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LIFT: INFORUM's Model of the U.S. Economy

MARGARET BUCKLER MCCARTHY

ABSTRACT *LIFT (for Long-term Interindustry Forecasting Tool) is a model of the economy of the United States built by INFORUM. Among the models in the INFORUM family, it is both the oldest and the most fully developed. Here, the evolution of our U.S. modeling efforts are quickly traced. Then the structure of LIFT is described. The remaining sections discuss data considerations, give some equation specifications, and present a selected bibliography.*

1. Evolution

In a model developed in the early 1960's, Clopper Almon combined input-output and regression-based econometrics. Final demands were determined by behavioral equations, which were estimated with econometric techniques. Input-output coefficients were projected to change. The resulting model could be used for business forecasting as well as government policy analysis. These efforts continue at INFORUM, Interindustry Forecasting at the University of Maryland, a project which Almon founded in 1967.

The first generation of INFORUM models of the U.S. economy emphasized the real or product side of the economy. These models were not closed with respect to income. Rather, the model was solved to determine the level of real income which was consistent with an assumed level of employment. Efforts were concentrated on the estimation of equations to explain the behavior of the components of final demand by category and product sector. Labor requirements were determined by productivity equations estimated at the industry level. These models were dynamic; investment demand, by industry, depended on the rate of growth of that industry. An "across-the-row" approach projected the I-O coefficients.

Several principles were developed in these initial models which continue to guide INFORUM's modeling efforts. Behavioral equations were estimated for detailed sectors, as functions of sector-specific variables. The models were dynamic, with changing I-O coefficients and with investment dependent upon the rate of growth of output. The models forecasted a specific sequence of future years, not an equilibrium at some future point without specifying the path to the equilibrium. The parameters of the various equations had to be sensible because the models were put to practical use. The causation in these models ran from the sectoral detail to the macroeconomic totals. The central I-O equation,

Margaret McCarthy, Dept. of Economics, University of Maryland, College Park, MD 20742 USA

$$\mathbf{q} = \mathbf{A}\mathbf{q} + \mathbf{f}$$

provided structural consistency to the model (where **f** is final demand, **q** is output, and **A** is the matrix of interindustry coefficients). Because each of the components of this equation (the final demands and the I-O coefficients) were explicitly modeled, activity in one industrial sector was linked, in a consistent manner, with the rest of the economy.

In this first generation of models, relative prices were often found to be useful variables in explaining final demand behavior. Relative prices appeared in the equations for personal consumption, exports, and imports; they were a component of the cost of capital in the investment demand equations. However, relative prices were essentially exogenous in these early models. They were forecast as trends which could be varied by assumption.

In what may be termed the second generation of its modeling efforts, separate price and income models were added to the model of the real side of the economy. Prices were estimated as a function of unit costs (for labor and materials) and a distributed lag on output. Of course, the most important component of this equation was unit labor costs, which were derived from wage rate equations and the product model's labor productivity.

INFORUM has tried several approaches to modeling the price-income side. Rather than describe these approaches, we will summarize our experiences. We have had the most success when we abandoned the price response equation described above, and instead, modeled the components of value-added. Then, we solved for prices with the dual equation,

$$\mathbf{p} = \mathbf{p}\mathbf{A} + \mathbf{v}$$

where **p** is a row vector of unit prices and **v** is a row vector of value-added per unit of output. (Early efforts to model the pass-through of material and labor costs tended to give problems with long-term stability. Considerable effort was put into data manipulation to match the sector definitions of different series. In retrospect, we can say that such an approach made the model unwieldy -- it was difficult to maintain, update and verify.)

In this second generation of modeling effort, we had separate models for the product side, for the price side, and for the income side of the economy. The models were run iteratively until they converged on a consistent solution.

In the third, current, generation of models, equations for the real side, the price side, and the income side became part of a single model, which was explicitly closed with respect to income. Thus, the current INFORUM model of the U.S. economy, LIFT, is a macroeconomic model in that it determines all the variables usually considered in macroeconomics -- income, savings, employment, unemployment, inflation, interest rates, and so on. There is no aggregate driver. Of course, the INFORUM model differs from most other macro models, for industry detail is central in the model's structure and causation.

Section 2 outlines the current model and summarizes its behavioral relationships in several tables. Section 3 discusses some data considerations of building INFORUM-type models. In section 4, some of the model's equations are presented. References at the end of the article acknowledge the contribution of the many people who have contributed to the model's development.

2. Model Description

INFORUM currently maintains two multisectoral models of the U.S. economy: LIFT (Long-term Interindustry Forecasting Tool) and DOM (Detailed Output Model). LIFT is a macroeconomic model with 78 producing sectors. DOM includes 420 producing sectors, but depends upon LIFT for its macroeconomic outlook. This article will describe LIFT.

LIFT has three component parts: 1) the real or product side, 2) the price or income by industry side, and 3) the accountant. The real side estimates final demands, output by producing sector, and labor requirements. The price side estimates both the components of gross product originating by industry (value-added) and unit prices by product. The accountant closes the model with respect to income, determines the economic aggregates, and estimates transactions which have not been calculated elsewhere in the model. The sides are run iteratively until the model converges on a solution. Tables at the end of this section show LIFT's exogenous variables and the influences in its behavioral equations. Section 4 presents some of the equation specifications. Now we will explain each of the three "sides" or components of the model.

LIFT: The Real Side

In the real side of LIFT, equations for final demands are evaluated and production and labor requirements are calculated for 78 producing sectors. Government purchases are exogenous; other components of final demand are determined by behavioral equations.

Personal consumption (PCE) equations have been estimated for nearly eighty categories of expenditures. These categories are defined by the National Income and Product Accounts (NIPA). The expenditure categories are translated into producing sectors with a variable bridge matrix. The PCE equations are derived from a two-step estimation procedure. From cross section data, parameters are estimated for the level and distribution of expenditures by income size class, the age structure of the population, and other demographic characteristics. The cross section estimates are combined with time series data to estimate parameters for relative prices, changes in income, and trends. The PCE equations are estimated as a system so that goods can be substitutes or complements with respect to relative prices. Total consumer spending is determined by disposable income less savings. The modest scaling of the sum of the individual PCE categories (less than one percent) necessary to meet this total spending constraint indicates that the system of equations is well-behaved.

The response of PCE to income is a key element in these functions. PCE responds to different levels of income; it also responds to changes in the size distribution of income. The equations use the distribution of expenditures over 5 classes, which is derived from functions that estimate the distribution of income, both before and after taxes, by twenty size classes. Such functions enable the model to study the impact of variations in income tax legislation.

Equipment investment equations have been estimated for 55 industries, aggregates of the 78 producing sectors, and utilize a Diewert cost function. Investment depends upon changes in industry outputs and changes in the relative prices of capital, labor, and energy. These changes are in the form of a distributed lag over five years. Investment by industry is translated into demands for capital goods with a bridge matrix. The bridge coefficients change in response to trends and the investment cycle.

For example, during investment booms, the share of machine tools in investment increases in many industries.

Construction is determined for 31 categories of structures. The private residential categories depend upon consumption or income, interest rates, stocks, and demographic data. The private non-residential categories depend upon industry outputs, interest rates and stocks.

Inventory change equations are always difficult to estimate. For an industry model, the problem is even more difficult because first we must obtain a time series of historical inventories *by product held*. (Most data is by holder of the inventory.) We have put together a crude series and estimated equations, by product, as functions of use of the product, interest rates, and stocks of inventories.

The INFORUM International System contributes product-specific explanatory variables for foreign trade. Exports by product are a function of foreign demand and relative prices. The foreign demands are demands by other countries for imports. The foreign prices have been adjusted for variations in exchange rates. Imports by product are a function of product-specific domestic demand and relative foreign to domestic prices.

The solution of the I-O equation,

$$\mathbf{q} = \mathbf{Aq} + \mathbf{f},$$

yields output. The solution for output is an iterative one. Because current output, imports, and inventory change depend upon one another, these three sets of equations are solved together. (Another iterative loop includes equipment and construction investment in the determination of output.) Coefficients in the intermediate and construction matrices are not constant, but change in response to trends. It is quite possible to change individual input-output coefficients by assumption or to make them fucntions of relative prices. In practice, trends are the basis of almost all of our coefficient changes. The trends are estimated as logistic curves and reflect an "across-the-row" approach. We should note that the A-matrix is a product-to-product matrix. Section 3 will have more to say about the A-matrix.

Labor productivity (output per hour) for the 78 sectors are estimated as a function of trends and changes in output. The equations recognize that the influence of output is *not* symmetric over the business cycle. (Labor hoarding occurs at the beginning of a downturn, while there is a reluctance to increase hiring in the early stages of recovery.) Other equations estimate the length of the work year. Employment is determined by labor productivity, output, and the length of the work year.

LIFT: The Price-Income Side

To determine unit prices for 78 *products*, we solve the dual equation,

$$\mathbf{p} = \mathbf{pA} + \mathbf{v}$$

(unit prices, $\mathbf{p}$, are the sum of unit material costs, $\mathbf{pA}$, plus unit value-added costs, $\mathbf{v}$). Value-added by *industry* is determined from equations for the components of Gross Product Originating (GPO) by some forty industries.

The real side of the model is defined in terms of *products*. Final demands are demands for products. Statistics on prices measure the prices of products. (For these reasons, our A-matrix reflects a commodity technology.) However, statistics on the factors of production (from the National Accounts) -- labor income, capital income, and indirect taxes -- reflect the organization of firms. Therefore, to translate between the real side's *product* classification and the income side's *industry* classification, we have constructed a "Product-to-Industry" Bridge. This bridge is similar to, but somewhat different from, the Make Table (which identifies where, in terms of industries, products are made). Our bridge translates value-added between its product and industry classification. This translation is made in both directions. When the GPO equations need an indicator of real activity, the bridge is used to produce "constant-price, value-added weighted, output." Alternatively, when we have determined nominal GPO by industry, we use the bridge to translate it into our estimate of value-added by product, the **v** vector.

Labor compensation is determined by hours (from the real side) and equations for average hourly compensation ("wage" rates). Industry wages are relative to either a manufacturing or non-manufacturing aggregate wage, and depend upon outputs, foreign trade, inflation and unemployment. In the aggregate equations are the growth of the money supply relative to real GNP, labor productivity, changes in the unemployment rate, and the difference between actual inflation and inflation implied by money growth.

Corporate profits and proprietor income, by industry, are functions of material and labor costs, and of various measures of economic activity (growth in output, changes in unemployment, etc.). Net interest payments are a function of interest rates. Interest rates are influenced by the rate of economic growth, by the rate of inflation, and by monetary tightness. (On the real side, they influence investment activity.) Other equations determine the remaining components of capital income: capital consumption allowances, inventory valuation adjustments, subsidies, and business transfer payments. Indirect business taxes (sales taxes, property taxes, excise taxes) are the other component of GPO.

LIFT: The Accountant

We refer to the third side of the model as the "accountant," for it does the work of the national income accountant. It compiles the aggregate national account tables by summing up the sectoral detail for final demands and income by industry. It determines aggregate prices as a weighted sum of product prices. It converts value-added information into personal income. It determines nominal GNP by applying the estimates of unit prices to the real (constant dollar) estimates of final demand. The accountant also completes transactions not done elsewhere in the model.

A major portion of the accountant deals with government transactions. Government expenditures begin with real purchases which are converted into current dollars. Next, transfer payments are added. Some transfer payments are assumed to be constant (or slightly trended) in real terms, per recipient. Among these types of transfer payments are those for old age, medicare, and the unemployed. Other types of transfer payments are exogenous in nominal terms. The other important category of government expenditure is interest payments which are a function of the debt and of interest rates. Behind the government revenue calculations are our estimates of the income distribution, together with tax functions which utilize the rate schedules of the current tax law.

The accountant constructs personal income as the sum of labor income, proprietor income, and dividends (from the income side), interest income from business and from government, and transfer payments from government and business. Taxes are removed from personal income to yield disposable income. When deflated, it becomes real disposable income, the variable used to explain the real side's personal consumption expenditures. The savings function is also calculated by the accountant. It is a function of the unemployment rate, the percentage change in income, auto purchases as a share of PCE, interest payments as a share of income, personal contributions to social insurance as a share of income, and inflation.

A key feature in the stability of the model is the role of the unemployment rate in several equations. As economic activity slackens, the savings rate falls. Thus, consumers spend a larger share of their income and help stimulate demand. On the price side, an increasing unemployment rate moderates increases in several of the components of income by industry (wage rates and profits in particular), thus moderating inflation and keeping up the level of real income.

Here, we have summarized the behavioral relationships in the model. The following tables show the economic content of the model's equations. In addition to these tables, some key equation specifications are given in Section 4 and further details can be found in works cited in the References.

Before turning to these details of equation specification, however, it is important to stress the fundamental importance of data for INFORUM-type models. In the USA, a rich array of statistics are available, but official sources leave many gaps and unresolved inconsististencies. We describe these problems in some detail, because similar problems are likely to be found in other countries. Also, we find that model builders in other countries assume that USA statistics are in good order while their own are in a most lamentable condition. Perhaps the next section will assure them that they are not alone.

3. Data Considerations

INFORUM-type models are not the only econometric models which use I-O techniques. They are, however, distinguished from many other such models of the U.S. economy in terms of their data foundation. This data foundation consists of updated I-O tables and *detailed* historical series of outputs, prices, final demands, and the components of income by industry. In the U.S, a relatively small part of the data is readily available from the National Income and Product Accounts (NIPA). Much of the data had to be gathered from a variety of sources and subjected to considerable scrutiny. Indeed, the data foundation is both the blessing and the curse of INFORUM-type models. The blessing is, of course, the richness of this data foundation which enables us to build models which emphasize behavioral equations at a detailed level. The curse is all the hard work which is necessary to amass and maintain the data. Perhaps half of our research effort is devoted to the development and maintenance of an adequate database. Here, with reference to the USA, we will describe our data efforts.

LIFT: INFORUM's Macro-Interindustry Model of the U.S. Economy
Components and Influences of Product Side

COMPONENT	SECTORS	INFLUENCES
Output	78	q = Aq + f, production = intermediate + final demand
Personal consumption by NIPA expenditure category	80	Disposable income Size distribution of income Change in disposable income Time Relative prices Age structure of population Other demographic data
Equipment investment by investing industry	55	Change in product outputs Change in relative prices: Cost of capital (post-tax), Labor, and Energy Stocks of equipment
Construction by category	31	Outputs, Income, or PCE Interest rates Stocks of structures Demographic data
Inventory investment	78	Product output Interest rates and Inflation Stocks of inventories
Imports	78	Domestic demand by product Foreign/domestic product prices Exchange rates
Exports	78	Foreign demand by product Domestic/foreign product prices Exchange rates
Labor productivity	78	Output cycles by sector; Time
Length of work year	78	Change in outputs; Time
Employment	78	Defined by labor productivity, output, work year
Consumption, Equipment, and Construction by *product* sector	78	Final demands by *category* are bridged to producing sectors

LIFT: INFORUM's Macro-Interindustry Model of the U.S. Economy
Components and Influences of Price-Income Side

COMPONENT	INFLUENCES
Product prices	p = pA + v Unit prices = sum of unit costs (materials and value-added)
Value-added by product sector	46 GPO industries are translated to 78 products with the Product-to-Industry Bridge
GPO by Industry:	
Labor compensation	
Aggregate equations:	
Manufacturing Wage Rate	Labor productivity Excess money growth (lagged over 5 years) Price shocks Changes in the unemployment rate
Non-manufacturing Wage Rate	Manufacturing wage rate Changes in the unemployment rate
Industry equations:	
Relative wages (industry/aggregate)	Unemployment, Inflation Industry output Industry exports and imports
Return to capital = (identity) (see: "Components and Influences of Capital Income")	Corporate profits + Proprietor income + Net interest payments + Depreciation allowances + Inventory valuation adjustments + Business transfer payments
Indirect business taxes (IBT)	
Total of all industries	Lagged IBT as share of nominal GNP Growth in real GNP
Industries	Share of total IBT

LIFT: INFORUM's Macro-Interindustry Model of the U.S. Economy
Components and Influences of Capital Income in LIFT

COMPONENT	INFLUENCES
Corporate Profits	Change in industry material costs
Equations by	Change in industry labor costs
46 GPO industries	Change in demand (output, unemployment)
Proprietor Income	
Equations for 4 industries	Change in industry labor costs
(80% of total: Agriculture,	Change in industry material costs
Construction, Business services,	Change in demand
Wholesale and retail trade)	Transitory nominal GNP
All other proprietor income	Change in profit share of income
(as share of value added)	Change in labor share of income
	Transitory nominal GNP
Net Interest Payments	
Total domestic payments	Current AAA-bond rate and smoothed average rate
Industries	Share of total domestic interest payments
Rest of world	Change in net factor income
Capital Consumption Allowances	
Corporate and Non-corporate	Inflation
Totals (same influences;	Change in equipment investment
different equations)	Change in structures investment
	Transitory nominal GNP
Industries	Share of total allowances
Inventory Valuation Adjustments	
Corporate, Non-corp. Totals	Inflation, Change in inventories
Industries	Share of total adjustments
Business Transfer Payments	
Total	Lagged real interest rate
Industries	Share of total transfers
Rental Income	Inflation, Change in output
	Rental income share of nominal GNP
	"Excess" nominal GNP

LIFT: INFORUM's Macro-Interindustry Model of the U.S. Economy

Other Variables

VARIABLE	INFLUENCE
Population	Exogenous: Census Bureau projections
Labor Force	Exogenous: Bureau of Labor Statistics projection
Tax policy	Exogenous: 1986 Tax Law
Monetary policy	Exogenous: INFORUM (M2 growth rate)
Government expenditures	
Purchases of goods and services	Exogenous: INFORUM assumption
Transfer payments	Exogenous: INFORUM assumptions
Old age	Constant in real terms per recipient
Medicare	3%/year growth real terms per recipient
Unemployment	Constant in real terms per recipient
Other	Nominal level assumed
Interest payments	Endogenous: depends on Debt and Interest rates
Other	Exogenous: INFORUM assumption
Price of Crude Oil	Exogenous: INFORUM assumption
Savings rate	Endogenous: Percent change in disposable income; Auto purchases as share of income; Transfer share of income; Unemployment rate
Interest rates	
3 month Treasury Bill Rate	Endogenous:
Commercial Paper Rate	Inflation
10 year Treasury Bond Rate	Unemployment rate
AAA Corporate Bond Rate	Velocity of money
Mortgage Rate	
Intermediate and Bridge Tables	
Intermediate materials coefficients	Across-the-row trends
Construction materials bridge	Across-the-row trends
Personal consumption bridge	Trends
Equipment investment bridge	Investment cycle; Trends

The Input-Output Table

In the U.S., a detailed, "benchmark" I-O table is prepared about every five years by the Bureau of Economic Analysis (BEA). It reflects data collected in the various economic censuses. A table for 1977, which had 540 sectors, is the most recently published "benchmark" table.[1] A principal use of these benchmark tables is the benchmark revision of the NIPA. In other words, every five years, the national account detail is adjusted to reflect, among other things, the detail revealed by the I-O table.[2]

BEA prepares both a "use" and a "make" table. The use table shows commodities purchased by each industry, and thus reflects the way in which census data was collected. The make table shows the commodities made by each industry. BEA also calculates a "commodity-to-commodity" table with the assumption of industry technology.[3]

INFORUM uses a commodity-to-commodity table in its model. However, we derive this table with a process we call "purification." From a modeling perspective, in our view, the industry technology assumption is a poor one with which to derive a commodity-to-commodity table. Perhaps a silly, but clear example can illustrate our objection to the industry technology assumption. Suppose ice cream is a secondary product in two industries, motor vehicles and electric utilities. Under the industry technology assumption, ice cream, as a secondary product in motor vehicles, is made with tires, steel, glass, plastics, etc. while as a secondary product in electric utilities, ice cream is made with coal, oil, and natural gas. Note that both of these technologies for making ice cream differ significantly form the technology of the ice cream industry, where we find milk, sugar, fruit, chocolate, etc. While this example is an extreme one, it illustrates the way in which the industry technology assumption leads to strange results. Notice also that this assumption implies that there are as many technologies for making a product as there are industries in which the product is made.

INFORUM's purification technique assumes that each product is made with a single, unique technology. Our method is similar to a "commodity technology" assumption, but avoids some of the problems (negative flows) that a strict application of the assumption can give. The algorithm[4] is an iterative one, in which the production technology is revised until the solution converges. The industry in which a product is primary provides the initial assumption for the production technology of a product. Inputs are transferred from the secondary to the primary producer. Transfers are made only to the extent that they are available from the secondary producer. In this way, negative transfers are avoided.

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[1] BEA is presently (September 1990) still at work on a benchmark table for 1982. The publication of the 1982 table is expected at the end of this year. BEA also has a program which prepares annual tables for 85 sectors. A 1985 table was published in January 1990.

[2] In some other countries, such as Canada, France, and Norway, the I-O effort is integrated on an annual basis with the construction of the national accounts.

[3] With the industry technology assumption, it is assumed that the secondary products of an industry are made according to the input structure of the industry.

[4] See Almon, *1985,Interindustry Forecasts of the American Economy*, for a complete description.

Why worry about whether the table is a "commodity-to-commodity" or a "commodity-to-industry" table? The commodity-to-industry table is the most faithful representation of data collected in the census. However, our objective as model builders is somewhat different from the objective of the statisticians. Final demands are demands for *commodities.* We want an I-O table, which when used for analytical purposes, will translate these final demands into production requirements. Similarly, when we use the I-O table to estimate the unit cost component of prices, we are trying to model the prices of commodities. Obviously, in models with a lot of sectoral detail, this consideration is of added importance. Each researcher should be aware of the structure of secondary products in the table with which he is working and evaluate the consequences. In one sense, a commodity-to-commodity table simplifies the modeling process. For if we did not have a commodity-to-commodity table, we would have to grapple with a way to determine transfers as we go from a product definition of final demands and prices to an industry definition of production requirements.

A second consideration which INFORUM has in regard to the I-O table is that it be reasonably up-to-date. Therefore, we use data from the most recent economic censuses to *update* the published table.[5] Census data is particularly useful in an update, because it contains information about interindustry flows. We make use, as well, of our estimates of outputs and final demands which are described below. In the spring of 1986, we completed our update of the 1982 table. In 1988, we did an update to 1985; however, this 1985 table was without the benefit of census data. Our tables are not constructed from scratch; they are updates of the most recent published table. They remain as close as possible to the base year table while achieving consistency with all the data we can muster for the update year.

Outputs and Prices

Perhaps the most important time-series for I-O model building is data on production. We need such estimates in both current and constant prices. In the USA, there is no single source for such data. The data on product shipments, from the Census and Annual Survey of Manufactures, is the principal source for current price outputs for this sector of the economy. For the non-manufacturing sector, we draw upon a variety of sources. Good data on the service sector of the economy is particularly hard to obtain.

We maintain data on manufacturing product shipments by five-digit SIC (Standard Industrial Classification). This data includes more than one thousand series. We have put considerable effort into keeping the series consistent over time in terms of the definitions of the data series. This data is the basis of our historical production series for manufacturing. We will see shortly that it is also an aid in the estimation of two components of final demand, personal consumption expenditures and producers' durable equipment investment.

For estimates of detailed manufacturing price deflators, we are indebted to the section of BEA which prepares estimates of gross product for the NIPA. (In this context, "gross product" refers to value-added, the components of income-by-industry.) At the level of 5-digit SIC product detail, BEA maintains price deflators derived from

[5]See Almon, *1985* for a description of the general update method.

producer prices indexes and other sources. Our non-manufacturing prices, like the estimates of output, come from a variety of sources.

One problem with I-O modeling is that of *current* data at a detailed level. For example, manufacturing product shipments from the economic census of 1987 were released in 1990. Therefore, alternate data sources must be used for current estimates of activity. Here, our principal source is the indexes of industrial production which are prepared by the Federal Reserve to measure monthly activity[6]. When these indexes are used for estimates of activity over longer periods of time, care must be exercised. We have had success in using regression analysis to extend our historical series with the industrial production indexes.

Investment in Producers' Durable Equipment (PDE)

As noted above in the model description, forecasts of investment by industry are translated into the PDE component of final demand with a capital equipment matrix (B-matrix). We have put considerable effort into the estimation of historical data for these three components (investment by investing industry, PDE by product purchased, and the B-matrix).

For about 20 product groups, estimates of PDE in purchasers' prices is available from the NIPA. To obtain estimates of PDE in greater detail, we adjust the 5-digit product shipments of include imports and to exclude exports. From the BEA I-O workfile, we computed the 1977 ratio of PDE to adjusted shipments. (At the 5-digit level of detail, products are frequently defined specifically enough that so that we can distinguish capital goods or consumer goods from intermediate products.) We obtain our time series of PDE by multiplying the ratio by the time series of adjusted shipments. The 5-digit PDE is aggregated to the 400 sectors of DOM (INFORUM's Detailed Output Model) and reconciled with the NIPA estimates.

We deflate PDE with weighted deflators which reflect our measures of domestic prices and import prices. We have chosen a computer deflator which differs significantly from the BEA hedonic index for computer prices.[7] We did not use the BEA deflators for PDE because of the computer deflator problem and because (at least until recently) BEA used only domestic prices to deflate PDE.

From a variety of sources, we determined investment by 55 industry groups. The Annual Survey of Manufactures provides data on new equipment purchases. Data for the non-manufacturing sectors is quite scarce. Estimates were adjusted as needed to match the PDE total from the NIPA.

Next, with the time series, in current prices, of PDE by producing sector and investment by industry and with a base year capital flow matrix, we use rAs balancing to estimate a time-series of capital flow tables. The capital flow tables are deflated with our PDE deflators. Then the column sums of the capital flows matrices yield constant price estimates of investment by industry.

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[6]In some instances, these industrial production indexes are measures of physical quantities, such as tons of coal. Such series are just the information which we need. For other sectors, it is more difficult to measure production directly and a proxy is employed by the Fed. One typical proxy is electricity use; another is hours of production workers.

[7]See McCarthy, "The Measurement of Real GNP" in INFORUM's Nov. 1988 Outlook.

Personal Consumption Expenditures

The NIPA provide data, in current and constant prices, by category of consumer spending, for which we estimate our consumption functions. The NIPA time series are based on retail sales, which are assigned to spending categories on the basis of Census information on merchandise line sales. (These time series are revised as part of the benchmark revisions to incorporate the work of the I-O division in preparing the benchmark I-O table.) To determine PCE by product, we pass consumer spending through a PCE bridge table.

Historically, we have made direct estimates of PCE in producers' prices. The 1977 PCE workfile was used to calculate (at the 5-digit level) the ratio of PCE to shipments which had been adjusted to include imports and exclude exports. The ratio and the time series of adjusted shipments yielded a time series of PCE. This source is generally the one which we used for our final demand estimates in the update of the I-O table. We deflated adjusted PCE with the weighted deflators described above. For many (but not all) manufacturing consumer goods sectors, if we know production and reduce it for exports and increase it for imports, we should have a good estimate of consumer purchases. Apparel and toys are examples where this method should provide reasonable estimates. Gasoline and motor vehicles are examples where the method is unreasonable.

However, there were some significant differences between the NIPA-bridged PCE and the 5-digit based PCE. These differences were particularly large in the constant dollar series. Of course the bridge table is not constant, but the differences did not seem to represent a bridging problem. (For a number of categories, such as apparel, bridging merely removed trade and transportation margins from data in purchasers' prices in order to derive the estimate in producers' prices. In such cases, we were perplexed when the two series exhibited significantly different trends.) For the constant dollar series, one possibility is that our prices, which reflect weighted domestic and import prices, differ from the NIPA deflators, which reflect the consumer price indices. Another troubling consideration is the degree of change which has occurred in the NIPA PCE detail as a result of the benchmark revisions in the national accounts.

This problem is one which we have not resolved to our satisfaction. It seems to represent inconsistences in the data sources. Therefore, we have constructed a measure, the INFORUM statistical discrepancy, which is the difference between historical output and the output predicted by our estimates of historical final demands (including bridged PCE) and our historical, updated I-O tables. Therefore, in the model, we use

$$\mathbf{q} = \mathbf{A}\mathbf{q} + \mathbf{f} + \mathbf{d}$$

to calculate output. In the forecast, $\mathbf{d}$ is constant.

Exports and Imports

Foreign trade is becoming increasingly important in the U.S. economy. INFORUM maintains detailed series of merchandise exports and imports in current and constant prices. The Census Bureau collects data on merchandise trade in tremendous detail. Until a few years ago, Census published detailed data on exports and imports in SIC-based product codes. Unfortunately, these volumes have been discontinued; detailed data is now published only in various foreign trade classifications. (This loss is a significant one, because those volumes made comparison with other domestic data a simple matter. Their detail also permitted the construction of unit value indexes to measure price change.) We are indebted to the International Trade Administration in the Department of Commerce for sharing with us their series of merchandise exports and imports classified by 4-digit SIC. With a few exceptions, data on trade in services is hard to obtain.

We deflate exports with domestic deflators for producer prices. We deflate imports with foreign producer-price deflators, adjusted for changes in exchange rates, and weighted by country of origin. The Bureau of Labor Statistics publishes some deflators for exports and imports. These series cover recent years and selected products. We have made some use of them, particularly as substitutes for the unit-value indexes.

Value-added

We obtain estimates of value-added, for some 14 components and about forty industries, from the NIPA as their series on gross product originating (GPO) by industry. The NIPA obtain much of the capital income data from tabulations of the income tax returns of companies. To translate between the GPO *industry* definitions and the price and output *product* definitions, we have constructed a "product-to-industry" bridge for value-added, which was described above.

All of this data effort is quite a lot of work. Not all of it is necessary for the first stages of a young INFORUM model. But it is essential if the model is to be used in current business forecasting and policy analysis. Furthermore, only with a firm foundation of historical data can we hope to build models of long-term growth by industry.

4. Some Equation Specifications for LIFT

In Section 2, a description of the behavioral relationships in LIFT was given. Space does not permit us to include complete specifications for all equations in LIFT. In this section presents some specifications are given for the major equations.

Because our equations are used in a forecasting and simulation model, we take care that the estimated parameters have sensible values. In several cases, we have constrained the estimated parameters to insure behavioral properties which are, in our opinion, reasonable. In particular, parameters in the equations for the savings rate and changes in wage rates have been constrained.

Key Macro Equations

4.1. The Savings Rate

$$S_t = 15.6 - 1.0 * UN_{t-1} - 1.0 * AUTO_t - 1.0 * IPBRAT_t + 0.56 * PCTDI_t + 0.33 * PCTPRI_t - 0.49 * SHSSC_t$$

where

S_t	=	savings rate (savings as a percentage of disposable income)
UN_{t-1}	=	unemployment rate
$AUTO_t$	=	auto purchases as a percentage of disposable income
$IPBRAT_t$	=	interest paid by consumers as a percentage of income
$PCTDI_t$	=	percentage change in real disposable income
$PCTPRI_t$	=	percentage change in prices
$SHSSC_t$	=	personal contributions for social insurance as a percentage of disposable income

4.2. Average hourly compensation in manufacturing

$$W_t = 1.0 * MOG_t + 1.0 * LP_t + 0.69 * DIFP_t + 11.33 * DIFU_t$$

where

W_t	=	percentage change in nominal average hourly compensation
MOG_t	=	percentage change of M2/real GNP (weighted sum over 6 years)
LP_t	=	percentage change of Labor Productivity in the private sector (3-year moving average)
$DIFP_{t-1}$	=	difference between last year's inflation and inflation implied by MOG_{t-1}
$DIFU_t$	=	percentage change in the reciprocal of the unemployment (2-year average)

4.3. The rate on 10-year Treasury bonds

$$RTB10Y_t = 19.1 + .096 * PCTGNP_t + .083 * PCTGNP_{t-1} + .776 * PCTPRI_t - 27.0 * \left(\frac{M2}{GNPZ}\right)_t + 2.00 * DISINT_t$$

where

$RTB10Y_t$ = Ten year Treasury bond yield

$PCTGNP_t$ = percentage change in real (constant $) GNP

$PCTPRI_t$ = percentage change in prices (GNP deflator, 3-year average)

$M2_t$ = money supply

$GNPZ_t$ = nominal (current $) GNP

$DISINT_t$ = dummy variable for disintermediation (zero prior to 1979, then 0.25 in 1979, and 1.0 in 1980 and later years)

Some Sectoral Equations

4.4. Personal Consumption Equations for 79 categories of consumer spending

This set of equations was estimated in two parts. A cross-section equation captures income and demographic effects. A time-series equation addresses cyclical factors, the influence of relative price changes, and changes in tastes. The 79 categories of consumer goods have been organized into 10 groups of related items in order to estimate parameters which could explain complementarity or substitutability on the basis of changes in relative price.

4.4.a. A cross-section equation was estimated for each category of consumer goods.

$$C_i = \left(a + \sum_{j=1}^{5} b_{ij} Y_j + \sum_{k=1}^{10} d_{ik} D_k \right) \left(\sum_{m=1}^{8} w_{im} N_m \right)$$

where

C_i = consumption of category i

Y_j = income by group, where each group contains 20% of individuals in sample

D_k = dummy variables for demographic characteristics (region of the country, educational attainment, working spouse, family size, age of head of household)

N_m = population, by age grouping

and

b_{ij}, d_{ik}, and w_{im} are the estimated parameters.

4.4.b. The time series equation for each consumer category is specified by

$$\frac{Q_{it}}{W_{it}} = \left(a_i + b_i C_{it} + c_i DC_{it} + d_i t\right) \prod_{j=1}^{10} \left(\frac{P_{it}}{PBAR_{jt}}\right)^{s_j z_{ij}} \prod_{k=1}^{2} \left(\frac{P_{it}}{PSUB_{kt}}\right)^{r_k v_{ik}}$$

where

Q_{it} = quantity (constant dollars) consumed of category i
W_{it} = age-weighted population
C_{it} = cross-section prediction of Q_{it}/P_{it}
DC_{it} = first difference in C_{it}
t = time trend
P_{it} = price of goods in category i
$PBAR_{jt}$ = average price of goods in group j
s_j = share of group j in total consumption in base year
$PSUB_{kt}$ = average price of goods in subgroup k
r_k = share of subgroup k in group in base year

and

a_i, b_i, c_i, d_i, z_{ij}, and v_{ik} are the estimated parameters.

4.5. Equipment investment by 53 industries

As described above, a generalized Leontief cost function is the basis of our investment functions. Constraints were employed to insure that the estimated parameters were sensible. In particular, they insured that own price elasticities were negative and that cross price elasticities between labor and capital were positive. Constraints across the capital, labor, and energy equations insured symmetry of the price response in labor and energy.

For each industry, the demand for capital is

$$K_t = e^{-a\,t}\, Q_t \left[b_1 \left(\frac{P_L}{P_K}\right)^{.5} + b_2 \left(\frac{P_E}{P_K}\right)^{.5} + b_3 \right]$$

where

K_t = optimal capital stock
Q_t = industry output
P_L = price of labor, the wage level
P_E = price of energy
P_K = price of capital, the user cost

and

a, b_1, b_2, b_3 are the estimated parameters for each industry.

The user cost of capital is calculated as

$$P_K = \frac{P_{eq}\,(\,r + dep\,)\;(\,1 - Tz - c\,)}{(\,1 - T\,)}$$

where

P_{eq} = average price of equipment purchased by the industry
r = the expected rate of return (assumed constant at 0.1)
dep = the annual economic depreciation
T = the corporate tax rate
z = the net present value of depreciation of one dollar's worth of investment
c = the investment tax credit.

From the demand for capital, we determine the optimal capital stock, which translates into a demand for investment (from the comparison of the current and optimal stock). Gross investment is separated into net investment (the change in the capital stock) and replacement investment.

4.6. Labor productivity (output per hour) was estimated for each of the 78 producing sectors. As noted, the simple equation described below outperformed (in simulation tests) other equations derived from production functions.

For each industry,

$$\ln\left(\frac{Q_t}{H_t}\right) = a + b\ T1_t + c\ T2_t + d\ QDOWN_t + e\ QUP_t$$

where

Q_t = output
H_t = hours worked
$T1_t$ = time trend, beginning in 1958, covering the entire estimation period
$T2_t$ = time trend, beginning in 1969 (zero prior to 1969)
$QDOWN_t$ = $\ln Q_t - \ln QPEAK_{t-1}$, when $QPEAK_{t-1} > Q_t$, otherwise 0
QUP_t = $\ln Q_t - \ln QPEAK_{t-1}$, when $QPEAK_{t-1} < Q_t$, otherwise 0
$QPEAK_t$ = Q_t when $Q_t > QPEAK_{t-1}$
= $QPEAK_{t-1}$ when $Q_t < QPEAK_{t-1}$

4.7. Foreign trade for each of 78 products

4.7.a. Exports

$$X_{it} = (a_i + b_i F_{it}) \left(\frac{P_{dit}}{P_{fit}} \right)^{c_i}$$

4.7.b. Imports

$$M_{it} = (a_i + b_{it} D_{it}) \left(\frac{P_{fit}}{P_{dit}} \right)^{c_i}$$

where

M_{it} = imports
X_{it} = exports
F_{it} = weighted foreign demands for imports
D_{it} = domestic demand
P_{fit} = weighted foreign prices
P_{dit} = domestic prices

See the Nyhus paper in this issue for further details on the export and import equations.

5. Conclusion

The LIFT model embodies a great deal of economic analysis and data organization. It has grown and been stregthened by being regularly applied to a variety of topics. One specific application is described in the Monaco paper in this issue. Other recent applications include a study of the national and regional implications of reduced defense spending (for the Congressional Budget office) and an analysis of the implications of a possible free trade agreement between the USA and Mexico. Regular, semi-annual meetings with subscribers compel us to keep the model up-to-date and relevant to the current situation. Many model improvements have come through weaknesses detected in the course of application. We are indebted to all users of the model for the contributions to the constant correction, expansion and refinement of INFORUM's work.

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See bibliography in Nyhus, "The INFORUM International System," in this journal.