Documentation of The DRI Model of the U.S. Economy

December 1993

Note: In accordance with Energy Information Administration standards regarding the use of proprietary models, this report documents the Data Resources, Inc. (DRI) Model of the U.S. Economy and the Personal Computer Input-Output Model. Both of these models were developed and are maintained by DRI as proprietary models. This documentation has been prepared by DRI and is being made available to the public as a service of EIA. Appendix B, "How Large are Economic Forecast Errors," was prepared by Stephen K. McNees of the Federal Reserve Bank of Boston.

Contents

1. The DRI Model of the U.S. Economy

The Energy Information Administration (EIA) uses models of the U.S. economy developed by Data Resources, Inc. (DRI) for conducting policy analyses, preparing forecasts for the Annual Energy Outlook, the Short-Term Energy Outlook, and related analyses in conjunction with EIA's National Energy Modeling System (NEMS) and its other energy market models. Both the DRI Model of the U.S. Economy[1] and the DRI Personal Computer Input-Output Model (PC-IO)[2] were developed and are maintained by DRI as proprietary models. This report provides documentation, as required by EIA standards for the use of proprietary models; describes the theoretical basis, structure and functions of both DRI models; and contains brief descriptions of the models and their equations.

Appendix A describes how the two large-scale models documented here are used to support the macroeconomic and interindustry modeling associated with the National Energy Modeling System. Appendix B is an article by Stephen McNees of the Federal Reserve Bank of Boston on "How Large are Economic Forecast Errors." This article assesses the forecast accuracy of a number of economic forecasting models (groups) and is attached as an independent assessment of the forecast accuracy of the DRI Model of the U.S. Economy.

The Model's Theoretical Position

For the last four decades, economists have theorized and developed models of the U.S. economy. Models built in the 1950's and 1960's were largely Keynesian income expenditure systems that assumed a closed domestic economy.[3] High computation costs during estimation and manipulation, along with the underdeveloped state of macroeconomic theory, limited the size of the models and

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[1] This description of the DRI Model of the U.S. Economy is derived from a summary of the DRI Model prepared by Roger E. Brinner and appearing in the document entitled, *Quarterly Model of the U.S. Economy: Version US89A*, March 1990.

[2] This description is derived from documentation of the Personal Computer Input-Output Model entitled, *Description and User Guide for PC-IO: The EIA Input-Output Model for the IBM PC*, August 30, 1990.

[3] See the following citations: Jan Tinbergen, *Selected Papers*, pp. 36-84, and *Business Cycles in the United States of America: 1919-1932*; Lawrence R. Klein, *Economic Fluctuations in the United States: 1921-1944*; Klein and Goldberger, *An Econometric Model of the United States, 1929-1952*; Duesenberry, Eckstein and Fromm, "A Simulation of the U.S. Economy in Recession", *Econometrica*, 1960, p. 749-809; Daniel Suits, "Forecasting and Analysis with an Econometric Model", *American Economic Review*, 1962, pp. 104-132; and Liebenberg, Hirsch, and Popkin, "A Quarterly Econometric Model of the United States: A Progress Report", *Survey of Current Business*, 1966, pp. 13-39.

the richness of the linkages of spending to financial conditions, inflation, and international developments. Since that time, however, computer costs have fallen spectacularly; theory has also benefitted from four decades of postwar data observation and from the intellectual attention of many eminent economists.

An Econometric Growth Model

The DRI Model of the U.S. Economy (hereafter, DRI U.S. Model) incorporates the best insights of many theoretical approaches to the business cycle: Keynesian, neoclassical, monetarist, supply-side, and rational expectations. In addition, the DRI U.S. Model embodies the major properties of the long-term growth models presented by James Tobin, Robert Solow, Edmund Phelps, and others.[4] This long-term structure guarantees that robust long-run properties will temper short-run cyclical developments.

In growth models, the expansion rate of technical progress, the labor force, and the capital stock determine the productive potential of an economy. Both technical progress and the capital stock are governed by investment, which in turn must be in balance with post-tax capital costs, available savings, and the capacity requirements of current spending. Thus, for example, monetary and fiscal policies will influence the short- and the long-term characteristics of such an economy through their impacts on national saving and investment.

A modern model of output, prices, and financial conditions is melded with the growth model to present the detailed, short-run dynamics of the economy. In specific goods markets, the interactions of a set of supply and demand relations jointly determine spending, production and price levels. Typically, the level of inflation-adjusted demand is driven by prices, income, wealth, expectations, and financial conditions. The capacity to supply goods and services is keyed to a production function combining the basic inputs of labor hours, energy usage, and the capital stocks of equipment and structures. The "total factor productivity" of this composite of tangible inputs is linked to accumulated expenditures on research and development. Prices adjust fully to gaps between current production and supply potential and to changes in the cost of inputs.

For financial markets, the model predicts exchange rates, interest rates, stock prices, loans, and investments interactively with the preceding variables. The Federal Reserve sets the supply of reserves in the banking system and the fractional reserve requirements for deposits. Private sector demands to hold deposits are driven by household disposable income, business cash flow, expected inflation, and by the deposit interest yield relative to the yields offered on alternative investments. Banks and other thrift institutions, in turn, set deposit yields based on the market yields of their investment opportunities with comparable maturities and on the intensity of their need to expand reserves to meet legal requirements; in other words, the contrast between the supply and demand

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[4] See the history of the New Economics in W.W. Heller, *New Dimensions of Political Economy*, 1967; Robert Solow, "A Contribution to the Theory of Economic Growth", *Quarterly Journal of Economics*, 1956, pp. 65-94; James Tobin, *Essays in Economics: Theory and Policy*, 1982; and Edmund Phelps, *Inflation Policy and Unemployment Theory*, 1972.

for reserves sets the critical short-term interest rate for interbank transactions, the Federal funds rate. Other interest rates are keyed to this rate, plus expected inflation, Treasury borrowing requirements, and sectoral credit demand intensities.

The labor market has three basic components. The supply of labor positively responds to the perceived availability of jobs and, albeit weakly, to the wage level. Demand for labor is keyed to the level of output in the economy and the productivity of labor, capital, and energy. Because the capital stock is largely fixed in the short run, a higher level of output requires more employment and energy inputs. Such increases are not necessarily equal to the percentage increase in output because of the improved efficiencies typically achieved during an upturn.

Wages, the price of labor, are adjusted to bring demand and supply into balance. Excess supply is obviously registered by a high unemployment rate, which reduces the rate of increase in wages. The expansion of wages in a fully employed economy is set by the growth in the expected value of output per hour. Wages will increase more rapidly the greater the expected expansion rates of labor productivity and output prices. Tempering the whole process of wage and price determination is the exchange rate; a rise signals prospective losses of jobs and markets unless costs and prices are reduced.

Monetarist Aspects

The model pays attention to valid lessons of monetarism by representing the diverse portfolio aspects of money demand and by capturing the central bank's role in long-term inflation phenomena.[5] The private sector may demand money balances as one portfolio choice among transactions media (currency, demand deposits, some savings deposits), investment media (bonds, stocks, short-term securities), and durable assets (homes, cars, equipment, structures). Given this range of choice, each medium's implicit and explicit yield must therefore match expected inflation, offset perceived risk, and respond to the scarcity of real savings. Nominal (real) money balances provide benefits by facilitating spending transactions and can be expected to rise nearly proportionately with nominal (real) transactions requirements unless the yield of an alternative asset changes. Now that even demand deposit yields can float to a limited extent in response to changes in Treasury bill rates, money demand no longer shifts quite as sharply when market rates change. Nevertheless, the velocity of circulation (the ratio of money demand to nominal spending) is still far from stable during a cycle of monetary expansion or contraction. Thus the simple monetarist link from money growth to price inflation or nominal spending is therefore considered invalid as a rigid short-run proposition.

Equally important, as long-run growth models demonstrate, induced changes in capital formation can also invalidate a naive long-run identity between monetary growth and price increases. Greater demand for physical capital investment can enhance the economy's supply potential in the event of more rapid money creation and hence higher inflation. The yield on currency is fixed and the yield on demand deposits will only partially reflect added inflation, but physical capital is a near-perfect

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[5] See Milton Friedman, *Studies in the Quantity Theory of Money*, 1956.

inflation hedge: a higher inflation economy can be a more capital-intensive economy with a greater productive potential. In the DRI U.S. Model, both prices and quantities can therefore change in response to monetary policy initiatives specified by the model user (see discussion in Financial section below). If simultaneous, countervailing influences prevent an expansion of the economy's potential, however, the model will (within a decade) translate all money growth into a proportionate increase in prices rather than in physical output.

Supply-Side Economics

Since 1980, supply-side political economists have pointed out that the economy's growth potential is sensitive to the policy environment.[6] They focused on potential labor supply, capital spending, and savings impacts of tax rate changes. The DRI U.S. Model embodies supply-side hypotheses to the extent supportable by available data, and this is considerable in the many areas that supply-side hypotheses share with long-run growth models. These features, however, have been fundamental ingredients of the DRI U.S. Model since 1976.

Rational Expectations

As rational expectations theory has pointed out, much of economic decision-making is forward looking.[7] For example, the decision to buy a car or a home is not only a question of current affordability but also one of timing; the delay of a purchase until interest rates or prices decline has become particularly common since the mid-1970's when both inflation and interest rates were very high and very volatile. Consumer sentiment surveys, such as those conducted by the University of Michigan Survey Research Center, clearly confirm this speculative element in spending behavior.[8]

However, households can be shown to base their expectations, to a large extent, on past experiences: households believe that the best guide to the future is an extrapolation of recent economic conditions and the changes in those conditions. Consumer sentiment about whether this is a "good time to buy" can therefore be successfully modeled as a function of recent levels and changes in employment, income, interest rates, and inflation. Similarly, inflation expectations (influencing financial conditions) and market strength expectations (influencing inventory and capital spending decisions) can be modeled as functions of recent rates of increase in prices and spending.

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[6] See discussion of supply-side economics in Dornbusch and Fischer, *Macro-Economics*, 1984, pp. 573-574.

[7] See Thomas Sargent and Neil Wallace, "Rational Expectations and the Theory of Economic Policy", *Journal of Monetary Economics*, 1979 and Robert Lucas and Thomas Sargent, "After Keynesian Macroeconomics", Federal Reserve Bank of Minneapolis, *Quarterly Review*, 1979.

[8] Survey Research Center, The University of Michigan, *Surveys of Consumers*. See discussion of consumer sentiment index modeling in the *DRI/McGraw-Hill Quarterly Model of the U.S. Economy: Version US89A, Model Documentation: Theory, Properties, and Coverage*, DRI / McGraw-Hill, 1990.

This largely retrospective approach is not, of course, wholly satisfactory to pure adherents to the rational expectations doctrine. In particular, this group argues that the announcement of macroeconomic policy changes would significantly influence expectations of inflation or growth prior to any realized change in prices or spending. If an increase in Government expenditures is announced, the argument goes, expectations of higher taxes to finance the spending might lead to lower consumer or business spending in spite of temporarily higher incomes from the initial Government spending stimulus. A rational expectations theorist would thus argue that multiplier effects will tend to be smaller and more short-lived than a mainstream economist would expect.

These propositions are subject to empirical evaluation. Expectations do play a significant role in private sector spending and investment decisions; but, until change has occurred in the economy, there is very little room for significant changes in expectations in advance of an actual change in the variable about which the expectation is formed. The rational expectations school thus correctly emphasizes a previously understated element of decision-making, but exaggerates its significance for economic policymaking and model building.

The DRI U.S. Model allows a choice in this matter. On the one hand, the user can simply accept DRI's judgments and let the model translate policy initiatives into initial changes in the economy, simultaneous or delayed changes in expectations, and subsequent changes in the economy. On the other hand, the user can manipulate the clearly identified expectations variables in the model, i.e., consumer sentiment, inflation expectations, and interest rate volatility; for example, if the user believes that fear of higher taxes would subdue spending, he could reduce the consumer sentiment index. Such experiments can be made "rational" through model iterations that bring the current change in expectations in line with future endogenous changes in income, prices, or financial conditions.

Theory as a Constraint

The conceptual basis of each equation in the DRI U.S. Model was thoroughly worked out before the regression was initiated. The list of explanatory variables includes a selected set of demographic and financial inputs. Each estimated coefficient was then tested to be certain that it meets the tests of modern theory and business practice. This attention to equation specification and coefficient results has eliminated the "short circuits" that can occur in evaluating a derivative risk or an alternative policy scenario.

Uncertainty and Alternative Forecasts

In order to address uncertainty in the forecast period, DRI provides alternative macroeconomic growth forecasts each month, incorporating lower and higher growth relative to the baseline path. The alternative scenarios use different assumptions regarding interest rates, labor force growth, productivity growth, energy prices, international developments and exchange rates. These alternative cases typically show a 0.8 percentage point bandwidth around the baseline growth path for GDP. These alternative cases are based on expert judgement, as are the probabilities assigned to each case.

Major Sectors

The DRI U.S. Model captures the full simultaneity of the U.S. economy, forecasting over 1200 concepts spanning final demands, aggregate supply, prices, incomes, international trade, industrial detail, interest rates, and financial flows. Chart 1 and Table 1 summarize the structure of the eight interactive sectors (noted in Roman numerals). The following discussion presents the logic of each sector and the significant interactions with other sectors.

Private Domestic Spending (Sector I)

Consumer. The domestic spending (I), income (II), and government (III) sectors model the central circular flow of behavior as measured by the National Income and Product Accounts. If the rest of the model were "frozen" these blocks would produce a Keynesian system similar to the models pioneered by Tinbergen and Klein.[9]

Consumer spending is divided into three durable goods categories (autos and parts, furniture, and "other"); five nondurable goods categories (food, clothing and shoes, gas, fuel, and "other"); three household operation subcategories (electricity, natural gas, and "other"); and three service subcategories (medical, financial, and transportation). In nearly all cases, real expenditures are motivated by real income and the price of a particular category relative to the prices of other consumer goods. Durable and semidurable goods are also especially sensitive to household net worth, current financing costs, and consumer speculation on whether it is a "good time to buy." The University of Michigan Survey of Consumer Sentiment monitors this last influence, with the index itself modeled as a function of current and lagged values of inflation, unemployment, and the prime rate.

Business Investment. Business spending includes six fixed investment categories (autos, office equipment, other producer durables, public utility structures, mining and petroleum structures, and buildings and other structures) and five inventory spending categories (farm, manufacturing, wholesale, retail, and "other"). Equipment and non-utility, non-mining, structures spending is determined by the effective post-tax capital costs, capacity utilization, and replacement needs. The cost terms are blends of post-tax debt and equity financing costs (offset by expected capital gains) and the purchase price of the investment good (offset by possible tax credits and depreciation-related tax benefits.

Given any cost/financing environment, the need to expand capacity is monitored by recent growth in national goods output. Public utility structure expenditures are motivated by similar concepts except that the output terms are restricted to electricity and gas utility output rather than total national goods output. Net investment in mining and petroleum structures responds to movements in real domestic oil prices and to the energy demands of the economy.

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[9] See Footnote 3.

Chart 1. Overview of the DRI Model

Table 1. Model Variables
(Number and Type of Variables in Each Sector of the Model)

Sector	Basic Behavioral (Stochastic)	Identities and Special Monitors	Exogenous	Total
I. Private Domestic Spending				
A. Consumption	17	35	19	71
B. Business Spending	7	44	23	74
C. Housing	13	22	9	44
D. Inventory Accumulation	9	16	1	26
II. Production and Income				
A. Wages	2	3	1	6
B. Corporate Profits & Depreciation	4	40	76	120
C. Industry Detail				
1. Production	63	100	4	167
2. Capacity, Operating Rates	1	1	1	3
3. Employment	27	7	0	34
D. Interest, Rent, Entrepreneurial, Misc.	9	3	3	15
III. Government				
A. Federal	3	39	34	76
B. State and Local	11	16	7	34
C. Aggregates	0	16	1	17
IV. International Transactions (Goods & Services, Prices and Quantities)				
A. NIPA & Census Exports & Imports	28	57	23	108
B. Exchange Rates, Foreign Interest Rates, Activity	1	7	8	16
C. Current Account (including Investment Income) and Net International Investment Position	1	16	14	31
V. Financial				
A. Monetary & Financial Aggregates	20	27	14	61
B. Interest Rates	23	10	1	34
C. Household & Mortgage Flow of Funds	10	9	1	20
D. Stock Market	4	2	0	6
VI. Inflation and Productivity				
A. Producer Prices	11	40	15	66
B. Deflators & CPI	34	57	5	96
C. Wages & Productivity	4	7	2	13
VII. Supply				
A. Nonresidential Capital Stocks	0	33	7	40
B. Labor Supply, Employment & Hours	4	2	2	8
C. Energy	4	10	13	27
D. Aggregate Supply	0	4	0	4
VIII. Expectations				
A. Consumer	1	0	0	1
B. Financial	1	4	0	5
IX. Population	0	0	8	8
X. Aggregates & Miscellaneous	5	34	9	48
TOTAL	317	661	301	1279

The fixed investment equations are more sensitive to changes in the economy than in pre-1985 models because of their new, Bischoff-based specification.[10] Most noteworthy is the greater sensitivity to interest rates. The estimated structure, with a clear separation of output and capital cost influences into change and level components, has clearly enhanced the accelerator properties of the model.[11] This improves its cyclical sensitivity but not at the expense of its long-run properties; its long-run properties remain robust because replacement needs are constrained to match the depreciation rates used to create corresponding capital stocks, and the capital stocks determine consistent estimates of capacity. These capacity measures, when contrasted with current and expected output, drive investment, wage, and price decisions.

Inventory. Inventory demand is the most erratic component of GDP, reflecting the procyclical, speculative nature of private sector accumulation during booms and decumulation during downturns. The forces that drive the four non-farm stock categories are changes in spending, short-term interest rates and expected inflation, surges in imports, and changes in capacity utilization or the speed of vendor deliveries. Surprise increases in demand lead to an immediate drawdown of stocks and then a rebuilding process over the next year; the reverse naturally holds for sudden reductions in final demand. Inventory demands are sensitive to the cost of holding the stock, measured by such terms as interest costs adjusted for expected price increases and by variables monitoring the presence of bottlenecks. The cost of a bottleneck that slows delivery times is lost sales: an inventory spiral can therefore be set in motion when all firms accelerate their accumulation during a period of strong growth but then try to deplete excessive inventories when the peak is past.

Housing. Residential construction is typically the first sector to turn down in a recession and the first to rebound in a recovery. Moreover, the magnitude of the building cycle is often the key to that of the subsequent macroeconomic cycle. This is as true today as in past decades, although changes in financial market regulation have altered this sector's behavior. Up until the 1980's surges in housing were produced by "disintermediation," i.e., cyclical losses and gains of deposits at thrift institutions (which were bound by the Regulation Q deposit-yield ceiling) to alternative investment media as market interest rates rose or fell.[12] With the removal of such ceilings, mortgage lenders-as well as homebuilders and buyers-can now obtain construction funds if they are willing to pay a competitive interest rate. Buyers are thus being priced out of the market by a high yield rather than rationed out by an absence of funds.

The housing sector of the DRI Model reflects this change, explaining new construction as a decision primarily based on the after-tax cost of homeownership relative to disposable income. This cost is estimated as the product of the average new home price adjusted for changes in quality, and the mortgage rate, plus operating costs, property taxes, and an amortized downpayment. "Lever

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[10] Charles Bischoff, "The Effect of Alternative Lag Distributions", *Tax Incentives and Capital Spending,* 1971, pp. 60-130.

[11] The accelerator property is the property that investment is proportional to changes in output.

[12] For a discussion of disintermediation, mortgage availability, and Regulation Q, see Dornbusch and Fischer, *Macro-Economics,* 1984, pp. 229.

variables" allow the model user to specify the extent to which mortgage interest payments, property taxes, and depreciation allowances (for rental properties) produce tax deductions that reduce the effective cost.

Due to the change in financial regulations, the equations for single- and multi-family housing are based only on data from 1978 through 1991. This brief estimation interval could potentially create problems for long-term forecasting except that the equations also include a careful specification of demographic forces. After estimating the changes in the propensity for specific age-sex groups to form independent households, the resulting "headship rates" were multiplied by corresponding population statistics to estimate the trend expansion of single- and multi-family households. The housing equations were then specified to explain current starts relative to the increase in trend households over the past year, plus pent up demand and replacement needs. The basic phenomenon being scrutinized is therefore the proportion of the trend expansion in households whose housing needs are met by current construction. The primary determinants of this proportion are housing affordability, consumer confidence, and the weather. Actual construction spending in the GDP accounts is the value of construction "put-in-place" in each period after the start of construction (with a lag of up to six quarters in the case of multi-family units), plus residential improvements, and brokerage fees.

Production and Income (Sector II)

Production. The industrial production sector includes 60 standard industrial classifications (SIC). Production is a function of various cyclical and trend variables and a "generated" output term, i.e., the input-output (I-O) relationship between the producing industry and both intermediate industries and final demand.[13]

Income. Domestic spending, adjusted for trade flows, defines the economy's value-added, or Gross Domestic Product (GDP). Because all value-added must accrue to some sector of the economy, the expenditure measure of GDP also determines the Nation's gross income. The distribution of income among households, business, and Government is determined in sectors II and III of the model.

Pre-tax income categories include private and Government wages, corporate profits, interest, dividends, rent, and entrepreneurial returns. Each pre-tax income category, except corporate profits, is modeled as a function of wages, prices, interest rates, debt levels, and capacity utilization or unemployment rates. Profits are logically the most volatile component of GDP on the income side.

When national spending changes rapidly, the contractual arrangements for labor, borrowed funds, and energy imply that the return to equity holders is a residual that will soar in a boom and collapse in a recession. The DRI U.S. Model reflects this by calculating wage, interest, and rental income as

[13] Although the DRI U.S. Model forecasts industrial production indices, these do not represent the basis for the industrial output used by the Energy Information Administration (EIA). For industrial output, EIA uses an input-output model which is linked directly to the DRI U.S. Model. The Personal Computer Input-Output (PC-IO) Model is discussed in the next section.

thoroughly reliable near-identities (e.g., wages equal average earnings multiplied by hours worked) and then subtracting each non-profit item from national income to solve for profits.

Taxes. Since post-tax rather than pre-tax incomes drive expenditures, each income category must be taxed at an appropriate rate; the model, therefore, tracks personal, corporate, payroll, and excise taxes separately. Users may set Federal tax rates; tax revenues are then simultaneously forecast as the product of the rate and the associated pre-tax income components. However, the model adjusts the effective average personal tax rate for variations in inflation and income per household, and the effective average corporate rate for credits earned on equipment, utility structures, and research and development. With the exception of corporate profits and social insurance tax rates, State taxes are fully endogenous. The DRI U.S. Model makes adjustments to press the sector toward the legally required approximate budget balance. The average personal tax rate rises with income and falls with the Government operating surplus. Property and sales taxes provide the bulk of State excise revenue and reflect changes in oil and natural gas production, gasoline purchases, and retail sales, as well as revenue requirements. The feedback from expenditures to taxes and taxes to expenditures reproduces both the secular growth of the State and local sector and its cyclical volatility.

Government (Sector III)

The last sector of domestic demand for goods and services, that of the Government, is largely exogenous (user-determined) at the Federal level and endogenous (equation-determined) at the State and local level. The user sets the real level of Federal nondefense purchases of goods and services, defense purchases, transfer payments, and grants to State and local governments. The model calculates the nominal values through multiplication by the relevant estimated prices. Changes in interest payments are determined by changes in the debt (the current deficit) and changes in the average interest rate as debt is expanded or rolled over.

The presence of a large and growing deficit imposes no constraint on Federal spending. This contrasts sharply with the State and local sector where legal requirement for balanced budgets mean that declining surpluses or emerging deficits produce both tax increases and reductions in spending growth. State and local purchases of goods and services are also driven by the level of Federal grants (due to the matching requirements of many programs), population growth, and trend increases in personal income.

International Transactions (Sector IV)

The international sector is a critical, fully simultaneous block that can either add or divert strength from the central circular flow of domestic income and spending. Depending on the prices of foreign output, the U.S. exchange rate, and competing domestic prices, imports capture varying shares of domestic demand. Depending on similar variables and the level of world gross domestic product, exports can add to domestic spending on U.S. production. The exchange rate itself responds to international differences in inflation, interest rates, trade deficits, and capital flows between the United States and its competitors. In preparing forecasts, DRI's U.S. Economic Service and the World Service collaborate in determining internally consistent trade prices and volumes, interest rates, and financial flows. While baseline forecasts for foreign interest rates, GDP, and prices are derived outside the scope of the DRI U.S. Model, the model includes reaction functions which simulate changes in these concepts based upon changes in U.S. interest rates, U.S. import demands, and exchange rate-adjusted world oil and U.S. export prices from their baseline values.

Export and import details for business machines is included as a natural counterpart to the inclusion of the office equipment component of producers' durable equipment spending. The business machines detail allows more accurate analysis because computers are rapidly declining in effective quality-adjusted prices relative to all other goods, and because such equipment is rising so rapidly in prominence as businesses push ahead with new production and information processing technologies.

Investment income flows are also explicitly modeled. The stream of huge current account deficits incurred by the U.S. during the 1980's, and the prospects for continued large deficits in the years ahead, have important implications for the U.S. investment income balance. As current account deficits accumulate, the U.S. net international investment position and the U.S. investment income balance deteriorate. U.S. foreign assets and liabilities are, therefore, included in the model, with the current account deficit determining the path of the net investment position. Investment income flows are modeled as rates of return on the corresponding foreign asset and liability categories.

Financial (Sector V)

The use of a detailed financial sector and of interest rate and wealth effects in the spending equations recognizes the importance of credit conditions on the business cycle and on the long-run growth prospects for the economy.

Interest rates, the key output of this sector, are modeled as a term structure, pivoting off the Federal funds rate, the discount rate, and the Treasury bill rate. As noted earlier, these short-term rates depend upon the balance between the demand and supply of reserves to the banking system. The supply of reserves is the principal exogenous monetary policy lever within the model reflecting the Federal Reserve's open market purchases or sales of Treasury securities. Banks and other thrift institutions demand reserves to meet the reserve requirements on their deposits and the associated (exogenous) fractional reserve requirements. The private sector in turn demands deposits of various types, depending on current yields, income, and expected inflation.

Longer-term interest rates are driven by shorter-term rates as well as factors affecting the slope of the yield curve. In the DRI Model, such factors include inflation expectations, Government short- and long- term borrowing requirements, corporate financing needs, and the recent volatility of interest rates. The expected real rate of return varies over time and across the spectrum of maturities. An important goal of the financial sector is to capture both the persistent elements of the term structure and to interpret changes in this structure. Twenty-four interest rates are included in the model.

Inflation and Productivity (Sector VI)

Inflation is modeled as a carefully-controlled, interactive process involving wages, prices, and market conditions. Equations embodying a near accelerationist point of view produce substantial secondary inflation effects from any initial impetus such as a change in wage demands or a rise in foreign oil prices.[14] Unless the Federal Reserve expands the supply of credit, real liquidity is reduced by any such shock; given the real-financial interactions described above, this can significantly reduce growth. The process also works in reverse. A spending shock can significantly change wage-price prospects and then have important secondary impacts on financial conditions. Inspection of the simulation properties of the DRI U.S. Model, including full interaction among real demands, inflation and financial conditions, confirms that the model has moved toward central positions in the controversy between fiscalists and monetarists, and in the debates among neoclassicists, institutionalists, and "rational expectationists."[15]

The principal domestic cost influences are labor compensation, nonfarm productivity (output per hour), and foreign input costs; the latter are driven by the exchange rate, the price of oil, and foreign wholesale price inflation. This set of cost influences drives each of the 18 industry-specific producer price indexes, in combination with a demand pressure indicator and appropriately weighted composites of the other 17 producer price indexes. In other words, the inflation rate of each industry price index is the weighted sum of the inflation rates of labor, energy imported goods, and domestic intermediate goods, plus a variable markup reflecting the intensity of capacity utilization or the presence of bottlenecks. If the economy is in balance - with an unemployment rate near 5 percent, manufacturing capacity utilization steady near 80-85 percent and foreign influences neutral - then prices will rise in line with costs and neither will show signs of acceleration or deceleration.

Supply (Sector VII)

The first principle of the market economy is that prices and output are determined simultaneously by the factors underlying both demand and supply. As noted above, the supply-siders have not been neglected in the DRI U.S. Model; indeed, substantial emphasis on this side of the economy was incorporated as early as 1976. In the DRI U.S. Model, aggregate supply (or potential GDP) is estimated by a Cobb-Douglas production function that combines factor input growth and improvements in total factor productivity. Factor input equals a weighted average of labor, business fixed capital, and energy. Based upon each factor's historical share of total input costs, the elasticity of potential GDP with respect to labor is 0.62 (i.e., a 1 percent increase in the labor supply increases potential GDP 0.62 percent); the capital elasticity is 0.33; and the energy elasticity is 0.05. Factor supplies are defined by estimates of the full employment labor force, the full employment capital stock net of pollution abatement equipment, and the energy demand that would prevail at full employment. Total factor productivity depends upon the stock of research and development capital and trend technological change (Chart 2).

Marginal and average federal and state and local personal income tax rates, statutory and effective corporate income tax rates, investment tax credits, effective federal and state and local social insurance tax rates, and numerous excise tax rates are included in the model. Taxation (and other

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[14] Otto Eckstein, *Core Inflation*, 1981.

[15] See Footnotes 5, 6, and 7.

Government policies) influences labor supply and all investment decisions, thereby linking tax changes to changes in potential GDP. An expansion of potential GDP first reduces prices and then credit costs, and thus spurs demand. The DRI U.S. Model does not incorporate the view that tax cuts will pay for themselves. While they can make a significant difference in per capita living standards, tax reductions do increase the deficit and thus imply higher interest rates unless Federal spending is simultaneously lowered.

The growth of aggregate supply is the fundamental constraint on the long-term growth of demand. Inflation created by demand that is approaching potential GDP raises credit costs and weakens consumer sentiment, thus putting the brakes on aggregate demand when the economy is overheating. Conversely, lower inflation and easier credit stimulate demand when the economy is slack. An increase in Government spending, when the economy is operating at full employment, for example, creates a gap between aggregate demand and aggregate supply, driving up output prices and lowering the unemployment rate (Chart 3). Higher prices and a tighter labor market then force up wage rates and further ignite inflation, although this effect is partially offset by an increase in labor productivity and the supply of labor. Higher inflation and a stronger real economy drive up interest rates and reduce real income gains. At the same time, the gap between aggregate demand and supply stimulates investment and leads to an expansion of the capital stock. The net effect is a dampening of aggregate demand and an expansion of aggregate supply, which eventually closes the gap.

Expectations (Sector VIII)

The contributions to the DRI U.S. Model and its simulation properties of the rational expectations school are as rich as data will support. The principal nuance relating to expectations in the DRI U.S. Model is an endogenous volatility factor influencing interest rates. Volatility, as measured by the difference between the monthly minimum and maximum values of the Treasury bill rate, increases significantly with Federal Reserve "changes of regime," shifts in wholesale price inflation and oil price shocks. Volatility adds moderately to the level of short-term rates and, by increasing the risk of investment, has an even greater impact on long-term rates.

The presence of the volatility variable allows users to achieve (and to enhance at will) the types of non-Keynesian influences stressed by the rational expectations theorists. The same may be said of the other expectational variables in the model: consumer sentiment (in household durables and semidurables), inflation expectations (in interest rates and capital spending), and growth expectations (in business investment).

Chart 2. Aggregate Supply

Chart 3. Aggregate Supply and Aggregate Demand

Estimation and Track Record

Estimation of Key Macroeconomic Variables

As indicated in Table 1 above, the DRI U.S. Model is comprised of 1,269 equations, of which 317 are behavioral. The categories of final demand which make up Gross Domestic Product (GDP) are key variables from both a macroeconomic perspective and as drivers to the PC-IO Model.[16] Table 2 below presents the R-bar squared and T-statistics for the final demands and other key macroeconomic variables.

Table 2. Estimation of Key Macroeconomic Variables

		T - statistics for independent variables (Where two values are listed first is for current value and second is for lagged value; constrained values reflect coefficients taken from the DRI Energy Model)				
Consumption Equations	**R-bar Squared**	**Real Disposable Income**	**Relative Price**	**Wealth**	**Consumer Confidence**	**Real Interest Rate**
Motor Vehicles & Parts	0.9447	1.736	-0.8809		8.878	-5.035
Furniture & Household	0.9969	4.8	-3.671			
Other Durables	0.9838	2.091	-1.848		6.511	-6.262
Fuel Oil & Coal	0.9892	constrained	constrained			
Food	0.9865	73.75	-5.849		1.666	
Clothing & Shoes	0.9982	4.127 / 2.188	-12.88	5.118	6.451	
Gasoline	0.8548	constrained	-19.03			
Other Nondurables	0.9936	34.85	-6.417		3.793	
Electricity	0.9826	21.14	-5.92			
Natural Gas	0.9288	constrained	constrained			
Other Household Operation	0.9988	6.052 / 4.432	-3.854			
Transportation	0.9565	26.5	-0.5308		6.941	
Other Services	Identity					
Investment - Structures	**R-bar Squared**	**(Change in Price)*Output**	**(Change in Output)*Price**	**Output**		
Public Utilities	0.9163			4.223		
Mining & Equipment	0.9184			1.538	17.45	
Buildings & Other	0.5997	4.47	6.063			
Investment - Producers' Durable Equipment	**R-bar Squared**	**Lagged Price * Output**	**Lagged Price * Lagged Output**			
Automobiles	0.8586	3.586	-3.205			
Office Equipment	0.9826	1.96	-1..771			
Other Equipment	0.9275	8.897	-8.46			

[16] Appendix A discusses the relationship between the DRI U.S. Model and the Macroeconomic Activity Module of the National Energy Modeling System. The disaggregated final demand detail, plus other macroeconomic variables such as interest rates, car sales and housing starts, are fundamental inputs into MAM.

Table 2. Estimation of Key Macroeconomic Variables (continued)						
		T - statistics for independent variables				
Trade - Exports	**R-bar Squared**	**Output**	**Relative Price**			
Foods, Feeds & Beverages	0.8545	4.624	-3.281			
Industrial Supplies	0.9818	15.36	-2.954			
Computers	0.9948		-6.693			
Capital Goods	0.9755	3.05	-13.6			
Autos	0.8828	11.04	-3.542			
Consumer Goods	0.9785	7.808	-6.069			
Other Goods	0.9260	1.388	-3.076			
Services	0.9896	44.28	-9.132			
Factor Income	Identity					
Trade Imports	**R-bar Squared**	**Output**	**Relative Price**	**Energy Imports**		
Foods, Feeds & Beverages	0.8443	20.51	-6.248			
Petroleum & Products	0.3480			constrained		
Industrial Supplies	0.8605	21.51	-7.056			
Computers	0.9585					
Capital Goods	0.9929	5.682	-3.734			
Autos	0.9838	13.71	-8.979			
Consumer Goods	0.9935	1.175 / 1.373	-14.04			
Other Goods	0.9639	3.638	-2.041			
Services	0.9898	28.26	-3.523			
Factor Income	Identity					
Other Equations	**R-bar Squared**	**CD Rate**	**Real Private Debt Holdings (Federal)**			
3 Month T-bill	0.9871	67.26	5.343			
	R-bar Squared	**10-Yr Bond Rate**	**Corporate Cash Flow**			
New Corporate Bonds	0.9819	34.04	-5.12			
Conventional Mortgage Rate	0.9644	6.21 / 1.823				
	R-bar Squared	**Domestic Demand**				
Unit Car Sales, Imports	0.8924	7.164				
	R-bar Squared	**Relative Price**	**Stock of Cars**			
Unit Car Sales, Total	0.9897	-19.3	-6.938			
	R-bar Squared	**Demographics**	**Real Interest Rate**	**Consumer Confidence**	**Property Taxes**	**Labor Market Slack**
Mobile Home Shipments	0.8913	11.17	-3.214	1.369	-2.321	-4.046 / -1.971
	R-bar Squared	**Affordability**	**Consumer Confidence**	**Heating Degree Days**	**Real Interest Rate**	
Single-Family Housing Starts	0.9224	-5.883	4.297 / 1.975	-3.883	-5.939	
Multi-Family Starts	0.9129	-6.315	2.775 / 3.243	-4.791		

Track Record

Short-Run Performance. The DRI U.S. Model is one of several which make regular forecasts of economic activity. Table 3 provides an assessment of the relative performances of a number of groups in forecasting economic activity from the second-quarter of 1992 through the second-quarter of 1993.[17] The main summary statistic calculated is the mean square error for the growth in Real GDP. Using this measure over successive forecasts from the various groups indicates that for GDP growth, the range of the mean square error was from 0.20 to 0.41, with DRI having the lowest at 0.20.[18]

Table 3. Comparison of DRI and Other Forecasting Groups

	UCLA	Merrill Lynch	Georgia State	Conference Board	L.H. Meyer	DRI	WEFA	Michigan RSQE
Real GDP Growth (Second-quarter 1992 to second-quarter 1993, percent) **Actual Growth = 2.6 percent**								
Forecasts by Date Published:								
August 1992	2.7	2.6	2.6	1.7	2.7	2.9	2.9	3.0
September 1992	1.8	1.9	2.4	1.8	2.3	2.8	2.6	3.0
October 1992	2.3	2.2	2.5	2.1	2.6	2.7	2.7	2.2
December 1992	2.9	2.7	2.8	2.5	3.1	2.7	3.0	3.1
January 1993	2.8	2.7	2.9	2.8	3.2	2.9	3.3	3.1
February 1993	3.4	3.2	3.4	3.1	3.5	3.3	3.4	3.5
March 1993	3.7	3.7	3.4	3.1	3.6	3.4	3.6	3.6
April 1993	3.7	3.6	3.4	3.1	3.6	3.3	3.5	3.6
May 1993	2.9	3.0	3.1	2.7	2.8	2.9	3.1	2.6
June 1993	2.7	2.7	2.8	2.6	2.7	2.8	2.9	2.6
Mean Square Error	0.41	0.35	0.23	0.23	0.35	0.20	0.34	0.37

Source: Conference Board, "Economic Times," calculations of MSE by DRI.
Notes: No November issues published by Conference Board; Conference Board only published inflation forecasts for fourth quarter versus year earlier.

Table 4 provides detail on how the August 1992 DRI forecast compared to the achieved growth based on the current government estimate. While the forecast of real GDP was fairly accurate, the composition of growth differed from actual growth. The DRI forecast of consumption and investment was below actual while its forecast of trade was too optimistic. On inflation and employment concepts, the DRI forecast tracked actual reasonably well.

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[17] Tables 3 and 4 are contained in the summary writeup, "Deja Vu," by Roger E. Brinner and David A. Wyss in the October 1993 DRI / McGraw-Hill *Review of the U.S. Economy*.

[18] The "actual growth rate" of 2.6 percent, reflects the July 1993, pre-revision, GDP statistics for the second quarter of 1992 and the second quarter of 1993.

Table 4. Detail of the August 1992 DRI Forecast vs. History (Second Quarter 1993: percent change versus year ago)

			Forecast Evaluation		
	Expected Growth (Aug. '92 DRI forecast)	Achieved Growth (August 1993 post-revision estimate)	DRI Too Optimistic	DRI Correct	DRI Too Pessimistic
Real Spending					
GDP	2.7	2.9		X	
Consumer	2.6	3.5			X
Producers' Durable Equipment					
Computer	25.5	33.8			X
Other	6.0	10.7			X
Nonres. Construction	-4.2	-1.1			X
Residential Construction	6.6	5.4		X	
Goods Trade - Exports	6.0	4.5	X		
- Import	7.5	11.1	X		
Gov't Purchases - Federal	-3.8	-2.7		X	
- State / Local	1.7	1.8		X	
Nonfarm Inventory (Stock Level)	1.4	1.7		X	
Other Forecast Variables					
Consumer Price Inflation	3.3	3.1		X	
Industrial Production	4.0	3.8		X	
Car and Light Truck Sales	8.4	10.1			X
Employment - Payroll survey	1.1	1.4		X	
- Household survey	1.4	1.2		X	
Labor Force	1.1	0.7		X	
Unemployment Rate (Q2 Level)	7.3	7.0			X
S&P 500 Stock Price	7.9	8.6		X	
10-Year Treasury Bond (Basis pt change)	-10	-139			X
Dollar Exchange Rate	-1.3	1.4			X

The August 1992 forecast is evaluated because this was the first forecast made after second-quarter 1992 data was published in late July 1992. Very similar results can be shown for subsequent DRI forecasts. See Table 3 for the real GDP outlook in each month.

Longer-Run Performance. The assessment of performance found in Tables 3 and 4, plus the McNees article presented in Appendix B, focus on the short-term. Unfortunately, the assessment of forecast accuracy of macroeconomic models in the literature is dominated by issues of short-run performance. There are a couple of reasons for this. Clients of these models typically are more interested in short-run issues and performance of the economy. Second, it is difficult to assess the accuracy of the longer-term model forecast because of historical data revisions by the Department of Commerce. These data revisions are not trivial. Every July, data for the past three years are revised. In addition, the underlying data base year of the National Income and Product Accounts (NIPA) is periodically changed. In November 1991, the base year was changed from 1982 to 1987. The previous revision occurred in December of 1985, shifting the base year from 1972 to 1982. In particular, the shifting of the base year makes assessment difficult because it limits the period where the forecast -- as presented in a given base year set of dollar values -- overlaps with the date prepared by the Department of Commerce.

Table 5 presents a simple assessment of the four-year accuracy of DRI's forecast of Real GNP for the period where the data were expressed in 1982 dollars. With the NIPA update in December of 1985, the first DRI long-term 25-year forecast to incorporate 1982 dollars was made in the summer of 1986. For assessment purposes, this yields data points for the year 1987, 1988, 1989 and 1990. The summer of 1987 DRI forecast yields values for 1988, 1989, and 1990; the summer 1988 DRI forecast gives 1989 and 1990; and the summer of 1989 forecast gives a 1990 value. Using this data, Table 5 shows that the DRI forecast in 1986 showed growth of 2.6 percent in the first year of the forecast, from 1986 to 1987; a two-year growth rate of 2.84 percent from 1986 through the second year; a three-year growth rate of 2.53; and a four-year growth rate of 2.61. The 1987 DRI forecast yields a one-year, a two-year, and a three-year growth rate. The 1988 forecast yields a one- and two-year growth rate, and the 1989 forecast is only for one year. These growth rates are then compared to growth rates using the NIPA first-estimate values for each year presented in the Survey of Current Business.

Two key observations can be made from this limited data set. First, the DRI forecast for the first year was better in the 1988 and 1989 forecasts than in the previous two sets of forecasts. While this might signal that the first year model accuracy has improved, it is probably more a simple misreading of the underlying short-term growth potential of the economy. In 1986 and 1987, DRI was simply suggesting that growth would be moderate and underestimated the potential for growth in the economy. Nonetheless, DRI did much better in 1988 and 1989. From a longer-term perspective, a second observation is more germane. With the exception of the 1988 forecast, the error has a tendency to get smaller as the forecast horizon is lengthened. While the 1986 DRI forecast was off by 1.0 percent in the one-year growth rate and 1.27 percent in the two-year growth rate, this had diminished to only -0.26 percent for a four-year growth rate.

Table 5. Forecast Accuracy of the Growth Rate of Real GNP (Compound Growth Rates)

	Years of Compound Growth Forecast			
	1	2	3	4
DRI 1986 Forecast	2.60	2.84	2.53	2.61
Survey of Current Business	3.60	4.10	3.51	2.86
Error	-1.00	-1.27	-0.98	-0.26
DRI 1987 Forecast	2.54	2.37	2.46	
Survey of Current Business	4.61	3.46	2.62	
Error	-2.07	-1.09	-0.15	
DRI 1988 Forecast	2.36	2.46		
Survey of Current Business	2.32	1.64		
Error	0.04	0.82		
DRI 1989 Forecast	1.20			
Survey of Current Business	0.96			
Error	0.23			

2. The Personal Computer Input-Output Model

The Energy Information Administration uses the Personal Computer Input-Output (PC-IO) Model to create the baseline forecasts of industrial activity supporting the Annual Energy Outlook. PC-IO was initially developed in 1990 as a small scale input-output system which is directly linked to the DRI U.S. Model of the U.S. Economy.[19] The PC-IO model is based on the large-scale mainframe input-output model which DRI maintains for its own use. The PC-IO model is principally an aggregation of the larger DRI model.[20] The interindustry sectoring scheme for PC-IO contains 114 sectors. This sectoring plan was developed to emphasize industries which have interesting energy use characteristics, or have important implications for energy demand and supply (see Table 2).

The Linkage to the DRI Model of the U.S. Economy

The PC-IO is an integrated environment for the investigation of the impacts of macroeconomic scenarios on industry level output. From the opening screen, the user has access to the DRI Model of the U.S. Economy, the PC-IO Modeling System, and LOTUS-1-2-3. Outputs from the PC-IO model can be viewed in LOTUS worksheets, and user assumptions or adjustments to final demands and rowscalers can be provided through LOTUS. The modeling system also contains capabilities for the production of quick on-screen graphs, as well as reports by industry concept in LOTUS.

The aggregate output of the economy is characterized in the macroeconomic model through Gross Domestic Product (GDP). This aggregate measure of GDP is made up of 46 final demand categories -- personal consumption expenditures (15 equations), investment (9 equations), government (3 equations), exports (9 equations), and imports (10 equations). The PC-IO model essentially calculates the level of industrial output needed to produce the level of GDP coming from the macro forecast. Chart 4 identifies the flow of information in the linked system.

The 46 final demands from the macro model are first transformed by the bridge matrix. The role of the bridge matrix is to allocate each concept of final demand to the industry(s) that produce that final demand. In the consumption of motor vehicles and parts, for example, the largest part of the value is allocated to the motor vehicles and equipment industry, but some is allocated to the synthetic rubber industry, the glass and glass products sector, and the wholesale and retail sector which sells the car.

The main body of the PC-IO Model is comprised of a set of coefficients which compute the output by industry required, directly and indirectly, to satisfy the set of final demands identified by the bridge calculation above. In essence, the system calculates all intermediate sales which occur

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[19] See Meade, D.S., *Description and User Guide for PC-IO: The EIA Input-Output Model for the IBM PC*, August 30, 1990.

[20] For a general description of the concepts input-output tables and models, refer to Miller, R. and Blair, P., *Input-Output Analysis: Foundations and Extensions*, 1985.

between industries plus the original set of final demands from the industry. This total concept is referred to as gross output by industry, and is the measure of real output by industry. Movements in this forecast series reflect not only growth in GDP, but also the composition of that growth. Faster growth in consumer purchases of services will result in relatively high growth in the services sector of the economy. If purchases of investment goods experience high growth, the manufacturing sector will show higher growth.

Chart 4. Overview of the PC-IO Model

Table 6. Sectoring Scheme for the PC-IO Model		
Sector Title	DRI 432 Sector Categories	SIC Code
1. Livestock and Products	1-3	01,02
2. Other Agricultural Products	4-11	01,02
3. Forestry and Fishery Products	12-13	08,09
4. Ag., Forestry & Fishery Services	14	0254,pt.07,085,092
5. Iron Ore Mining	15	101,108
6. Nonferrous Metals Mining	16-17	102,103-105,pt 108,109
7. Coal Mining	18	111,121
8. Crude Petroleum	19	131,pt 138
9. Natural Gas	20	132, pt 138
10. Stone/Clay Mining & Quarrying	21	141-5,pt 148,149
11. Chem and Fertilizer Mineral Mining	22	147
12. New Oil & Gas Well Drilling	42	pt 138
13. New Electric Utility Facilities	35	pt 16, pt 17
14. New Gas Utility Facilities	38	pt 15, pt 17
15. New Petroleum Pipelines	37	pt 16, pt 17
16. New Highways & Streets	40	pt 16, pt 17
17. Other New Construction	23-34-38-39-41-43-46	pt 15-17
18. Maintenance & Repair Construction	47-49	pt. 15-17, pt 13819.
19. Ordinance & Accessories	50-55	3761,3795,348
20. Food & Kindred Products	55-99	20
21. Tobacco Manufactures	100-103	21
22 Fabric, Yarn & Thread Mills	104-107	221,222,224,226,228
23. Miscellaneous Textile Foods	108-111	227,229
24. Apparel	112-114	225,231-8,39998
25. Misc. Fabricated Textile Products	115-116	239
26. Lumber & Wood Products	117-129	24 exc 244
27. Wood Containers	130	244
28. Household Furniture	131-138	251

Table 6. Sectoring Scheme for the PC-IO Model (continued)

Sector Title	DRI 432 Sector Categories	SIC Code
29. Other Furniture & Fixtures	137-143	252-259
30. Paper Mills, Exc. Building Paper	145	2621
31. Paper & Allied Products	144,146-154	26, exc 2621,265
32. Paper board Containers & Homes	155	265
33. Printing & Publishing	156-167	27
34. Inorganic & Organic Chemicals	168	281,285
35. Fertilizers	169-170	2873-5
36. Agricultural Chemicals, NEC	171	2879
37. Miscellaneous Chemical Products	172-177	288-289
38. Plastic Materials & Resins	178	2821
39. Synthetic Rubber	179	2822
40. Cellulosic & Noncellulosic Fibers	180-181	2823,2824
41. Drugs, Cleaning and Toilet Prep.	182-188	283-284
42. Paints & Allied Products	187	2851
43. Petroleum Refining	188	2911
44. Misc. Petroleum & Coal Products	189-190	299
45. Paving Modules, Asphalt	191-192	295
46. Rubber Products	193-196,198	301,302,303,304,306
47. Miscellaneous Plastic Products	197	3079
48. Leather & Footwear	199-204	31
49. Glass & Glass Products	205-208	321-323
50. Hydraulic Cement	207	3241
51. Stone & Clay Products	208-222	325-329
52. Coke Oven Products	pt 223	pt 3312
53. Blast Furnaces & Basic Steel	pt 223,224,227	pt 3312,3313-17
54. Steel Foundries, Head Treading	228,230,231	332,339
55. Ferrous & Nonferrous Forgings	229,245	3462,34633
56. Primary Aluminum	235	3334
57. Primary and Basic Nonferrous Metals	232-234,236-244	3331-3,3339,334-338

Table 6. Sectoring Scheme for the PC-IO Model (continued)		
Sector Title	DRI 432 Sector Categories	SIC Code
58. Metal Containers	246-247	341
59. Fabricated Structural Metal Prod.	248-258	343,344
60. Screw Machine Products & Fasteners	257	345
61. Automotive and Other Stampings	258-259	346
62. Other Fabricated Metal Products	260-270	342,347,349
63. Engines and Turbines	271-272	3511,351
64. Farm and Garden Machinery	273-274	3523,3524
65. Construction and Mining Machinery	275-278	3531-2
66. Oil Field Machinery	277	3633
67. Materials Handling Machinery	278-281	353
68. Metalworking Machinery & Equipment	282-287	3354
69. Special Industry Machinery	288-293	355
70. General Industrial Machinery	294-300	356
71. Miscellaneous Nonelectrical Mach.	301-302	359
72. Office, Computing & Account. Mach.	303-306	357
73. Service Industry Machinery	307-311	358
74. Electrical Machinery	312-319	362,3825
75. Household Appliances	320-326	363
76. Electrical Lighting & Wiring Eq.	327-329	364
77. Radio, TV and Communication Equipment	330-333	385-388
78. Electronic Comp. & Accessories	334-340	367
79. Misc. Electrical Machinery & Eq.	341-345	369
80. Motor Vehicles & Equipment	346-350	371
81. Aircraft & Parts	351-353	372-376
82. Ship & Boat Building & Repairing	354-355	373
83. Railroad Equipment	356	3743
84. Miscellaneous Transportation Eq.	357-360	2451,3751,3716,379
85. Instruments & Supplies	361-368	381,382,384,387
86. Optical, Ophthalmic & Photo Eq.	367-369	383-385

Table 6. Sectoring Scheme for the PC-IO Model (continued)

Sector Title	DRI 432 Sector Categories	SIC Code
87. Miscellaneous Manufacturing	370-379	39
88. Railroads and Related Services	380	40,474,pt 4789
89. Passenger Transportation, NEC	381	41
90. Motor Freight	382	42,pt 4789
91. Water Transportation & Related Serv.	383	44
92. Air Carriers & Related Services	384	45
93. Pipelines, Except Natural Gas	385	48
94. Transportation Services, NEC	388	pt. 47
95. Communications, Exc. Radio & TV	387	48 exc 483
96. Radio & TV Broadcasting	388	483
97. Electric Utilities	389	491, pt 493
98. Gas Utilities	390	492, pt 493
99. Water & Sewer Services	391	494-497,pt 493
100. Wholesale Trade	392	50,51
101. Retail Trade	393	52,57,59,7398,8042
102. Finance and Insurance	394-398	60,61,62,63,64,67
103. Real Estate & Rentals	397-398	65,66, pt 1531
104. Personal Services, Exc Automotive	399-401	pt 70
105. Business Services	402-414	73,76,8911,893,899
106. Eating & Drinking Places	415	58 pt 70
107. Automobile Repair & Service	416-17	75
108. Movies and Amusements	418-419	78,79
109. Medical, Educational Services, NPO	420-425	80,82,83,84,85,89
110. Federal Government Enterprises	427-428	4311
111. State & Local Government	429	pt.41
112. Noncomparable Imports	430	NA
113. Scrap, Used & Secondhand Goods	431	NA
114. Dummy Sector	432	NA

Mathematical Structure of the PC-IO Model

The A and B Matrices

Since output for each sector is simply the sum of its sales to other industries plus its sales directly to final demand, the following equation holds for any given year:

$$q = Aq + f = Aq + Bg \qquad \textbf{(1)}$$

where:

q = the vector of output by 114 industries
f = the vector of 114 final demands by industry
g = the vector of 47 final demands by category from the Macro model.

The two matrices needed for the PC-IO model are the *A*-matrix (direct requirements matrix, with each component a_{ij} showing the proportion of good *i* used in the production of good *j*), and the *B*-matrix (final demand bridge, with each component b_{ij} showing the proportion of final demand category *j* comprised of demand for industry *i*). The columns of the bridge matrix, *B*, each add to one, since each category of final demand is fully allocated among industries. In the base year, each column sum of the I-O coefficient matrix (*A*) is constrained to equal one minus the value added per dollar of output for that industry. Because the table is in constant dollars and there is no calculation of value added, there is no explicit constraint on the column sum in any other year.

The A-matrix was converted to flows, aggregated to 114 X 114 sectors, and downloaded to the PC. The B-matrix was converted to flows, aggregated to 114 X 47 sectors, and downloaded. The history and forecast of total final demands for 167 categories were aggregated to 47 categories and downloaded. All eight major categories of final demand were also aggregated and downloaded at the 114 sector level.

All data in the PC-IO Model are in constant 1982 dollars. These matrices were updated from the 1977 tables released by the Department of Commerce using a row and column scaling technique. The scaling is done by first converting the matrix to flows. Control totals are derived for each row and column, then the matrix is iteratively scaled to these control totals until it converges. For example, each row of the *A*-matrix should sum to total intermediate demand for that industry. Total intermediate demand is calculated as output minus final demand. Each column of the *A*-matrix should sum to total materials input usage, which is equal to output minus taxes minus value added and depreciation. The *B*-matrix is updated in a similar manner, using known final demand totals as controls.

Rowscalers

The *A*-matrix and *B*-matrix are not static, but rather are forecasted to change each year. With the *A*-matrix this is done through rowscalers. A rowscaler is a number which changes over time, and is used to multiply all elements in one row of the matrix. Since each row of coefficients represents the usage of that industry as an input into all other industries, the rowscaler multiplies the proportion of input usage into all other industries by the same factor for each year. The rowscalers are created through a combination of regression analysis on historical data and judgment.

For example, to calculate the rowscaler for the steel industry, we would compare actual historical input usage of steel versus the historical input usage that would be calculated with a constant *A*-matrix. The ratio of these two numbers would be the historical rowscaler, i.e., the amount by which all coefficients in the steel row would have to be multiplied to be consistent with historical data.

$$r_i = q_i / [\Sigma_j (a_{ij} * q_j) + \Sigma_j (b_{ij} * g_j)] \ , \qquad \textbf{(2)}$$

where r_i is the ith rowscaler and *a* and *b* are coefficients in the *A* and *B* matrices. In practice, since historical values are known for individual industry exports and imports, the bridge calculation is not used to estimate these two final demand components when creating the rowscalers.

To forecast the rowscalers from the mainframe model, a regression would then be run using the historical rowscaler as the dependent variable, and using a curvilinear time trend and potentially other variables as regressors. The forecast from this equation would be used as the rowscaler for steel in the forecast. Therefore, since steel input usage has been declining for the last 20 years, the regression equation would forecast a falling rowscaler for steel, which would translate into falling coefficients in the forecast. For some industries, the rowscalers calculated from regression analysis may not be consistent with other information we have about that industry. Therefore, for some industries, rowscalers are derived using informed judgment. For the years 1978 to 1991, actual data is available on output and final demand, from which we can derive a control total for intermediate demand. For these historical years, rowscalers are created to make the results of a historical I-O simulation consistent with historical data.

In order to create rowscalers at the 114 sector level, two series of intermediate demand are constructed at the 432 sector level, one derived using a constant base year matrix, and one derived using a row-scaled *A*-matrix. These two intermediate series are then aggregated to 114 sectors, and the row-scaled series is divided by the non-row scaled series to generate a forecast of rowscalers at the 114 sector level. In this way the output forecasts of the PC-IO model are made to be consistent with those of the mainframe 432 sector model.

The *B*-matrix on the mainframe is changed partly through row-scaling, and partly through add-factors. Consumption, investment, and residential construction are row-scaled, whereas exports, imports, inventory change and defense expenditures are add-factored. To make the PC-IO *B*-matrix consistent with that on the mainframe, a separate *B*-matrix is saved for each year of the forecast which includes the effects of row scaling and add-factors. Thus the original equation for output becomes

$$q_t = r_t A q_t + B_t g_t \ , \qquad (3)$$

where: B_t is the final demand bridge matrix in year *t*, adjusted for add factors and rowscalers. Note that by using the rowscalers in this way, we need not store a separate *A*-matrix for every year of the forecast.

Solution Procedure

The output solution in the PC-IO model, like that on the mainframe, does not use the Leontief inverse matrix directly, but rather solves using an iterative technique called the Gauss-Seidel technique.[21] This technique is used because it is much faster than calculating the inverse matrix for each year of the forecast, and it is just as accurate.[22] It is based on the identity:

$$(I - A)^{-1} = I + A + A^2 + A^3 + A^4 + \ldots \qquad (4)$$

Intuitively, this identity expresses the multiplier impact of a change in final demands. The equation says that total requirements resulting from a given level of final demands equals the direct impact, plus the first round input requirements of the direct impact, plus the second round input requirements resulting from the first round, all the way to the n^{th} round, when the process converges. Usually about 8 to 10 iterations are required with the current model. When the output calculation has converged for each year, the I-O model solution is complete.

[21] Wassily Leontief developed input-output analysis in the late 1930's. The terms Leontief model, input-output and interindustry analysis are often used interchangeably.

[22] For a discussion of the Gauss-Seidel method of approximating an input-output inverse matrix, see Chiang, *Fundamental Methods of Mathematical Economics*, 3rd ed., pp. 120-122.

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Appendix A

The Macroeconomic Activity Module in the National Energy Modeling System

The Macroeconomic Activity Module (MAM) provides forecasts of economic variables to the energy models in the National Energy Modeling System (NEMS) and forecasts the impacts on the aggregate economy of changes in energy market conditions. To support these two functions, the National and Interindustry Submodules of MAM are response surface representations of their respective large-scale DRI counterpart: the National Submodule is based on the DRI Model of the U.S. Economy and the Interindustry Submodule is based on the Personal Computer Input-Output Model. The differences between the large-scale DRI models and their response surface representations are based on the level of detail and structure.

As to the level of detail, NEMS requires only a subset of variables generated by the structural macroeconomic model (1269 equations) and the input-output model (114 sectors). The National Submodule forecasts 110 macroeconomic variables, including such concepts as final demands, prices, interest rates, disposable income, and housing starts (Table A1). The Interindustry Submodule aggregates the 114 sectors up to 45 sectors and, of these, 35 sectors are key inputs to the industrial energy demand model in NEMS (Table A2).

The structure of the response surface models is fundamentally different from that of the core DRI models. The response surface models cannot create a baseline forecast independent of the core models. To derive the initial baseline forecast the full DRI macroeconomic model is run first, followed by a simulation of the full PC-IO model. This set of forecast data is aggregated to the level of detail required in NEMS, then inserted into MAM as an initial set of data for the National and Interindustry Submodules of MAM. MAM thus serves as the principal direct link to the NEMS demand and supply modules, providing the key macroeconomic and industrial drivers.

MAM serves a second function beyond setting the initial conditions. MAM reacts to changes in prices internal to NEMS. The NEMS energy supply and demand modules determine the reaction of energy prices to changes in energy events or policies. These energy price impacts are passed to MAM and the economy reacts, producing altered macroeconomic and industrial variables. These altered variables are then passed back to other NEMS modules for the next iteration. The role of the response surface models is to replicate the behavior of the larger, structural DRI models for a specified set of energy events, principally energy price changes.[23]

[23] Refer to *Model Documentation Report: Macroeconomic Activity Module (MAM) of the National Energy Modeling System Used for AEO94,* November, 1993 for a detailed discussion of the National and Interindustry Submodules of MAM.

Table A1. **Macroeconomic Variables in MAM**
(b$87 = Billions of 1987 Dollars)

Note: Variables in **bold** are baseline variables which do not vary in response to changes in energy prices.

Consumption		
1.	CDMV&P87	Consumption of Motor Vehicles and Parts, b$87
2.	CDFURN87	Consumption of Furniture & Household Equ., b$87
3.	CDO87	Consumption of Other Durables, b$87
4.	CNFUEL87	Consumption of Fuel Oil & Coal, b$87
5.	CNFOOD87	Consumption of Food, b$87
6.	CNCS87	Consumption of Clothing & Shoes, b$87
7.	CNGAS87	Consumption of Gasoline & Oil, b$87
8.	CNOO87	Consumption of Other Nondurables, b$87
9.	CSHHOPE87	Consumption of Electricity, b$87
10.	CSHOUS87	Consumption of Housing, b$87
11.	CSHHOPG87	Consumption of Natural Gas, b$87
12.	CSHHOPO87	Consumption of Other Household Operation, b$87
13.	CSTRANS87	Consumption of Transportation Services, b$87
14.	CSO87	Consumption of Other Services, b$87
15	CSMED87	Consumption of Medical Care, b$87
Investment		
16.	IPDER87	Investment in Producer's Durable Equipment, b$87
17.	ICR87	Investment in Total Construction, b$87
18.	ICNRPU87	Investment in Pvt. Struct.: Public Utilities, b$87
19.	ICNRMI&PET87	Investment in Pvt. Struct.: Mining & Explor., b$87
20.	ICNRB&O87	Investment in Pvt. Struct.: Bldgs. & Other., b$87
21.	IPDENROTHR87	Investment in Non-Res. Durable Eq.: Other, b$87
22.	IPDENRMCOF	Investment in Non-Res. Durable Eq.: Office, b$Current
23.	IPDENRAUTO87	Investment in Non-Res. Durable Eq.: Autos, b$87
24.	INV87CH	Inventory Change: Total, b$87
Government		
25.	**GFO87**	**Government Spending: Total Non-Defense, b$87**
26.	**GFML87**	**Government Spending: Total Defense, b$87**
27.	GSL87	Government Spending: State & Local Purchases, b$87
Exports		
28.	EX87NIA0	Exports of Food, Feed, and Beverages, b$87
29.	EX87NIA1	Exports of Industrial Supplies & Materials, b$87
30.	EXNIA2BM	Exports of Computers & Peripherals, b$Current
31.	EX87NIA2@BM	Exports of Capital Goods excl. Autos, Computers & Peripherals, b$87
32.	EX87NIA3	Exports of Autos, b$87
33.	EX87NIA4	Exports of Consumer Goods, b$87
34.	EX87NIAO	Exports of Other Goods, b$87
35.	EXS87	Exports of Services, b$87
36.	TYF87	Exports of Factor Income, b$87
Imports		
37.	M87NIA100	Imports of Petroleum & Products, b$87
38.	M87NIA0	Imports of Food, Feed, and Beverages, b$87
39.	M87NIA1@PET	Imports of Ind. Supp. & Maters., excl. Petro, b$87
40.	MNIA2BM	Imports of Computers and Peripherals, b$Current
41.	M87NIA2@BM	Imports of Capital Goods excl. Autos, Computers & Periph., b$87
42.	M87NIA3	Imports of Autos, b$87
43.	M87NIA4	Imports of Consumer Goods, b$87
44.	M87NIA5	Imports of Other Goods, b$87
45.	MS87	Imports of Services, b$87
46.	PAYYF87	Imports of Factor Income, b$87

Table A1. Baseline Macroeconomic Variables in the MAM (continued)

Other Variables

47.	GDP87	Gross Domestic Product, b$87
48.	GNP87	Gross National Product, b$87
49.	GDP87FE	Full Employment GDP, b$87
50.	PGDP	Implicit Price Defl., GDP, 1987 = 1.0
51.	PEX	Impl. Price Defl., Exp. of Goods & Serv., 87=1.0
52.	PM	Impl. Price Defl., Imp. of Goods & Serv., 87=1.0
53.	RMGBS3NS	Avg. Market Rate on U.S. Govt. 3-month Bills
54.	RMMBCNEWNS	Avg. Yield on New Issues of High Grade Corp. Bond
55.	RMMTGCCNS	Conventional Mortgage Commitment Rate
56.	RMPUAANS	Yield on AA Utility Bonds
57.	REALRMGBLUS	Real Avg. Yield on 10-year U.S. Govt. Bonds
58.	ECIWSP	Employment Cost Index, Wages & Salaries
59.	JULCNF	Unit Labor Costs Index, Nonfarm Business Sector
60.	SQTRCARSIMP	Unit Sales of Automobiles, Imported
61.	SQTRCARSDOM	Unit Sales of Automobiles, Domestic
62.	SQDTRUCKS	Truck Deliveries, Total
63.	RUC	Unemployment Rate, All Civilian Workers
64.	**EXCH**	**U.S. Trade Weighted Exchange Rate**
65.	WPI	Producer Price Index, All Commodities
66.	WPI14	Producer Price Index, Transportation Equipment
67.	CPI	Consumer Price Index, 1982 = 1984 = 1.0
68.	YD87	Disposable Personal Income, b$87
69.	WSD	Wage and Salary Disbursements, b Current Dollars
70.	YP87	Personal Income, b$87
71.	SHUMBL	Mobile Home Shipments, Million Units
72.	HUSTS1	Single Family Housing Starts, Million Units
73.	HUSTS2&	Multi Family Housing Starts, Million Units
74.	KQMH	Stock of Mobile Homes, Million Units
75.	KQHUSTS1	Stock of Single Family Housing, Million Units
76.	KQHUSTS2&	Stock of Multi Family Housing, Million Units
77.	**N**	**Population Incl. Armed Forces Overseas, Millions**
78.	**N16&**	**Population Aged 16 and Over, Millions**
79.	PEXNIA2BM	Implicit Price Deflator, Exp. of Computers and Peripherals, 1987=1.0
80.	PMNIA2BM	Implicit Price Deflator, Imp. of Computers and Peripherals, 1987=1.0
81.	PIPDENRMCOF	Implicit Price Defl., Inv in Non-Res Prod. Dur. Equ.-Office, 1987=1.0

Employment

82.	EEA	Employment, Nonagricultural Estab., Millions
83.	EC	Employment, Contract Construction, Millions
84.	**EGF**	**Employment, Federal Government, Millions**
85.	EFIR	Employment, Fin., Insur., Real Estate, Millions
86.	EMI	Employment, Mining, Millions
87.	ESV	Employment, Services, Millions
88.	**EGSL**	**Employment, State & Local Government, Millions**
89.	ER	Employment, Trans. & Public Utilities, Millions
90.	ET	Employment, Wholesale & Retail Trade, Millions
91.	E24	Employment, Lumber & Wood Products, Millions
92.	E25	Employment, Furniture & Fixtures, Millions
93.	E32	Employment, Stone, Clay, and Glass, Millions
94.	E33	Employment, Primary Metal Industries, Millions
95.	E34	Employment, Fabricated Metal Products, Millions
96.	E35	Employment, Machinery Except Electrical, Millions
97.	E36	Employment, Electrical Machinery, Millions
98.	E37	Employment, Transportation Equipment, Millions
99.	E38	Employment, Instruments, Millions
100.	E39	Employment, Miscellaneous Manufacturing, Millions
101.	E20	Employment, Food and Products, Millions
102.	E21	Employment, Tobacco Manufactures, Millions

Table A1. Baseline Macroeconomic Variables in the MAM (continued)

103.	E22	Employment, Textile Mill Products
104.	E23	Employment, Apparel & Other Txtl. Prods, Millions
105.	E26	Employment, Paper and Products, Millions
106.	E27	Employment, Printing and Publishing, Millions
107.	E28	Employment, Chemicals and Allied Prods., Millions
108.	E29	Employment, Petroleum and Products, Millions
109.	E30	Employment, Rubber and Misc. Plastics, Millions
110.	E31	Employment, Leather and Products, Millions

Table A2. Industrial Variables in MAM

1. Food & Kindred Products (SIC 20)
2. Tobacco Products (SIC 21)
3. Textile Mill Products (SIC 22)
4. Apparel & Other Textiles (SIC 23)
5. Lumber & Wood Products (SIC 24)
6. Furniture & Fixtures (SIC 25)
7. Paper & Allied Industries (SIC 26)
8. Printing & Publishing (SIC 27)
9. Inorganic Chemicals (SIC 281)
10. Organic Chemicals (SIC 286)
11. Plastic Materials & Synthetics (SIC 282)
12. Agricultural Chemicals (SIC 287)
13. Other Chemicals & Allied (SIC 28,nec)
14. Petroleum Refining (SIC 291)
15. Asphalt, Coal & Miscellaneous Products (SIC 295,299)
16. Rubber & Miscellaneous Plastic Products (SIC 30)
17. Leather & Leather Products (SIC 31)
18. Glass & Glass Products (SIC 321-323)
19. Cement, Hydraulic (SIC 324)
20. Other Stone, Clay, & Glass Products (SIC 32,nec)
21. Blast Furnace & Basic Steel (SIC 331)
22. Primary Aluminum (SIC 3334)
23. Other Primary Metals (SIC 33,nec)
24. Fabricated Metal Products (SIC 34)
25. Industrial Machinery & Equipment (SIC 35)
26. Electronic & Other Electric Equipment (SIC 36)
27. Transportation Equipment (SIC 37)
28. Instruments & Related Products (SIC 38)
29. Miscellaneous Manufacturing Industries (SIC 39)
30. Agricultural Production - Crops (SIC 01)
31. Other Agricultural - Including Livestock (SIC 02,07-09)
32. Coal Mining (SIC 11,12)
33. Oil & Gas Mining (SIC 13)
34. Metal & Other Mining (SIC 10,14)
35. Construction (SIC 15-17)
36. Transportation Services (SIC 40-47)
37. Communications (SIC 48)
38. Electric Utilities (SIC 491,pt493)
39. Gas Utilities (SIC 492,pt493)
40. Water & Sewer Services (SIC 494-497,pt493)
41. Wholesale Trade (SIC 50,51)
42. Retail Trade (SIC 52-57,59,739)
43. Finance, Insurance, Real Estate (SIC 60-63,65-66,153)
44. Services (SIC 58,70,73,75,76,78,79,80,82,83,84,86,89)
45. Government Enterprises (SIC pt41,431)

The following industrial output sectors are summed in MAM:

46. Chemicals & Allied Products (SIC 28) = 9 + 10 + 11 + 12 + 13
47. Petroleum & Coal Products (SIC 29) = 14 + 15
48. Stone, Clay, & Glass Products (SIC 32) = 18 + 19 + 20
49. Primary Metals Industries (SIC 33) = 21 + 22 + 23

Appendix B

How Large are Economic Forecast Errors

Appendix B is an article by Stephen McNees of the Federal Reserve Bank of Boston on "How Large are Economic Forecast Errors." This article assesses the forecast accuracy of a number of economic forecasting models (groups) and is attached as an independent assessment of the forecast accuracy of the DRI Model of the U.S. Economy.

This paper is not available for disk on the CDROM. Copies may be received from Ronald Earley, Room 2H-082, 586-1398.