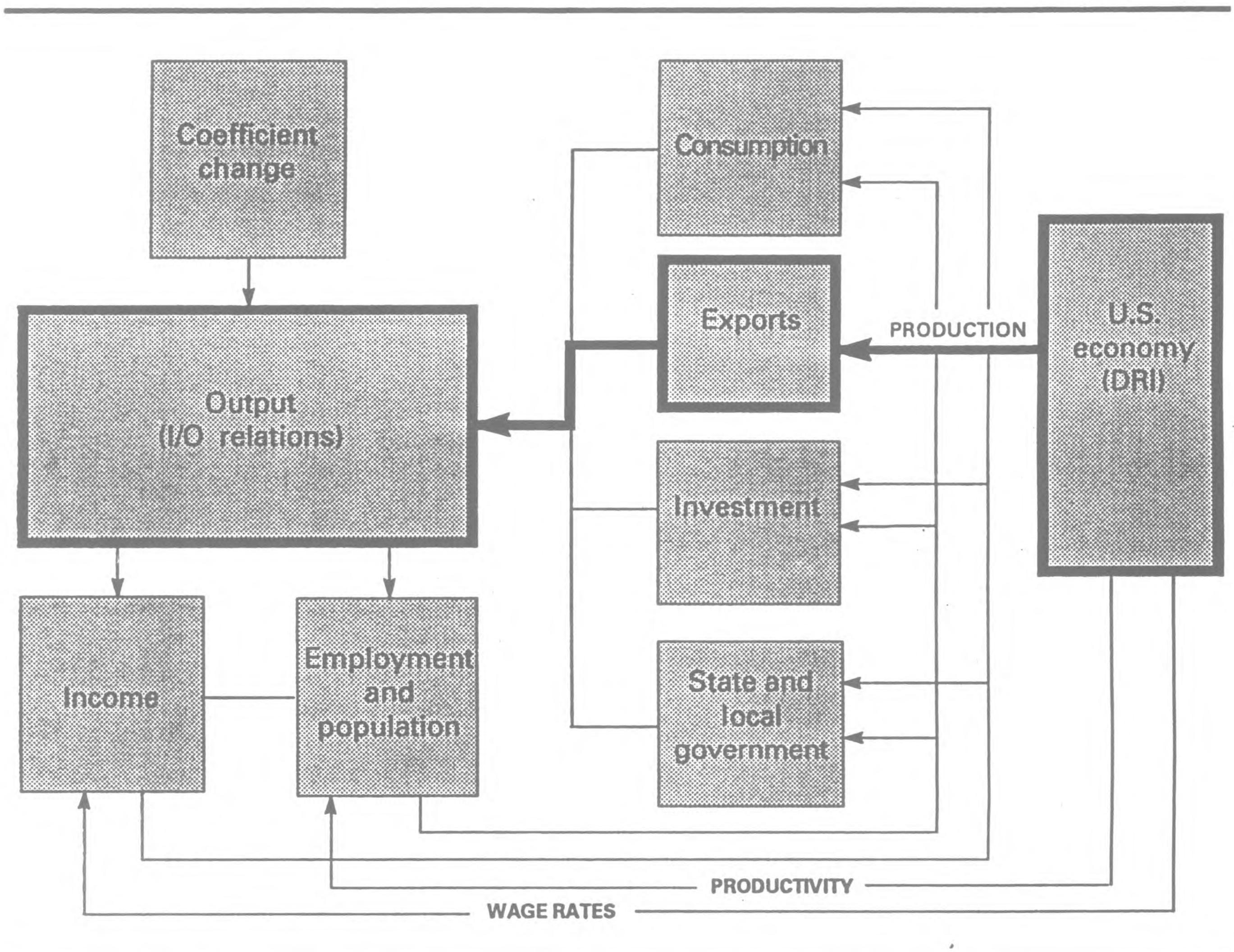


Table 1
Description of the Major Components of the Chicago Model

Projection Horizon

1-25 years

Model Size

156 endogenous variables
55 exogenous variables
143 behavioral equations
13 identities

Industry Detail

36 industries with projections of
- output
- employment
- earnings

Other Selected Endogenous Variables

Gross Regional Product
personal consumption expenditures
housing construction
nonresidential investment
state and local government expenditures
exports (including federal government expenditures)
imports
labor force
unemployment rate
personal income
per capita income
net migration
population by age and sex
consumer price index

nonlinear and estimated in a recursive fashion (usually, incorporating autoregressive lags of order one or two). As a result, the relationships of one sector to another include the formal input-output link as well as a set of complex linkages through a chain of actions and reactions that could potentially involve the whole economy. However, the output of one industry can be related to the output of another industry; in CREIM, this is specified through first derivatives. It would be very difficult to derive these derivatives analytically due to the nonlinearity of many of the equations and their incorporation of autoregressive components; in the solution to the model, these derivatives are calculated numerically. Then, the whole system is tested to ensure that these numerical derivatives are stable with respect to the shocks that were used in the process of estimating the derivatives.

Among the other variables depicted by the model are gross regional product, personal consumption expenditures, investment, state and local government expenditures, exports, labor force, unemployment rate, personal income, net migration, population, and the consumer price index.

The Input-Output Module

This module was constructed from establishment-level data obtained from the U.S. Bureau of the Census. Two models have been developed, one based on 1982 and one on 1987 data; the possibility for updating these models with 1992 data will exist when the various censuses are made available in late 1995.

Since survey-based systems are prohibitively expensive, researchers developing regional input-output models have relied on a variety of adjustments of national level data. There are many problems with this approach; first, for many years, the latest available U.S. national table was for 1982, and this table only appeared in mid-1991[2]. While updates have been made annually, the reliability of these updates is not known. Secondly, the adjustment process in developing regional from national tables relies on a large number of assumptions; the most critical being the one that assumes that the technology at the regional and national levels is identical. Since there has been little survey work done to test this assumption, it often reverts to an assertion.[3] Preliminary analysis with the Census data suggests that differences between national and regional technologies may be significant.

REAL's approach to table construction avoids many of these problems, since survey data is used to build the manufacturing portions of the tables. Since the data have already been collected by the Bureau of the Census, the tables are constructed at a fraction of the time and expense usually associated with survey-based methods. once constructed, the input-output table reveals the linkages that exist between the sectors in the region. Thirty six sectors were

Table 2

Sectoring Scheme

Sector	*Description*	*SIC Codes*
1	Livestock and Other Agricultural Products	01, 02
2	Forestry and Fishery; Agricultural Services	07-09
3	Mining	10-14
4	Construction	15-17
5	Food and Kindred Products	20
6	Tobacco Manufactures	21
7	Textiles and Apparel	22, 23
8	Lumber and Wood Products	24
9	Furniture and Fixtures	25
10	Paper and Allied Products	26
11	Printing and Publishing	27
12	Chemicals and Allied Products	28
13	Petroleum Refining and Related Industries	29
14	Rubber and Miscellaneous Plastics Products	30
15	Leather and Leather Products	31
16	Stone, Clay, Glass, and Concrete Products	32
17	Primary Metal Industries	33
18	Fabricated Metal Products	34
19	Machinery, Except Electrical	35
20	Electrical and Electronic Machinery	36
21	Transportation Equipment	37
22	Scientific Instruments; Photographic and Medical Goods	38
23	Miscellaneous Manufacturing Industries	39
24	Transportation and Warehousing	40-42, 44-47
25	Communication	48
26	Electric, Gas and Sanitary Services	49
27	Wholesale and Retail Trade	50-57, 59
28	Finance and Insurance	60-64, 67
29	Real Estate and Rental	65, 66
30	Hotels; Personal and Business Services	70-73, 76, 81, 89
31	Eating and Drinking Places	58
32	Automobile Repair and Services	75
33	Amusement and Recreation Services	78, 79
34	Health, Educational and Nonprofit Organizations	80, 82-84, 86
35	Federal Government Enterprises	
36	State and Local Government Enterprises	

identified for Chicago - essentially, the two-digit SIC manufacturing sectors and somewhat more aggregated sectors for non-manufacturing. Table 2 describes the sectoring scheme used. While data are available at the individual establishment level, Federal Disclosure Rules preclude the publication of data that would reveal the transactions of individual firms or would enable reasonable estimation from information presented.

In addition to the transactions between sectors, the table also records the purchases made from labor (wages and salaries), capital (profits and undistributed dividends) and imports from outside the state. Complementing the sales made to other sectors are sales to households (consumers), government, investment and exports outside of Chicago. With this table one has, in essence, an economic photograph of the state of Chicago, captured at one point in time. Adding the econometric component enables the analyst to extend this photograph back in time to test the reliability of the system in tracking the changes that have been observed in the economy and to redevelop this photograph each year for the next twenty to twenty-five years producing the annual forecasts.

Solving the Model

The model is solved in a number of ways; in this example, assume that US exports increase as a result of a stimulus generated by increased demand in Eastern Europe or the Former Soviet Union. In Stage I, the model first allocates a share of these exports to the Chicago region and these provide the first stimulus to an increase in local production. In Figure 1, the stimulus would be shown as entering the system through the US economy model (in this case DRI's model) to generate an increase in Chicago's exports.

In Stage II, production of local exports generates a set of internal demands - i.e., the regional interindustry demands. The individual output equations capture these internal demands using the input-output relationships. Unlike many other models that use national input-output coefficients, CREIM uses Chicago-specific input-output transactions. In addition, input-output coefficients are adjusted for changing supply-demand relationships, thus creating the possibilities for changes in interindustry dependencies on an annual basis. This equilibrium adjustment process - that includes a complex system of interacting equations - avoids one of the major criticisms of the input-output models, namely their static nature.

Within CREIM, there are two types of output; we refer to these as *actual* and *predicted* output. An industry's actual output is the historical or forecasted value of shipments (vector X). Predicted output of a given industry is the output that is calculated by the Chicago input-output table (vector Z). In Israilevich *et al.* 1995, it is shown that Conway's (1990, 1991) specification of actual and expected outputs can be expressed as one equation:

$$X_t = \hat{\beta}_t A X_t + \hat{\beta}_t f_t \tag{1}$$

where A is the Chicago input-output matrix, f is the final demand vector, t time subscript, and $\hat{\beta}_t$ is a diagonal matrix with elements defined as follows:

$$\hat{\beta}_{i,t} = \exp\left[\alpha_0 + \alpha_z \ln\left(\frac{z_{i,t-1}}{x_{i,t-1}}\right) + \alpha_g g_{i,t}\right] \tag{2}$$

where α and β are estimated parameters from the regression that relates z_i to x_i, and g_i are exogenous variables (for detailed description see *ibid*).

Equation (1) transforms the static input-output equation into a dynamically determined relationship between the intermediate demand and final consumption matrix. Notice, that β are determined by outputs of the previous period; therefore, if a shock is introduced to the system, β will 'transmit' this shock to the current period. To measure the effect of a shock, we would have to accumulate the shock effects over several periods. The derivative of an output related to a shock would have to be a function of outputs affected by the shocks over time. In other words, if we collect terms in (1) we can derive a reduced form:

$$X = \left[\left(I - \hat{\beta}A\right)^{-1} \hat{\beta}\right] f \tag{3}$$

If we assume that shock is expressed as f and introduced in t and *(t-1)* and we want to determine the effect of two shocks on X_t then:

$$\frac{\delta X_t}{\delta f_t} + \frac{\delta X_t}{\delta f_{t-1}} = \sum_{t=1}^{2}\left[\left(I - \hat{\beta}_t A\right)^{-1} \hat{\beta}_t\right] + \frac{\delta\left[\left(I - \hat{\beta}_t A\right)^{-1} \hat{\beta}_t\right]}{\delta f_{t-1}} \cdot f_t \tag{4}$$

These derivatives would have to be accumulated and averaged over time. (4) was simplified for the exposition purposes by assuming that f is a vector, and that f_t is independent of f_{t-1}. However, in CREIM f is matrix and only one column (export) can be shocked; thus, the actual reduced form is more complicated than

(4). In addition, final demands are related over time. We will show that other blocks of the model complicate even further the relationship between the shocks and output; therefore, analytic derivative derivation is impractical. As a result, we are utilize a numeric derivative.

In Stage III, forecasts of output (obtained using national data and exports) are combined with forecasts of labor productivity and wage rates to predict employment and earnings by industry. These projections are further combined with projections of the labor force participation rate, the unemployment rate and natural population changes to obtain population forecasts. Meanwhile, total earnings are obtained by predictions of property income, transfer payments, residence adjustments and personal contributions to social insurance.

The productivity relationship equation determines employment (N). This equation explains the linkage between an industries' total shipments and total employment by modeling productivity changes through time. This is an econometrically estimated specification. Typically, we model productivity changes using changes of employment-related variables such as hours worked, unemployment, earnings, or aggregate output indices. As with the output correction equations, the estimated equation is normalized to isolate employment on the left-hand-side:

$$\ln\left(\frac{x_i}{N_i}\right) = g(\cdot) + \varepsilon_i \rightarrow N_i = \frac{x_i}{\exp[g(\cdot) + \varepsilon_i]} \qquad (5)$$

Here N_i is total employment within industry i, and ε is a white noise. Notice, that employment is a function of output

Total earnings are then combined with population forecasts to obtain estimates of personal income in Stage IV. The final equation in the industry block is the wage equation. This equation describes the relationship between an industry's employment and income through changes in average wages and salaries per employee. This is an econometrically-specified relationship where the change in average wage is modeled as dependent on the changes of variables impacting employees' income such as compensation rates, hours worked, total production, relative unemployment rates, and economic growth. Again the estimated equation is normalized to isolate income on the left-hand-side:

$$\ln\left(\frac{w_i}{N_i}\right) = h(\cdot) + \phi_i \rightarrow w_i \cdot \exp[h(\cdot) + \phi_i] \qquad (6)$$

Here w_i is total income within industry i, and ϕ is a white noise. Again income is a function of output via employment. Typically, the structural econometric specifications for the equations for each industry will vary.

This completes the path of the first set of demands - those originating initially outside the system (Chicago Region). Personal income and population now expand internal demands, the final demand sectors, comprised of consumption, investment, and government (Stage V). Very briefly, four types of consumption expenditures and three types of investment expenditures are considered, along with one type of state and local government expenditure.

Within CREIM, there are ten final demand variables that are modeled: gross regional product, four types of consumption, three types of investment, and two types of government spending. These ten series are then combined to calculate net exports through an accounting identity. For each final demand series, there is an econometrically-specified equation that links it to the 36 production sectors of the economy. A typical final demand equation is estimated with the dependent variable measured in per capita terms or as a proportion of personal income. The econometric specification is then normalized so that final demand is isolated on the left-hand-side providing:

$$FD_k = f\left(POP, Y(Y_i)\rho\right) \tag{7}$$

where ρ is a set of exogenous variables, Y is income and POP is population. Again final demand is a function of output via income.

The growth of gross regional product, which equals the total value added produced in the economy, is econometrically-related to total personal income that includes all wages and salaries along with net income from non-work related activities and transfer payments. For each of the four types of consumption, the change in the proportion of personal income spent on each category of consumption is related to similar changes for the nation as well as other factors such as population growth and interest rates. Growth of the investment series is then related to changes in value added, cost of capital, savings, and population. Finally, the growth of government expenditures is determined as a function of changes in personal income, and population.

The population block within CREIM links the demographic characteristics of a region with their underlying economic determinants. This block has been designed to forecast total population along with eight age and sex cohort groups along with birth, death, and net-migration totals. Only total population is directly related to economic variables. Total population is directly determined through a combination of employment, labor force participation, and unemployment information. Changes in total population due to changes in employment demand or other employment series will be met by an adjustment of migration flows. Regional changes of employment characteristics will not affect local birth or death rates, and hence cohort groups, although, at the national level in the long term, this constraint does not hold. The age- and sex-cohorts are estimated as shares of total population whose change over time is then related to similar changes for the nation. Birth and death rates are similarly related to female and total population respectively; these are then related to corresponding national characteristics.

Within each industry group, the structural equations, when normalized, are all interrelated. That is, predicted output is dependent on actual output of all industries including its own, actual output is dependent on predicted output, employment is dependent on actual output, and income is dependent on employment. Each industry grouping has output, employment, and income linked in a similar manner. These linkages are incorporated with econometric specifications of final demand, and thus directly influences sectoral predicted output. It can also appear on the right-hand-side of the sectoral econometric equations, and the demographic block, which influences many of the final demand and other sectoral equations. The complete system of equations is then solved simultaneously to forecast all the left-hand-side variables.

This unique structure of REAL's models overcomes one of the primary problems of most input-output based forecasting models, namely, the static input-output relationships. In fact, the model allows for the extraction and forecasting of input-output tables on an annual basis. The interindustry relationships detailed within these input-output tables have been shown to have changed significantly over the past twenty years and are forecast to continue to do so in the future (for prior analysis, refer to Israilevich, *et al.* 1994, and Schindler *et al.* 1994).

Until now, the entire stimulus to the Chicago economy has come from external demand (in this case, exports). Tracing through the effects, one arrived at increases in personal income, the expenditures of these increases in personal income give rise to the second set of demands that drive the model. These are the internal demands and, in some cases, these can account for the more significant part of the total changes in the regional economy.

In the final stage, Stage VI, the model is brought to closure as the internally-generated final demands are feed into the input-output sectors; the system then produces a set of outputs that are derived from the local stimulus. The increased demand so generated works its way through the input-output module in exactly the same way as the export stimulus did - resulting in another chain of increases in output, employment, earnings, population, income, and again, final demand. This is a slice of the ripple or multiplier effect; it will continue to work its way through the system but each time around the impact will become smaller and smaller until the effects are negligible. The model mimics this process through a series of iterations until convergence is obtained for each year the model is run; the more complex the economy, the greater the number of iterations required before convergence is achieved.

The original formulation of the WPSM system (Conway, 1990, 1991) equilibrates outputs demanded by both intermediate and final sectors with the supply of output. Hence, to draw on Takayama (1985), the dynamic output adjustment equation for this system of markets can be presented as:

$$\dot{q} = \tilde{k}\left[D(q) - S(q)\right] \tag{8}$$

where both demand, D(q) and supply S(q) are expressed as functions of output and k is the speed of adjustment of the market. The process described above may be referred to as an adjustment along the lines of a Marshallian output adjustment process (see Takayama, 1985 p. 295ff).[4] Takayama (1985) noted that there has been some confusion about the differences between Walrasian and Marshallian adjustment processes; he notes that

> ..... the Marshallian adjustment is better suited (for the case in which) the adjustment of output is explicitly considered. It is important to note that the Marshallian output adjustment process is .... perfectly relevant for a competitive market.

In CREIM, there is an underlying (though not observed) price adjustment process but the operation of the model focuses on the market clearing quantity adjustment mechanisms. Hence, the system shares more of a Marshallian character in the terms defined by Takayama (1985). Since regional price differentials for goods and services are generally unavailable, Marshallian equilibrium adjustment is easier to model than a Walrasian process.

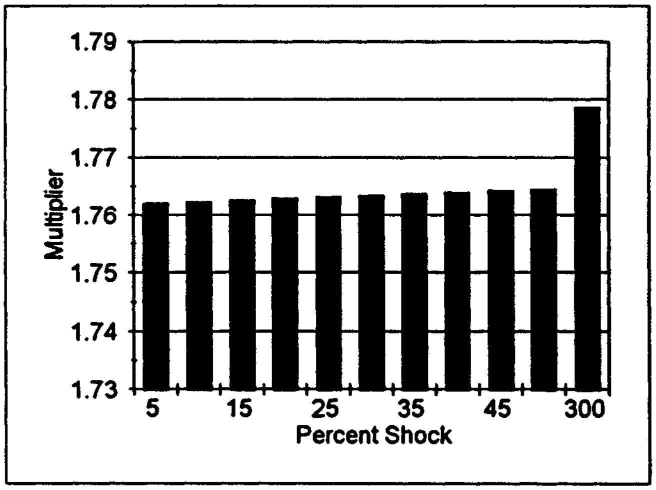
Extracting the Input-Output Coefficients

However, CREIM offers a different path for calculating economic interdependence over time. Recall that individual time series regressions that include input-output relations, make up only 36 of the 150 equations in the system; many of the remaining equations are highly nonlinear and recursive, involving AR lags of 1 or 2. As a result, the output of one sector is related to the output of other sectors through a complex, multiple chain process in which the input-output relationship is only one component of the chain. Nevertheless, one can relate the output of one industry to the output of another industry within CREIM; this is accomplished through the use of first derivatives. It would be a difficult procedure to derive such derivatives analytically, as a result of the nonlinearities and AR components that are present in many equations. Therefore, these derivatives are calculated numerically; then, tests are conducted to examine the stability of these derivatives.

Essentially, CREIM has an expanded input-output structure - the model is closed in a far more complex fashion than ones that involve making households endogenous - and in many ways retains the appearance and character of a general equilibrium formulation. However, CREIM is solved through adjustment of quantities rather than prices, but market clearing assumptions do hold. Shocks are introduced through the final demand components; given a change in final demand of Δf_j, the model is solved to calculate $\frac{\delta X_i}{\delta f_j}$. For each Δf_j, n partial derivatives can be obtained; if all Δf_j $j = 1,\ldots n$ (where n is the number of sectors) are considered, then n^2 partial derivatives will result. However, these derivatives represent the elements of Leontief inverse matrix. One vexing question that arose concerned the degree to which the magnitude of the change, Δf_j, might affect the value of the derivative, $\frac{\delta X_i}{\delta f_j}$. If the value is sensitive to the size of the initial shock, then this procedure would be somewhat limited; fortunately it was demonstrated that significant variations in Δf_j implied the same derivative. This is shown in Figure 2; the sector illustrated in the oil refining sector but all sectors exhibit the same stability properties.

The inverse of the whole matrix of such derivatives then becomes the matrix of direct input coefficients. However, note that this matrix is not derived from the traditional process of using the direct coefficient matrix derived from observed technologies, or derived through the application of Shephard's Lemma (neoclassical approach). The process described here is a reverse process. While these input coefficients can be interpreted as traditional coefficients, the world from which these coefficients are derived is created by CREIM. As a result, these input coefficients will be sensitive to changes in some of the macro economic indicators (such as a change in national GNP, bond rates, or steel exports). The degree of sensitivity has yet to be explored together with an appreciation of the varying degrees of relationships that selected coefficients might have with different external changes. In this regard, the procedure opens up a whole new vision for the definition of error and sensitivity analysis within the context of extended input-output systems (see Sonis and Hewings, 1991). In many price-adjusted computable general equilibrium models, the direct input coefficients are often placed at the bottom of a nested production function that admits (via a CES specification) substitution between aggregate inputs (i.e., the sum of intermediate inputs) and value added but usually employs a Leontief technology for individual inputs. CREIM, in essence, allows for substitution between inputs in response to changes in demand generated by shocks to the system. Potentially, underlying this system, there is a dual in which some implicit price elasticities could be calculated.

Figure 2
Multiplier Stability and Exogenous Shock: Sector 13, 1999



The input coefficients that are derived from this process may be considered to reflect the underlying technology; even though they are derived from a much more complex system than is usually associated with input-output analysis, they are not *amalgams* of relationships that embody the full complexity of interactions described in earlier sections.

The degree of what may be referred to as *Leontief closure* determines the degree to which the input-output multipliers fully capture the interactions in the economy. It is well known that input-output multipliers derived only from the *nxn* interindustry transactions table will yield lower multipliers than those derived from an *(n+1)x(n+1)* system such as would be the case in which households were made endogenous. In the latter case, the feedback effects derived from increases in wages and salaries and their expenditures are accounted for in this expanded system. In our case, where the coefficients are derived, the completeness of information is judged by the A matrix not the Leontief inverse; the derived matrix is a static (annual) representation of the interactions that is based on all the interactions modeled in CREIM. In this paper, the derived input coefficient matrix corresponds to the output of n sectors of the economy while the number of variables in CREIM is about five times the number of sectors. Hence, the derived input coefficients may be considered to be analogous to those associated with a Type I multiplier. We recognize that the derived system is, in this sense, incomplete but our main interest is in the properties of the derived tables and not the precision of these tables. The correspondence between the derived tables and observed tables is beyond the scope of this paper.

In this paper, we derive the matrix B_n, associated with the output of n sectors; by deriving numeric derivatives with respect to other variables, we could potentially form a B_{n+k} matrix where *(n+k)* is the total number of variables in CREIM. Hence, A_n is derived (from B_n) by assuming that the derivatives represented by $B_{k,\bullet}$ rows and $B_{\bullet,k}$ columns are all zero. However, the process is not easily tractable and it is often unclear how to include this system of numeric derivatives into the form of the traditional Leontief inverse. For example, changes in demographic variables, in respect to an output shock, would not easily place itself in the form of the traditional Leontief matrix.

To appreciate the limitation of the incompletely derived input-output system, we will illustrate the differences between the input-output coefficients that we have obtained with those that are based on a greater number of variables from CREIM. Let B_{n+1} indicate the Leontief matrix that includes an additional row and column (such as the household sector); from B_{n+1} we can derive the input coefficient matrix, $\tilde{A}_{n+1}$, and then exclude from this matrix the $(n+1)^{st}$ sector resulting in the matrix, $\tilde{A}_n$. Obviously, $\tilde{A}_n$ and A_n will differ; we will show that $\tilde{A}_n \le A_n$. Therefore, additional rows and columns of derivatives from CREIM, while adding new rows and columns to the input coefficient matrix will reduce the size of the remaining (interindustry) input coefficients. Schematically, the process is as follows:

$$\begin{aligned} &B_n \Rightarrow A_n \\ &B_{n+1} \Rightarrow \tilde{A}_{n+1} \Rightarrow \tilde{A}_n \end{aligned} \tag{9}$$

This implies that the information missing from CREIM in the estimation of the input coefficients will cause underestimation of the direct relationships between the n sectors. However, by expanding the matrix B_n towards B_{n+k}, $\widetilde{A}_n$ will approach the true static representation of the complete matrix that would be found in CREIM. [The proof is provided in an Appendix.]

Numeric derivatives beyond the traditional A matrix are much harder to construct. This is the first paper to address this approach and we have limited ourselves to the derivation of the $\widetilde{A}$ matrix only. At this point, we are more interested in the properties of the derived input-output matrix rather than the precision of the derived input-output. Again, if precision was an issue, then more work should be done in expanding numeric derivatives for other variables such as population, capital expenditures, employment etc.

Hence, this matrix is not a matrix of pure technical coefficients or regional purchase coefficients in the sense in which these have been employed in regional models. However, the extraction process is consistently applied over the time period in terms of the type of coefficients that are derived, facilitating year-to-year comparisons. There is precedence for the development of a somewhat non-traditional input coefficient in the earlier work of Solow (1952). In his case, a series of difference equations was developed to analyze an expenditure-lagged input-output system:

$$x(t) = Ax(t-1) + c \tag{10}$$

where, in this case, the input coefficient is defined as:

$$a_{ij} \equiv \frac{x_{ij}(t)}{x_j(t-1)} \tag{11}$$

However, in our case, the numerator and denominator in (11) have the same time subscript although they reflect the influence of the lag effects of prior years' activities.

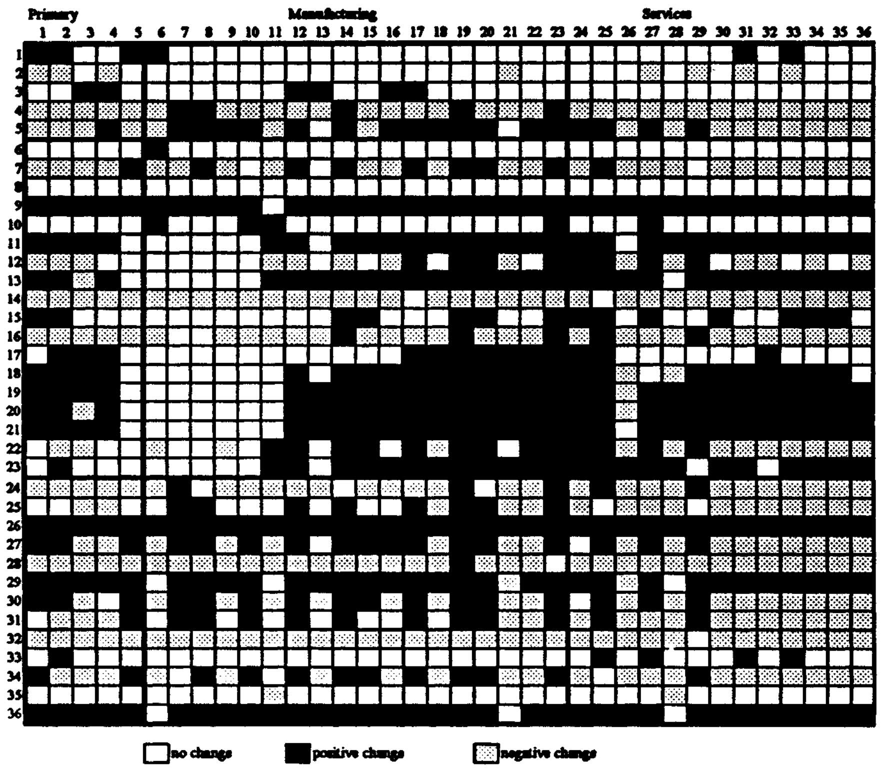
Prior to a discussion of some of the results, it is interesting to point out that *the derived input-output coefficients* fluctuate during the model calibration period but that this annual fluctuation end once the model enters the projection period. This results from the fact that the projection of exogenous variables are entered into CREIM in the form of trends, while during the historical period these variables fluctuate. However, the changes in the coefficients that result in the model are not linear, in part because the full effect of any shock does not manifest itself immediately, due to the AR process included in CREIM. Therefore, to determine full effect of the shock, the model has to be simulated for several periods. Somewhat arbitrarily, a five year period was chosen; however, changing this to 6 or 4 years would not necessarily change the results. After the model is shocked, output variables from this simulation are calculated and the relative difference between the simulated variables and variables from the basic runs of the model are determined. This difference determines the numeric value of $\frac{\delta X_i}{\delta f_j}$. This procedure has been performed for the output values only since it corresponds to one of the traditional applications of input-output analysis; the analysis might be expanded to other variables such as gross regional product change as a result of a shock, unemployment change, or investment, in other words, second order changes, $\frac{\delta^2 X_i}{\delta f_i \delta GNP}$.

Empirical Evaluation

General Observations

In this paper, attention will be focused on a general description of some of the changes that have been observe; a more complete, detailed evaluation will be provided in later papers. The empirical work is presented first for the 36-sector version, then a 3x3 analysis and finally focus is directed to one sector. Figure 3 presents a summary of the differences between the structures of the region's input-output coefficients measured in 1975-80 compared to 2105-2018 (recall the moving average-type process that was used to extract the coefficients to accommodate the nonlinearities and the lead and lag structures in many of the equations). The changes have been summarized into three categories - positive, negative and no change. However, some of the changes are very small and the appearance in the figure of dramatic changes in the economy overstates the modest nature of many of the changes. Sectors 1 through 4 represent primary activities and construction; sectors 5 through 23 are manufacturing and the remaining sectors (24 through 36 are services broadly defined). Some general features stand out: first, the changes provide little evidence for some monotonic process operating. Secondly, the changes in the manufacturing sector noted by Israilevich and Mahidhara (1991) for the period from the early 1970s to the late 1980s seem to be continuing although at a slower rate. Negative changes in manufacturing seem to be larger in the manufacturing to service flows than within manufacturing. Finally, the largest (absolute) changes appear to be concentrated in the services' sectors.

Figure 3
Changes in Input Coefficients between 1975-80 and 2015-2018

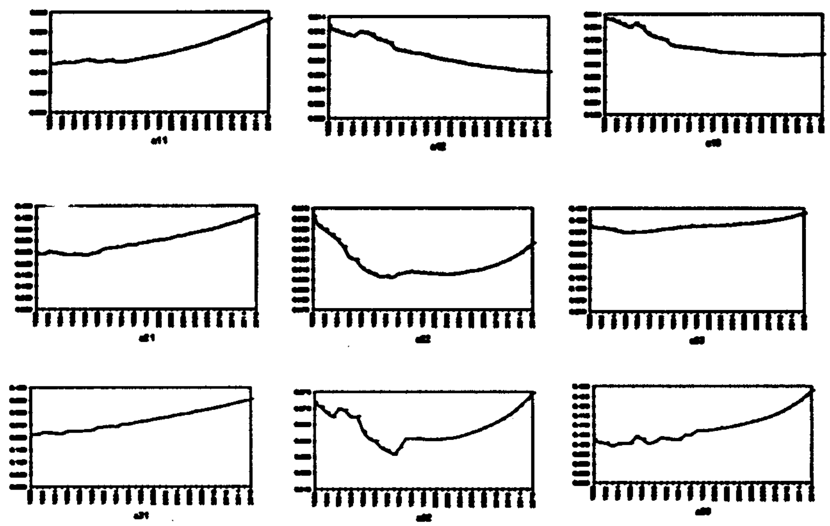


These findings are not dramatic in the sense of portending a significant change in the structure of the region's economy; a parsimonious view of the expected changes would be ones that continue some of the prior trends albeit with a less dramatic set of outcomes than the ones observed earlier. Part of the reason for this comment relates to the significant growth in manufacturing productivity that was observed over the period 1970-1987; during this period, Chicago led the nation, and for many years, Japan in manufacturing productivity (output per employee). The general sense is that the remaining manufacturing base is now more nationally and internationally competitive and less likely to erode (in employment terms) quite as rapidly in the 1990s. The growth in the non-manufacturing coefficients reflect a continuing trend that reflects overall system-wide growth in service demand.

The 3-sector analysis

To provide some sense of the temporal nature of the changes, the projected input-output tables were aggregated into three sectors (primary, manufacturing and services) to enable an evaluation of the macro-level changes. Figure 4 shows the changes in the direct coefficients for each of the nine elements of this aggregated (3x3) matrix; note that the scales are not the same for each coefficient. They are presented in this fashion to provide a broad-brush comparison across coefficients. Recall, also, that the forecast period for the model runs from 1992 on. There are some potentially interesting findings: note, for example, that intra-sectoral transactions in the primary sector are projected to increase while the reverse will be true for purchases of primary goods from the other two sectors. The manufacturing coefficients provide intriguing findings; of especial interest is the shape of the intra-manufacturing sector coefficient which first drops (extending a downward trend from the calibration period), then holds constant before beginning a slow rise in 2006. The manufacturing to services coefficient exhibits a slight upward trend. Similar upward trends are observed for the services coefficients, although the pattern of the services to manufacturing coefficient is reminiscent of the intra-manufacturing curve.

Figure 4
Changes in Individual Coefficients, 1975-80 to 2015-2018, *3x3* matrix



A single sector: food and kindred products

Finally, the changes for a single sector are highlighted. In examining the structure of the economy at an earlier time period, the behavior of the food and kindred products sector appeared to be of considerable interest, especially given the $2 billion ($1982 dollars) intrasectoral flow observed in 1987. Figures 5 and 6 provide a summary of the projected changes in purchases and sales coefficients for this sector using the complete 36-sector tables. Some striking results may be found; for example, a rather large increase in purchases from the stone, clay and glass sector and an increase in the intra-sectoral transactions, perhaps reflecting increased segmentation of the production processes. These gains are balanced by decreases in purchases from fabricated metals, machinery and transportation equipment and utilities (adoption of energy saving technology?). The sales coefficients reflect more systematic trends; with the exception of the increase in intra-sectoral transactions, almost all sales to other manufacturing sectors exhibit decreases. Sales to the leather sector are the other exception. The largest increase is recorded in sales to eating and drinking establishments.

Figure 5
Changes in Input Coefficients, 1975-80 to 2015-2018: Food and Kindred Products

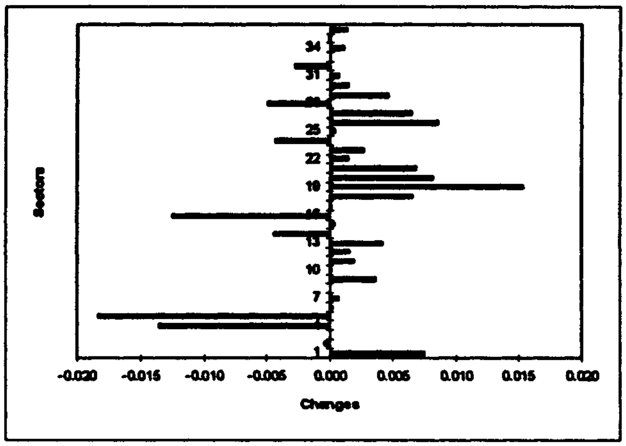
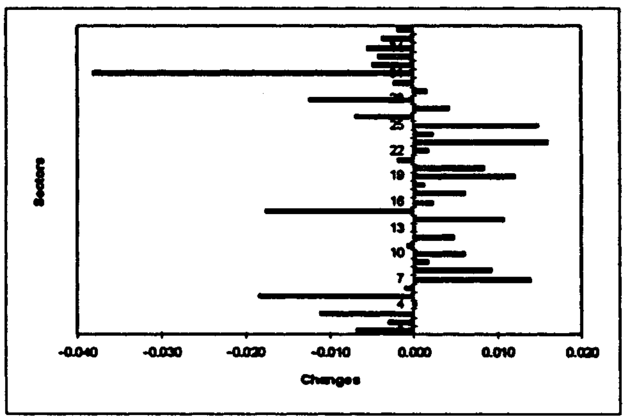


Figure 6
Changes in Output Coefficients, 1975-80 to 2015-2018: Food and Kindred Products



Interpretation

The results presented here are broad-brush in scope. In addition, the trends projected here need to be compared with those being made at the national level for similar, broad industry aggregates; this is not to suggest that Chicago will myopically follow whatever it projected for the nation as a whole. In fact, the Chicago region has revealed a penchant for moving in directions that are often counter to the United States or even in anticipation of trends in the country as a whole.

Unfortunately, there is really no completely satisfactory way of verifying these results; a proposal has been made to present them to major actors in the relevant industrial sectors to gauge their reaction to the trends that have been projected. While this approach may seem to be in the same spirit as Fisher's (1975) *ex ante* method, the major difference here is that the coefficients are derived from the model not from industry analysts. Further, the coefficients are consistent in the holistic sense articulated by Jensen (1980); whether they make sense from an industry specific sense remains to be seen.

Conclusions

In attempting to evaluate this exercise, it might be tempting to engage in some of the usual exercises of critical self-immolation that usually characterize analysis based on input-output methodology. By moving away from the classical, but comfortable, world of Leontief to a system in which direct coefficients are derived from an analytically-derived inverse matrix, problems of evaluation arise. Is this system to be judged on the basis of a sensitivity exercise within a quantity-adjusted general equilibrium format? What type of production function is subsumed in this system? These questions, and many others, need to be answered to place the analytical work within the framework that will allow careful, rigorous scrutiny.

In this regard, one other important concept may be raised. The procedure described here may also be considered a good test of the soundness of the model. Usual forecasts of the variables may not reveal incorrect structures in the regression equations; however, the derived input-output system is very sensitive to incorrect specifications. For example, in the first 100 or so runs, negative input-output coefficients were obtained. While initially it was thought that these values reflected problems with the procedure, it turned out that these negative coefficients were always an indicator of a mistake in the specification of one or more equations in the model. It so happened that, initially, it was a serious effort to discern the exact cause of this negativity, since there were multiple errors.

The next steps will center around detailed evaluation of the projections, including the application of various decomposition procedures, and a careful evaluation of the sensitivity of the derived coefficients to alternative specifications of the exogenous variables. The challenge now is not to produce more forecasts but rather to produce forecasts that can be interpreted and explained.

Appendix

Proof of the relationship between Derived Input Coefficients

Using the bordering method (Faddeeva, 1959, p. 107), we can present the Leontief inverse as:

$$B_{n+1}^{-1} = \begin{bmatrix} B_n^{-1} & 0 \\ 0 & 0 \end{bmatrix} + \frac{1}{\alpha}\begin{bmatrix} C \cdot R & C \\ R & 1 \end{bmatrix} \qquad \text{(A1)}$$

where

$$R = -b_{n+1,*} B_n^{-1}$$

$$C = -B_n^{-1} b_{n+1,*}$$

$b_{n+1,*}$ represents the first n elements of the $n+1$ row vector of B_{n+1}; similarly, $b_{*,n+1}$ represents the corresponding column vector;

and

$$\alpha = b_{n+1,n+1} - b_{n+1,*} B_n^{-1} b_{n+1,*}.$$

Since:

$$B^{-1} = (I - A) \qquad \text{(A2)}$$

we can rewrite (A1) as:

$$\left(I - \tilde{A}_{n+1}\right) = \begin{bmatrix} (I - A_n) & 0 \\ 0 & 0 \end{bmatrix} + \frac{1}{\alpha}\begin{bmatrix} C \cdot R & C \\ R & 1 \end{bmatrix} \qquad \text{(A3)}$$

Denote $Z = \frac{1}{\alpha} C \cdot R$. Now we can prove that $Z \geq 0$. Since R and C represent the first n elements of row and columns of $\left(I - \widetilde{A}_{n+1}\right)$, we can present the row as $R = -\widetilde{a}_{n+1,\bullet}$ and the column as $C = -\widetilde{a}_{\bullet,n+1}$. Therefore, $C \cdot R \geq 0$.

Using the determinant of the bordered matrix (see Henderson and Searle, 1981, p. 54), we can define α as follows:

$$\det B_{n+1} = b_{n+1,n+1} \det B_n - b_{n+1,\bullet}(\mathrm{adj} B_n) b_{\bullet,n+1} \tag{A4}$$

then:

$$\frac{det\, B_{n+1}}{det\, B_n} = b_{n+1,n+1} - b_{n+1,\bullet}\left(B_n^{-1}\right) b_{\bullet,n+1} = \alpha \tag{A5}$$

Since B is positive definite, $\alpha > 0$, then $Z \geq 0$. Now we can rewrite part of (A3) as:

$$\left(I - \widetilde{A}_n\right) = \left(I - A_n\right) + Z \tag{A6}$$

or

$$\widetilde{A}_n = A_n - Z \tag{A7}$$

therefore,

$$\widetilde{A}_n \leq A_n \tag{A8}$$

References

Almon, C. (1967) *The American Economy* to 1975 New York:

Bacharach, M. (1970), *Biproportional Matrices and Input-Output Change*, Cambridge: University Press.

Barker, T.S. (1985) "Endogenising input-output coefficients by means of industrial submodels," in *Input-Output Modeling*, Edited by A. Smyshlyaev, pp. 183-192 Berlin: Springer-Verlag.

Bullard, C.W., and A.V. Sebald (1977) "Effects of parametric uncertainty and technological change in input-output models." *Review of Economics and Statistics* 59, 75-81.

Bullard, C.W., and A.V. Sebald (1988). "Monte Carlo sensitivity analysis of input-output models." *Review of Economics and Statistics* 70, 705-12.

Carter, A.P. (1970) *Structural Change in the American Economy.* Cambridge: Harvard University Press

Conway, R. (1990) "The Washington projection and simulation model: a regional interindustry econometric model," *International Regional Science Review*, 13:141-166

Conway, R. (1991) "An empirical comparison of regional multipliers," in John J. Ll. Dewhurst, Geoffrey J.D. Hewings and Rodney C. Jensen eds: *Regional Input-Output Modelling: New Developments and Interpretations* Aldershot: Avebury

Faddeeva, V.N. (1959) *Computational Methods of Linear Algebra*, Dover.

Fisher, W.H. (1975) "*Ex-ante* as a supplement or alternative to RAS in updating input-output coefficients," in *Estimating and Projecting Input-Output Coefficients*, Edited by R.I.G. Allen and W.F. Gossling, London: Input-Output Publishing.

Giarratani, F. and R.E. Garhart, "Simulation techniques in the evaluation of regional input-output models: a survey, in John J. Ll. Dewhurst, Geoffrey J.D. Hewings and Rodney C. Jensen eds: *Regional Input-Output Modelling: New Developments and Interpretations* pp. 14-50 Aldershot: Avebury

Henderson, H.V. and Searle, S.R. (1981) "On deriving the inverse of a sum of matrices," *SIAM Review*, 23:53-60

Hewings, G.J.D. (1984) "The role of prior information in updating regional input-output tables," *Socio-Economic Planning Sciences*, 18:319-336

Hewings, G.J.D. and Jensen, R.C. (1988) "Emerging challenges in regional input-output analysis," *Annals of Regional Science*, 22:43-53

Hudson, E. and Jorgenson, D.W. (1974) "US energy policy and economic growth, 1975-2000," *Bell Journal of Economics* 5:461-514

Israilevich, P.R. (1991) "The construction of input-output coefficients with flexible functional forms," in John J. Ll. Dewhurst, Geoffrey J.D. Hewings and Rodney C. Jensen eds: *Regional Input-Output Modelling: New Developments and Interpretations* Aldershot: Avebury.

Israilevich, P.R. and R. Mahidhara (1991) "Hog butchers no longer: 20 years of employment change in metropolitan Chicago," *Economic Perspectives* 15, 2-13

Israilevich, P.R., Hewings, G.J.D. Schindler, G.R. and Mahidhara, R. (1995) "The choice of input-output table embedded in regional econometric input-output models," *Papers in Regional Science* (forthcoming)

Jackson, R.W. and West, G.R. (1989) "Perspectives on probabilistic input-output analysis," in R.E. Miller, K.R. Polenske, and A.Z. Rose, *Frontiers of Input-Output Analysis*, Oxford: University Press.

Jensen, R. 1980. The Concept of Accuracy in Regional Input-Output Models. *International Regional Science Review*, 5(2): 139-154.

Kop Jansen, P.S.M. (1994) "Analysis of multipliers in stochastic input-output models," *Regional Science and Urban Economics*, 24:55-74

Lecomber, R. (1969) "RAS projections when two or more complete matrices are known," Economics of Planning, 69:267-78

Miernyk, W.H. (1970) *Simulating Regional Economic Development: An Interindustry Model of the West Virginia Economy*, Lexington: Heath.

Nakamura, S. (1984) *An Inter-Industry Translog Model of Prices and Technical Change for the West German Economy*, Berlin: Springer-Verlag.

Okazaki, (1989) "The 'hollowing out' phenomenon in economic development," paper presented at the Pacific Regional Science Conference, Singapore.

Solow, R.M. (1952) "On the structure of linear models," *Econometrica* 20:

Sonis, M., and G.J.D. Hewings, (1989) "Error and sensitivity input-output analysis: a new approach," in *Frontiers of Input-Output Analysis*, edited by R.E. Miller, K.R. Polenske, and A.Z. Rose, pp. 232-244, New York: Oxford University Press.

Sonis, M. and G.J.D. Hewings, (1991) "Fields of influence and extended input-output analysis: a theoretical account," in John J. Ll. Dewhurst, Geoffrey J.D. Hewings and Rodney C. Jensen eds: *Regional Input-Output Modelling: New Developments and Interpretations* pp. 141-158 Aldershot: Avebury

Sonis, M., and G.J.D. Hewings, (1992) "Coefficient change in input-output models: theory and applications." *Economic Systems Research* 4, 143-57 1992.

Stevens, B.H. and G.A. Trainer, (1980) "Error generation in regional input-output analysis and its implications for nonsurvey models," in S. Pleeter ed:

Economic Impact Analysis: Methodology and Applications, pp. 68-84 Boston: Martinus Nijhoff

Stone, R.A. (1961) *Input-Output and National Accounts*, Paris: OECD

Tiebout, C.M. (1970) "An empirical regional input-output projection model: the state of Washington, 1980," *Review of Economics and Statistics*, 51:334-40

West, G.R. (1981) "An efficient approach to the estimation of input-output multipliers." *Environment and Planning A* 13, 857-67.

Wrigley, K.J. (1970) "Production models and time trends of input-output coefficients," in *Input-Output in the United Kingdom*, edited by W.F. Gossling, pp. 89-118 London: Cass.

---

[1] Earlier versions of this paper were presented at the Regional Science Association International British and Irish Section Meeting, Dublin, Ireland, September 14-16, 1994 and the Western Regional Science Meeting in San Diego, California, February, 1995. The authors would like to thank the many comments received from these presentations as well as the comments of Jan Oosterhaven. In addition, we would like to acknowledge the contributions of Ramamohan Mahidhara and Eduardo Martins and the computational assistance of Jiemin Guo. Richard Conway's contribution to the creation and development of the econometric-input-output system that is used in this application should also be acknowledged.

[2] The 1987 benchmark tables appeared in April, 1994.

[3] The work of Stevens and Trainer (1980) would refute this claim (in favor of the importance of the regional purchase coefficients) while Giarratani and Garhart (1991) work offers support. Israilevich *et al.* (1995) show that the choice of input-output table is an important consideration in undertaking impact analyses and forecasting with econometric-input-output tables.

[4] As Takayama (1985) notes, the Walrasian equilibrium system would solve $\dot{p} = k\left[D(p) - S(p)\right]$ where demand and supply are functions of prices, p.