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MODEL DOCUMENTATION REPORT: MACROECONOMIC ACTIVITY MODULE (MAM) OF THE NATIONAL ENERGY MODELING SYSTEM

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Table of Contents

1. Introduction

Purpose of This Report

This report documents the objectives, analytical approach, and development of the National Energy Modeling System (NEMS) Macroeconomic Activity Module (MAM) used to develop the Annual Energy Outlook for 2001 (AEO2001). The report catalogues and describes the module assumptions, computations, methodology, and parameter estimation techniques.

This document serves three purposes. First, it is a reference document providing a description of the NEMS MAM used for the AEO2001 production runs for model analysts, users, and the public. Second, this report meets the legal requirement of the Energy Information Administration (EIA) to provide adequate documentation in support of its models (*Public Law 94-385, section 57.b.2*). Third, it facilitates continuity in model development by providing documentation from which energy analysts can undertake model enhancements, data updates, and parameter refinements as future projects.

Model Purpose

NEMS

The National Energy Modeling System (NEMS) is a comprehensive mid-term energy forecasting and policy analysis tool used by EIA. NEMS projects energy supply, demand, prices, and environmental emissions, by region, given assumptions about the state of the economy, international markets, and energy policies. The MAM links NEMS to the rest of the economy by providing projections of economic driver variables for use by the supply, demand, and conversion modules of the NEMS system. Macroeconomic variables such as GDP, disposable income, industrial gross output, inflation, interest rates, and employment drive energy demands and are important determinants of energy prices and quantities. Changes in energy supplies and prices can in turn affect GDP, inflation, interest rates, and other macroeconomic variables. To capture these effects, NEMS allows for feedback to and from the macroeconomy.

MAM

The MAM is able to address the macroconomic impacts associated with changing energy market conditions and alternative macroeconomic growth cases. Energy price changes represent a critical source of interaction between energy markets and the economy. Consumers facing higher prices for energy may reduce their energy consumption. Nonetheless, because a large component of energy expenditures is non-discretionary, nominal expenditures on energy are likely to rise, consuming a larger share of the household budget. As a result, consumers are likely to reduce expenditures on other goods and services.

Energy services also represent a key intermediate input in the production of goods and services. After energy prices increase, production costs per unit of output are likely to rise for firms, at least initially. Reacting to higher prices in general, wages increase as consumers attempt to maintain real disposable income. Higher wage costs and spillover price effects on other variable costs further escalate production costs throughout the economy. This process places upward pressure on the nominal prices of all intermediate goods and final goods and services in the economy. As prices increase, so do interest rates. The increase in interest rates in turn causes reductions in interest-rate sensitive components of aggregate demand. Aggregate demand declines, leading to reductions in output as a result of rising energy prices. The MAM provides such dynamic macroeconomic impacts to the rest of the NEMS.

Model Summary

The MAM of NEMS is composed of four submodules: the National Submodule, the Interindustry Submodule, the Employment Submodule, and the Regional Submodule. Each of these submodules is designed to mimic the response of one of the large, proprietary econometric models developed by Data Resources, Inc./McGraw-Hill (DRI) to changes in energy market conditions. The National Submodule of MAM is a kernel regression representation of the DRI U.S. Quarterly Macroeconomic Model. The Interindustry Submodule of MAM is a response surface approximation of DRI's Personal Computer Input-Output (PCIO) Model. The Employment Submodule of MAM is a response surface approximation of DRI's Employment Model. The Regional Submodule is a straightforward sharing algorithm that applies factors based on simulations of DRI's U.S. Quarterly, PCIO, Employment, and Regional Models to disaggregate the National, Interindustry, and Employment Submodule results to the nine Census Division level. The regional shares used in the module change over the forecast period, reflecting the changing growth patterns across regions over time.

DRI's U.S. Quarterly Model, PCIO Model, Employment Model, and Regional Model are designed to work in tandem with each other, and are used in this way by EIA to create the macroeconomic baselines which are input to the MAM. DRI's PCIO uses final demands generated by the DRI U.S. Quarterly Model as inputs; DRI's Employment Model uses the gross output generated by PCIO as well as some macroeconomic concepts as inputs; the DRI Regional Model uses DRI U.S. Quarterly Model, PCIO Model, and Employment Model outputs as inputs.

The Submodules of MAM operate in a similar, sequential manner. The set of variables generated by the National Submodule includes final demands for goods and services, interest rates, inflation, housing starts, and disposable income. The Interindustry Submodule calculates the industrial gross output needed to satisfy the final demands forecasted by the National Submodule. The Employment Submodule calculates 2-digit SIC level employment by manufacturing industries, as well as employment for aggregated construction, services and trade sectors based on the gross output projections of the Interindustry Submodule. The Regional Submodule disaggregates the forecasts generated by the National, Interindustry, and Employment Submodules so that they can be used by the NEMS end-use sector demand models.

The configuration of MAM is flexible. If one of the NEMS models is modified to require a new macroeconomic input variable, MAM can be expanded to add the new driver, as long as the new variable is contained in one of the full DRI models. Currently, MAM forecasts nearly 200 macroeconomic variables, a subset of which is passed back to the NEMS common data structure to be used by the energy demand, supply, and conversion models.

MAM National Submodule

The MAM National Submodule is a kernel regression representation of the DRI Quarterly Model of the U.S. economy, modeled using annual data. The National Submodule supports the NEMS energy supply, demand, and conversion modules by providing mid-range macroeconomic projections for the period from 1990-2020. The National Submodule also provides feedback effects for analyses of different energy scenarios by capturing the macroeconomic effects of changes in energy variables.

The growth potential of the economy is rooted in the growth of the factors of production, specifically, labor, capital, and energy, and the aggregate productivity of these factors. The user may choose one of the three growth scenarios provided in the National Submodule (low, mid, or high growth) and subsequently incorporate energy market feedbacks.

The National Submodule responds to information concerning energy price and quantity changes, and carbon tax revenues if appropriate, from the other NEMS modules. The NEMS system determines the reaction of energy prices and quantities to changes in events or policies. These energy impacts are passed to the National Submodule of MAM and the economy reacts, producing altered macroeconomic variables. The altered macroeconomic variables are then passed back to the other NEMS modules for the next solution iteration.

Additional discussion of the National Submodule methodology is provided in Chapter 3 of this Volume. A listing of inputs to and outputs from the National Submodule is provided in Appendix A to this Volume.

MAM Interindustry Submodule

The Interindustry Submodule provides industrial gross output projections to the NEMS system for use principally by the Industrial Demand Module. The Interindustry Submodule also calculates the interindustry impacts based upon changes in the final demand forecasts generated by the National Submodule. The feedback mechanism in the Interindustry Submodule is modeled in an analogous manner to the DRI-PCIO modeling relationships.

The Interindustry Submodule contains detail for thirty-five industrial(manufacturing, agriculture, mining, and construction) sectors and ten non-industrial service sectors and develops projections for the period of 1990-2020. The Interindustry Submodule calculates deviations from a given baseline industrial gross output projection when macroeconomic final demands change. Because of the structure of input-output modeling, the Interindustry and National Submodules do not iterate directly with each other, but are instead processed sequentially. However, through their effect on the projections of the energy supply and demand submodules, which in turn alter the macroeconomic outlook, changes in interindustry projections do affect the results of the National Submodule during the next solution iteration. The NEMS energy supply and demand modules determine the reaction of energy variables to changes in energy market conditions and carbon abatement policies. These energy market results, and revenue collections if relevant, are passed to the National Submodule and the economy reacts to the altered inputs. The resulting macroeconomic final demands are in turn passed to the Interindustry Submodule, which calculates the effects on industrial gross output. The altered industrial gross output projections are then passed back to the other NEMS modules, and the system iterates until convergence is attained. Additional discussion of the inputs and outputs to the Interindustry Submodule is provided in Appendix A to this Volume.

MAM Employment Submodule

The Employment Submodule calculates the employment impacts of altered energy market conditions based on the following causal relationships. When energy market conditions change, the level and composition of macroeconomic final demands are affected. In turn, the level and composition of industrial gross outputs required to satisfy the new final demands are changed. Finally, faced with new demands for their output, industries will adjust the number of workers employed. The response surface Employment Submodule represents this last link in the chain. Additional discussion of the inputs and outputs to the Employment Submodule is provided in Appendix A to this Volume.

MAM Regional Submodule

The Regional Submodule is a sharing algorithm based upon simulations of the DRI U.S. Quarterly Macroeconomic Model, the DRI PCIO Model, the DRI Employment Model, and the DRI Regional Model. This sharing algorithm is utilized to disaggregate some of the National, Interindustry, and Employment forecasts to the nine Census Division level of detail. The regional shares vary over time through the forecast period.

Kernel Regression and Response Surface Modeling

The use of kernel regression and response surface approximations of the proprietary DRI models allows distribution of the MAM to users outside of EIA. The kernel regression approach employed within the National Submodule requires that a database of representative simulations of the full DRI model be generated. “Representative” means that the simulations comprising the database must be of the same type as the policy or scenario under consideration, and that the simulations adequately cover the important dimensions of variation.

The response surface approximations of the Interindustry and Employment Submodules are constructed by estimating the relationships found in the large DRI models discussed above on "pseudo data" which are generated through repeated simulations of the DRI models. The Interindustry and Employment Submodule response surfaces are generated from scenarios of the DRI models that primarily vary macroeconomic final demands or industrial gross output, because the goal of the MAM in NEMS is to provide output or employment feedback to the NEMS system. The resulting changes to the macroeconomic variables of interest are recorded, and then each of these macroeconomic variables is regressed on the exogenous variables to obtain a single response surface equation for each dependent variable. The response surface feedback models respond to changes in either macroeconomic final demands (the Interindustry Submodule) or changes in industrial gross output (the Employment Submodule) in a way that replicates the behavior of the much larger and more complex DRI models upon which the response surfaces are based.

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2. Theoretical Overview and Selection Rationale

Alternative Macroeconomic Modeling Approaches

Background

The following theoretical discussion was primarily written during the design phase for the MAM (circa 1992). The issues raised and taken into consideration when selecting the modeling approach for the MAM are still relevant and informative.

National Submodule

This section identifies and critically discusses alternative macroeconomic and interindustry modeling approaches. The discussion first treats the most widely used large macroeconomic models. Small structural macroeconomic models are next reviewed as possible alternatives to the chosen response surface approach. General equilibrium models that focus on the long-run growth path of the economy are then addressed. A discussion of input-output based macroeconomic models that attempt to bridge between the large macroeconomic models and the general equilibrium approaches is provided next. Last, vector autoregressive models are explored.

Large Macroeconomic Models. DRI, The WEFA Group, and other macroeconomic forecasters produce large econometric models of the U.S. economy. The DRI model has been used at EIA for many years. A large macroeconomic model such as the DRI model has the advantage of sufficient detail that it is likely to be able to address the majority of requested analyses. It is also likely to include the variables required as drivers by the NEMS supply, demand, and conversion models. Such models also have large staffs devoted to the maintenance and improvement of the model and the provision of base case forecasts.

The DRI Quarterly model is composed of 1200 equations.[1] It provides detail on final demands, aggregate supply, prices, incomes, interest rates, and U.S. trade flows. The DRI model incorporates a short-term specification of financial conditions, output, and prices into a long-term growth model. 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, capital, and energy. Prices adjust when there is excess demand or supply or when the prices of inputs change.

The DRI Quarterly Model excels at short-run and mid-term analyses and forecasts and does reasonably well in long term analyses through the potential GDP equation and its

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[1] Brinner, Roger E. "Philosophy and Properties of the DRI Model of the U.S. Economy." Quarterly Model of the U.S. Economy: Version US89A., March 1990.

components. It is extremely useful in the assessment of the time-profile of the adjustment path over the 5 to 20 year horizon. The DRI model is capable of analyzing the effects of price changes for energy or other goods, or any policy having only direct price effects, such as energy taxes. It is also able to differentiate estimates of both short-run and long-run adjustment costs, with the long-run being dependent on their depiction of one long-term aggregate production function.

The types of analysis in which the DRI model is suboptimal include the effects of incorporating specific types of energy technology changes and the issue of efficiency in energy use. DRI includes energy use as part of its long-run production function. However, the long-term general equilibrium constraints imposed in the model are weak.

There is also a fundamental inconsistency in the use of a large macroeconomic model as a part of NEMS. Since NEMS focuses primarily on energy, the objective of MAM, as one of twelve modules in NEMS, is to provide the feedbacks between the energy markets and the rest of the economy. Large macroeconomic models are designed as stand alone models, and therefore typically include an energy block within their own structure. Consequently, use of these large models implies the use of *two* energy models: EIA's and the energy sector in the macroeconomic model. These two energy models may not be consistent.

A second alternative is to utilize a large macroeconomic model and replace its energy sector representation with a set of equations that replicate NEMS behavior for the energy sector. In one mode, the macroeconomic model's energy equations are disabled and simply pass through unaltered the energy price and quantity calculated from the other NEMS components. In another mode, the macroeconomic model energy equations are run separately from the energy model if standalone macro simulations are appropriate. It must be recognized, however, that stripping out the energy sector of a macro model is not trivial and may significantly alter the behavior of the remaining equations.

Small Macroeconomic Models. One alternative to a large macro model is a small model tailored precisely to the needs of the NEMS system. A small model has the advantages of ease of development and maintenance. However, problems with this approach, and any approach in which an independent macroeconomic model is developed, include lack of support for the provision of base case forecasts and considerable resource costs for development and maintenance of a tailored macroeconomic model.

The lack of detail in a small macroeconomic model another potential concern. A small model may not provide sufficient detail to execute all scenarios that a large model is able to address. Also, small models suffer from the criticism that important linkages are necessarily omitted in their design. Small models also have the potential to grow into large models, because adding new variables required by the NEMS may involve creating one or more new blocks within the model, each consisting of several additional equations. The result may be a much larger model than originally intended with attendant increases in the time and resource costs of maintenance.

General Equilibrium Models. The fundamental theme of the general equilibrium model is that the production side of the economy (the transformation of commodities into other commodities) is distinguished from the consumption side (the acquisition and eventual consumption of goods and services). The two are then linked to provide a simultaneous determination of equilibrium balances between the production and consumption sides of the economy.[2]

Stocks of commodities, which may be consumed directly, maintained as inventories or offered as factors of production, are owned by households in their physical form or by means of a variety of financial instruments. Each consumer's income, or wealth, is determined by evaluating the consumer's stock of commodities in terms of those prices at which the commodities can be sold. Income and a knowledge of relative prices permit the consumer to express demands for goods and services and supply of labor that are made available for the productive side of the economy.

In the general equilibrium model, producers are assumed to be informed of the prices of all inputs and the prices at which outputs can be sold. These prices are taken to be independent of the scale and composition of productive activity; each producer then selects, from the technically available choices, the production plan that maximizes profits. The general equilibrium model explicitly addresses the substitutability of factors of production (or consumption) by either incorporating separate translog production functions (such as Jorgenson's DGEM model[3]) or CES functions for each industry and then obtaining the aggregate production.

A standard procedure has evolved among general equilibrium modelers to calibrate the whole model to a benchmark observation coupled with use of literature estimates for certain key parameters, particularly elasticities. A sequence of data adjustments is frequently used to force equilibrium conditions on observed data before calibration begins. With these adjustments in mind, no test of the model to data is employed, and sensitivity analysis is widely used for parameters whose values are uncertain and/or crucial to the results.

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2 Much of the general equilibrium analysis draws heavily from the following sources: Applied General Equilibrium Analysis by Herbert Scarf and John Shoven, Cambridge University Press, 1984 and Dale Jorgenson and Peter Wilcoxen, "Environmental Regulation and U.S. Economic Growth", Energy and Environmental Policy Center Discussion Paper, November 1989.

3 Dale Jorgenson and Peter Wilcoxen, "Environmental Regulation and U.S. Economic Growth," Energy and Environmental Policy Center Discussion Paper, November 1989.

The assumption of an "observable" equilibrium leads directly to the construction of a data set that fulfills the equilibrium conditions for some form of general equilibrium models. A benchmark equilibrium data set is a collection of data in which equilibrium conditions of an assumed underlying equilibrium model are satisfied. If equilibrium is reflected, demands equal market supplies for all commodities and supplies and demands can be separately disaggregated by agent. Four sets of equilibrium conditions satisfied by most of the constructed benchmark equilibrium data sets are: (1) Demands equal supplies for all commodities; (2) Nonpositive profits are made in all industries; (3) All domestic agents (including the government) have demands that satisfy their budget constraints; and (4) The economy is in zero external sector balance.

These conditions are not all satisfied in input-output or other national income account data. In constructing benchmark data sets, various adjustments are necessary to the blocks of data involved and the nature of these adjustments varies from case to case as alternate sets of benchmark accounts are constructed to fit differing models. The data usually refer to a single year, although some averaging across years is done in constructing portions of those data sets where substantial volatility occurs.

Although most general equilibrium models use literature estimates of crucial elasticities, Jorgenson's model uses econometrically estimated values of these elasticities. The endogenous variables in his model of producer behavior are the value shares of sectoral inputs for the four commodity groups. There are 14 unknown parameters for each industry. These parameters are estimated using data from 1974-1985 for each industry, subject to restrictions implied by the monotonicity of the input value shares. Some authors have argued that there is an hierarchy of submodels, and that the number of restrictions required to estimate the parameters for each industry may present interpretational problems.[4]

In addition, the general equilibrium models are full employment models. These models cannot calculate disequilibrium costs because the models describe equilibrium points. Factors of production are treated as perfectly mobile between alternative uses and the allocation of factors by industry in equilibrium equalize the returns received net of taxes and gross of subsidies in all industries. The models solve for a steady-state equilibrium, but ignore the path of adjustment.

Much of the policy analysis that the macroeconomic models analyze implies some calculation of the adjustment costs. Some authors have argued that the general equilibrium model results show relatively rapid change in capital stock in the face of a price change. Additionally, neither the financial nor the international sectors are fully modeled and the working assumption is that all private and public agents are bound by the budget

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[4] See Chapter 3, "Numerical Specification of Applied General Equilibrium Models: Estimation, Calibration, and Data," written by Mansur and Whalley in the Scarf and Shoven book.

constraint.[5]

The difficulty in incorporating system energy price and quantity results is a significant drawback to incorporating a general equilibrium macroeconomic model for NEMS, because estimates of energy's substitutability in the production functions and the consumer choice equations are implicit in the general equilibrium component.

A more fundamental problem with general equilibrium models is that their scope is far beyond that of macroeconomic analysis; they embody a fully developed energy-economy feedback mechanism. As such, general equilibrium models have even more fully developed energy sectors than the large macroeconomic models and are capable of substituting for the entire NEMS system. It would be extremely difficult to strip out the energy sector from a general equilibrium model and make it exogenous. Also, because general equilibrium models are academic rather than commercial tools, it is not clear that support is available for provision of base case forecasts.

General equilibrium models have the advantage that they explicitly incorporate general equilibrium constraints, are based on optimizing behavior on the part of economic agents, and have a considerable amount of detail for investment decisions. The latter point makes these models particularly well equipped to analyze the capital costs of environmental policies and the introduction of new technologies. The inability to address the path of adjustment is a problem. They are therefore of little use in answering questions concerning the short-run disequilibrium costs associated with energy taxes, although they are well equipped to predict long-term impacts.

Input-Output Based Macro Models. The LIFT (Long-term Interindustry Forecasting Tool) available from INFORUM at the University of Maryland is a large macroeconomic model based on a 78-sector input-output model.[6] The advantage of this approach is that, like the DGEM model, the computable general equilibrium constraints imposed by theory are maintained by the model so that the model is theoretically satisfying. The bottom up approach to modeling is ideal for analyses of technology, productivity change and capital costs.

LIFT is a blend of the econometrically estimated equations coupled with the general

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5 See the preface of the Scarf and Shoven book for a good description of the advantages and disadvantages to general equilibrium modeling. See also John Shoven and John Whalley, "Applied General-Equilibrium Models of Taxation and International Trade: An Introduction and Survey," in the Journal of Economic Literature, Vol. XXII, September 1984, pp. 1007-1051.

6 The LIFT analysis draws heavily from the following sources: "The INFORUM Approach to Interindustry Modeling" by Clopper Almon and "LIFT: INFORUM's Model of the U.S. Economy" by Margaret Buckler McCarthy. Both articles are contained in special issue of Economics Systems Research, Vol. 3, No. 1, 1991.

equilibrium emphasis on building a model of the aggregate economy based on producer and consumer decisions. While conforming to these equilibrium conditions, the model forecasts the path to the equilibrium. Final demands are determined by behavioral equations, which were estimated with econometric techniques. These categories are based on the National Income and Product Accounts (NIPA). It uses input-output coefficients that change over time to calculate industrial output.

LIFT consists of three general blocks. The first block calculates output for 78 industrial sectors, using dynamic input-output coefficients. The second part of the model is the price block, which calculates factor income, by estimating the components of gross product originating by industry (value-added) and unit prices by product. The final component is what Inforum refers to as the accountant. This is the part of the model that insures that the aggregations of individual components are calculated, and is concerned with macroeconomic variables that are not industry-specific, such as the savings rate, interest rates, government sector, and the unemployment rate.

Personal consumption expenditure (PCE) equations have been estimated for the categories corresponding to the NIPA. The PCE equations are derived from a two-stage estimation procedure. First, from cross-sectional data, parameters are estimated for the level and distribution of consumption expenditures by income size class, the age structure, and other demographic characteristics. Second, the cross sectional estimates are combined with time series data to estimate parameters for relative prices, changes in income, and trends. Total consumption is disposable income less savings.

A strength of the model lies in its treatment of investment decisions. Investment consists of equipment, construction, and inventory change, corresponding to the NIPA. The level of disaggregation available in the model is a distinguishing feature. Equipment investment equations have been estimated for approximately 50 industries. Investment depends on changes in industry output and changes in the relative prices of capital, labor, and energy, with a lag of 5 years. Construction is determined for approximately 30 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.

The input-output model determines the unit prices for the 78 products by solving the dual pair of equations. The real side of the model is in terms of products. Income is defined in terms of industries. This portion of the model contains a bridge that translates value added between its product and industry classification. In the equation formulation, there are variables that capture the tightness of the economy in determining prices and incomes.

The model derives aggregated totals consistent with the detailed information contained in the other two components concerning production techniques and consumption equations. It also consists of macroeconomic variables that are not industry-specific yet are needed in order to arrive at industry totals. Examples of such variables include the government sector, interest rates, unemployment rates, and the savings function.

The LIFT model derives aggregate totals of final demands based on a detailed specification of industrial output. In addition, investment categories are analyzed in terms of the 78 industrial sectors, so capital stock changes reflect detailed investment specifications. Third, LIFT is capable of addressing income distributional effects as the consumption equations are estimated with data from 20 income groups, aggregated in the model to five income classes.

The LIFT model, having large amounts of detailed sectoral information, requires more analysis of both inputs and model results. The complexity and integrated aspects of LIFT increase the challenge and time required to identify and analyze the contributing factors underlying anomalous results obtained from a model run.

The model contains an accounting system that considers both income and price effects, with a complete representation of both the production and consumption sides of the economy. In this respect, the model resembles the general equilibrium models. Unlike general equilibrium models, LIFT does not focus on the derivation of the steady state equilibrium, but instead on the path to reach the equilibrium. The model is explicit in the treatment of investment, and capital cost effects when energy prices change are better handled in these models. However, the ease of use and the relative simplicity of calculating energy price feedback effects may be sacrificed.

Vector Autoregressive Models. VAR models are pure time series models estimated on historical data. The approach is non-theoretic in that the theoretical linkages between variables (the model structure) are ignored. The model is entirely specified by the length of lags and the endogenous variables. For example, if five endogenous variables are to be forecasted, then there are five equations in the model and each equation contains the lags of the dependent variable and lags of all of the other endogenous variables. If the lag length is one, then each of the five equations would contain five lagged variables. If the lag length is two, then each equation would have ten arguments, etc.

Ease of model development is the primary advantage of the VAR approach. Implementation requires only the list of variables to be predicted and the correct lag length. One drawback to VAR models is their tendency to become cumbersome as the number of variables increases, because the lag terms required for this approach impact the degrees of freedom and result in potential collinearity issues. In addition, it is difficult to specify the correct lag length, because too many lags implies inefficiency while too few implies omitted variable bias. Imposing a priori constraints is difficult in that there is little guidance from theory and the behavior of the model is fundamentally altered with each constraint.

Another consideration with this approach is that VAR models are fundamentally altered whenever an equation is added or removed. If a sixth variable is added to the original five equation model, the model behavior is likely to change. This feature is a source of instability and unreliability as the model develops. Finally, it is difficult to imagine the ability of a VAR model to address complex analyses such as a carbon tax with revenue neutrality.

Comparison of approaches. The **time period of the forecast** varies among the model approaches reviewed. The DGEM currently extends the furthest to 2050, while the DRI model forecasts to the year 2023 and LIFT goes to 2015. The theoretical underpinnings of each approach differ, and affect the level of support for long-run analysis. Accordingly, the applicability of a functional form is partly dependent upon the forecast horizon.

Most large scale macroeconomic models such as DRI and WEFA are essentially demand-driven and contain key equations to address the aggregate supply curve of the economy. In the short and mid-run, this structure may be the most desirable depiction of the economy. The DRI and WEFA models are capable of extension to the year 2030, but this strains the credibility of a quarterly model. The theoretical structure of the LIFT model lends itself to extension to the year 2030, but the model is data intensive and the extension challenging and difficult to support. DGEM exclusively focuses on the long-term.

The **path of adjustment to the new equilibrium** is an important component of the modeling system. The general equilibrium approach addresses the supply and demand of each industrial sector and consumer group assuming no short-run dislocation costs in getting from one equilibrium position to another. These models are capable of comparing two steady-state situations, where all factors are fully employed, as compared to explicit modeling of dislocation costs.

Large macroeconomic models, such as those developed by DRI and WEFA, are strongest in evaluating short to mid-term changes in aggregate demand, as opposed to detailed sectoral demands. These models incorporate aggregate supply constraints, but not at the sectoral level of detail. Consequently, aggregate supply is determined by a single production function driven by labor supply, the aggregate capital stock, energy, and a technology trend. This results in a weak treatment of the sectoral tradeoffs among capital, labor, energy, and other materials. This lack of detail fundamentally weakens the large models' ability to address long-run issues.

The LIFT model represents an effort to blend explicit treatment of the adjustment path into a long-run general equilibrium view of growth. LIFT represents both the production and demand sides of the model, incorporating detailed industrial and investment detail.

All three modeling systems provide extensive **industrial detail**, but differ fundamentally in the industrial structure development. The DRI approach is **top-down**, responding to the question "what is the level of industrial output needed to satisfy a given level of final demand?" The DGEM and LIFT approaches both are **bottom-up**. The industrial outputs are integral to the determination of the level of the aggregate economy. Conceptually, the bottom-up view of the economy is more appealing, but the models relying on this view are typically larger and more complex to understand and operate.

Interindustry Submodule

The modeling methodology for industrial activity is linked directly with the choice of the model used for the national economy. Issues introduced in the previous section describing alternative national economic modeling approaches apply to modeling industrial activity as well. The discussion of LIFT and the general equilibrium models are examples of embedded industrial modeling within a national framework. The Industrial Submodule must model industrial activity to support the Industrial Energy Demand Model, as well as other energy modules in NEMS. The choice of which industrial activity model to use as part if MAM depends on several criteria. First, is the industrial model consistent with the National Submodule? Second, does the industrial model forecast output for the energy consuming industries in the detail required by the Industrial Energy Demand Module? Third, is the industrial activity model flexible enough to handle possible future changes in industrial aggregation needed by other NEMS energy modules?

Using an input-output model directly linked to the macroeconomic model which estimates national economic impacts satisfies all of these criteria needed for the Industrial Submodule of MAM. The following section describes input-output modeling in general, along with the extensions to standard input-output analysis that makes the input-output model used by MAM more flexible.

Input-output analysis was developed by Wassily Leontief in the late 1930s to determine the level of output that each of the ***n*** industries in an economy must produce in order to just satisfy the total demand for each product, with no shortages or surpluses. A representative equation of this model (for interindustry sector ***1***) can be expressed as:

$$x_1 = a_{11} x_1 + a_{12} x_2 + \ldots + a_{1n} x_n + d_1 \qquad \textbf{(1)}$$

where

x_1	is output from industry ***1***,
a_{1j}	is the input from industry ***1*** required for production of each unit of output from industry ***j***,
x_j	is output from industry ***j***,
d_1	is the final demand for industry ***1***'s output, and
j	indicates the industry, ranging from ***1*** to ***n***

Rearranging terms in the above equation gives:

$$(1 - a_{11}) x_1 - a_{12} x_2 - \ldots - a_{1n} x_n = d_1 \qquad \textbf{(2)}$$

The variables representing output of every sector within the economy (x_is) appear on the left side of equation (2). A similar equation is constructed to represent the output of each industrial sector. The system of equations for the entire economy then consists of a square matrix of dimension ***n*** whose elements are all $-a_{ij}$ except for those which lie along the principal diagonal of the matrix, which are $(1 - a_{ij})$ for $i = j$, multiplied by the column vector of variables that represent each industry's output, and equated to the column vector of final demands. Switching to matrix notation for brevity, the system can be expressed as:

$$(I - A)\, x = d \tag{3}$$

where

I	is the ***n x n*** identity matrix,
A	is the ***n x n*** input coefficient matrix,
x	is the ***n x 1*** variable vector,
d	is the ***n x 1*** final demand vector, and
n	is the number of industrial sectors

The matrix $(I - A)$ is called the technology matrix. In order to solve the above system for interindustry activity, the matrix $(I - A)$ must be inverted, which is possible as long as $(I - A)$ is nonsingular. Premultiplying both sides by $(I - A)^{-1}$ gives:

$$\bar{x} = (I - A)^{-1}\, d \tag{4}$$

where

$\bar{x}$	is the column vector of computed output,
$(I - A)^{-1}$	is the inverse of the technology matrix, and
d	is the column vector of final demand

The model given by equation (4) translates final demand by industrial sector into total output by each sector. However, the National Submodule provides final demands by macroeconomic concepts. These macroeconomic final demands must be passed through a bridge matrix that translates them into the form required by the input-output model.

The model described to this point is a static model. Because the technology matrix is fixed in the model described to this point, a specific level of final demand in one category requires the same level and proportions of output from all interindustry sectors, regardless of the year to which the forecast pertains. This is an unduly restrictive and unrealistic assumption for the purposes of long-term forecasting. In order to provide a more reasonable forecast, DRI employs two methods within the input-output model that introduce temporal change to the interindustry forecasts. The first uses a unique bridge matrix for each year of the forecast (through 2020). The second applies row-scalars to the technology matrix.

The purpose of the bridge matrix is to allocate final demand by macroeconomic concept to those industries which produce the final products. By using a unique bridge matrix for each year of the forecast period, a given level of macroeconomic final demand does not translate into the same levels of final demand broken out by industrial sectors for each year. How the bridge matrix allocates final demand across a number of industrial sectors can be illustrated by looking at the final demand component *Non-Residential Producers' Durable Equipment -- Other* (excludes Automobiles and Office & Computing Equipment). Within the DRI model, final demand in this category is allocated across 47 of the 114 industrial sectors, including: *Farm & Garden Machinery*; *Construction & Mining Machinery*; *Metalworking Machinery & Equipment*; *Electrical Machinery*; and *Radio, TV and Communications Equipment*. Because the bridge matrix simply translates final demand by macroeconomic concepts into final demand by industrial sectors, each column of the bridge matrix must sum to 1.0. Therefore, a unique bridge matrix for each year indicates that the interindustry mix of final products required to satisfy a given level of macroeconomic final demand changes over time. As an illustration of a changing bridge matrix it may be that in the future more *Electrical Machinery* and less *Farm & Garden Machinery* is required to satisfy a given level of *Non-Residential Producers' Durable Equipment -- Other* macroeconomic final demand. In this case the *Electrical Machinery* coefficient within the *Non-Residential Producers' Durable Equipment -- Other* bridge matrix column rises over time while that for *Farm & Garden Machinery* falls. The full DRI-PCIO Model develops the bridge matrix projections through logistic time trends, which are adjusted using recent historical values corresponding to the model components.

The second method of introducing change, applying row-scalars to the technology matrix, has a different intent and a different effect. A row-scalar is a number that changes over time, and is used to multiply all elements in one row of the direct requirements matrix. The row scalars introduce general trends in technical requirements to the input-output modeling framework, but should not be construed as a method for representing specific technological changes within industry. Since each row of coefficients in the matrix represents the usage of that industry as an input into all other industries, the row scalar multiplies the proportion of input usage into all other industries by the same factor for each year. This does not allow for cell-by-cell adjustment of the technical coefficients. The historical row scalars are reconciling terms. Actual historical final demand is provided to the static input-output model. If the resulting computed output exceeds the actual output for a given industry, the row scalar for that industry and that year is less than one. If the computed output is less than the actual output for a given industry, the row scalar for that industry and that year is greater than one. Making this comparison for all industries results in time-series of row scalars over the historical period. Regression on these historical row scalar time-series results in forecasted annual row scalars for each industry through the year 2020. These forecasted row scalars are then analyzed and adjusted if the historical trends are not expected to continue in the future.

The final model, including the bridge matrix and row scalars, is:

$$\overline{x_{i,t}} = [I - (A_{ij} \times rs_{i1,t})]^{-1} (B_{ik,t} \cdot d_{k1,t}) \quad \textbf{(5)}$$

where

$\bar{x}$	is the column vector of computed output,
I	is the ***n x n*** identity matrix,
A	is the ***n x n*** direct requirements matrix,
rs_t	is the column vector of row scalars for year ***t***,
B_t	is the bridge matrix for year ***t***,
d	is the column vector of final demand for year ***t***,
i , ***j***	is the interindustry sector, ranging from ***1*** to ***n***, and
k	is the final demand component, ranging from ***1*** to ***m***

The full DRI model does not calculate the Leontief inverse matrix ($(I - A)^{-1}$) when computing a solution. Instead, an iterative technique is used because it is computationally simpler than calculating the inverse matrix for each year of the forecast, and it provides a close approximation to the actual Leontief inverse matrix.[7] The technique is based on the identity:

$$(I - A)^{-1} = I + A + A^2 + A^3 + A^4 + \ldots \quad \textbf{(6)}$$

where

I	is the identity matrix, and
A	is the direct requirements matrix, with each component a_{ij} showing the proportion of good ***i*** used in the production of good ***j***

Intuitively, this identity expresses the multiplier impact of a change in final demands. The total requirements resulting from a given level of final demand $(I - A)^{-1}$ equals the direct impact ***I***, plus the first round input requirements of the direct impact ***A***, plus the second round input requirements resulting from the first round A^2, all the way through the ***n***th round when the process converges. Usually about eight to ten iterations are required for convergence with the current approach.

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[7] See Chiang, Fundamental Methods of Mathematical Economics, Third Edition, pp.120-122 for a discussion of approximating an inverse matrix in the context of input-output modeling.

The Interindustry Submodule structure in MAM is grounded in the classical approach to I-O modeling. Alternative I-O modeling approaches build upon the framework presented by Leontief and described above, but the foundation is structurally similar for this class of model.

Employment Submodule

Just as maintaining consistency between the Interindustry and National Submodules is critical for deriving meaningful industrial gross output projections, maintaining consistency between the Employment and Interindustry Submodules is critical to ensuring meaningful employment results. The Employment Submodule calculates the employment impacts of altered energy market conditions based on the following causal relationships. When energy prices change, the level and composition of macroeconomic final demands are affected. In turn, the level and composition of interindustry gross outputs required to satisfy the new final demands are changed. Finally, faced with new demands for their products, industries will adjust the number of workers employed. The response surface Employment Submodule represents this last link in the chain.

The DRI Econometric Model of Employment by Industry,[8] on which the response surface Employment Submodule is based, uses interindustry gross output from DRI's Personal Computer Input-Output (PCIO) Model[9] as its major input when determining employment. Final demand components are used to calculate interindustry gross outputs, which in turn are used to determine employment.

The DRI Econometric Model of Employment by Industry provides the baseline employment projections for use within MAM. It is linked to forecasts of real Industry output produced by PCIO, and to aggregate macroeconomic variables from the U.S. Quarterly Model. Employment for each sector is derived as labor hours divided by the average number of hours worked per employee:

$$Employment \quad (LaborHours) \;/\; (Hours\ Worked\ per\ Employee)$$

Labor hours are calculated as:

$$LaborHours \quad (RealOutput) \;/\; (Hourly\ Output\ per\ Employee)$$

8 DRI/McGraw-Hill, *An Econometric Model of Employment by Industry*, (Lexington, MA, May 1994).

9 DRI/McGraw-Hill, *Description and User Guide for PCIO, the EIA Input-Output Model for the IBM PC*, (Washington, DC, August 1990).

Real output for each industry is an exogenous input passed from the PCIO model. Hourly output per employee (productivity) is the ratio of total output from an industry to the total labor hours required to produce the output. Explanatory variables for labor hours by industry include:

- year-over-year change in output
- ratio of wages to product prices
- ratio of wages to capital costs
- aggregate sector productivity
- exogenous shifts, represented by time trends

Explanatory variables for hours worked per employee (average hours) include:

- year-over-year change in employee hours
- ratio of actual to potential output
- aggregate hours per week
- ratio of non-wage compensation

The sectoring chosen for the Employment Submodule is based on that used for the Interindustry Submodule, but is somewhat less disaggregated for two reasons. The first is that the raw employment data upon which the structural model was based did not allow for some of the industry disaggregations supported by the gross output data. The second is that some of the manufacturing sectors maintained in the Interindustry Submodule are large in terms of energy use, but small in terms of employment. In these cases, the energy-intensive three- and four-digit SIC manufacturing sectors are combined to the two-digit level in the Employment Submodule.

MAM Regional Submodule

Regional models generally fall into three broad classes: top-down models, bottom-up models, and input/output models. Each class of models has a particular set of characteristics. Top-down or shift-share models are desirable from the perspective of consistency and short-run forecasting capability. A top-down model contains simple sharing techniques that assure that the sum of the parts equals a predetermined national total. In addition, because shares do not change radically over the short-term horizon, the top-down approach forecasts well in the short run. One drawback to top-down models is that they are not designed to explain why one region gains in share at the expense of another.

Bottom-up models are better suited to explain interregional shifts in national market share. These are structural models of a region's economy. There are limitations to bottom-up models. In a national system, each regional model is estimated separately. As a consequence, the sum of the parts rarely equals a predetermined national total. Another disadvantage relates to the unconstrained nature of estimating the models. Because of the unconstrained nature of the models, the elasticities of regional employment or value added with respect to national employment or production may be significantly different from one. In the long run, these models tend to over- or under-forecast economic activity if these elasticities are greater or less than one when aggregated over all regions. Since the data needed to develop detailed models that forecast regional economic activity is not readily available, there is substantial cost of developing and maintaining large-scale, well developed regional econometric models for the nation as a whole.[10]

Regional input-output models are frequently discussed in regional economics literature. Input-output tables contain information about interindustry flows and simulate well over the historic period from which they are constructed. There is nothing in an input-output table that can determine why a state or region is gaining or losing share or why a region's industry mix is changing. In addition, the time path of impacts is difficult to determine using regional input/output multipliers.

Most regional models described in the literature are detailed representations of a particular region of the U.S. as opposed to a regional representation of a national model. Few organizations maintain regional models of the nation as a whole, and those that do use different methodologies depending on the time horizon of the forecast, detail of industrial aggregation, and consistency with national macroeconomic forecasts. WEFA, for example, has 51 state models and does regional analysis, but the WEFA state models are not linked to yield a national aggregate consistent with their national forecasts.

Of the regional models that incorporate the entire national economy, there are different methodologies, corresponding generally to the three types of regional models. Each class of models has strengths for certain types of analyses. The discussion below focuses on different examples of these classes of regional modeling. Four regional models are presented: the DRI Regional Information Service (RIS), the Bureau of Economic Analysis (BEA) National-Regional Impact Evaluation System (NRIES), the BEA Regional Input-Output Modeling System (RIMS), and the Regional Economic Models, Incorporated (REMI) Economic-Demographic Forecasting and Simulation (EDFS) Model. These models contain regional representations of a model that is national in scope, rather than separate regional models that are not automatically consistent to a national aggregate. In addition, these models are used frequently by other government agencies and businesses in analyzing regional impacts in both forecast and impact analyses.

DRI Regional Information Service (RIS). The RIS uses a system of quarterly models to

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[10] An article by Farrell and Hall (1991) described the extent to which regional economists were engaged in measuring and forecasting local economic activity. They conducted a survey of regional economists and found that roughly 12 percent of the respondents were measuring and forecasting local activity and that data collection was the foremost problem encountered in forecasting regional economic activity.

forecast over 100 concepts for each state and region.[11] The forecast horizon is 25 years, to 2015. The principal indicator of sectoral economic activity is employment, which is forecast separately for 20 manufacturing and about 10 nonmanufacturing industries. Wage rates and major components of income are modeled, and the housing sector is examined in detail, with forecasts of single- and multi-family housing starts, and the corresponding actual and desired stocks. Population, labor force, and unemployment rates are also predicted within the model. Variations in regional energy prices also determine regional output; however, only regional industrial electricity prices are used as part of the RIS model.

The RIS model analyzes the different parts of the U.S. in a two-stage procedure. The country is first broken down into nine regions (approximately the nine Census Divisions[12]) in the core model and then individual state models use the regional results to derive state impacts. This approach has been adopted both because it reduces the costs of solving whenever the complete 50-state detail is not required, and also for theoretical reasons. DRI argues that the factors determining the choice of location are different at the regional than at the state level.

The focus of DRI's core nine-region model is an analysis of the relative success of each geographical area in attracting and retaining the types of industries that serve national markets. This leads directly to the study of industrial location, in which context it is clear that the factors determining the choice of location are different at the regional level and the state level. For example, when a firm is deciding whether to set up in the West or the South, it considers general cost comparisons, proximity to markets, and general attractiveness. The choice between San Diego and Phoenix, however is more likely to be influenced by many other considerations such as tax burdens and home prices as examples.

One of the fundamental features of the DRI RIS system of nine regional models is the direct link to the other models in the DRI system. In particular, the regional totals are constrained to yield the national control totals from the macro model for key variables such as employment by industry, wage rates, population, and the labor force. While it is possible that the summation of the nine regions may yield different results, a balancing procedure ensures consistent results between the national and regional estimates. The model forces regional relocation and adjustment in order to attain a national result.

The RIS system focuses squarely on the determination of employment by region. Three factors essentially drive the regional growth differentials: national industrial mix, amplitude of the business cycle in each industry, and regional cost differentials. Regional costs, in

11 Data Resources, Inc., "An Overview of DRI's Regional Information Service."

12 Two Census regions, the Pacific and Mountain, are instead split into Pacific Northwest and Pacific Southwest.

turn are functions of wage rates, tax burdens, energy prices, unionization and education of the labor force, and home prices. The determination of regional output is derivative from the employment growth patterns given a fixed set of productivity by industry measures. Also, regional investment patterns follow movements in regional employment growth.

Even at only the nine-region level, the RIS model is large and requires much hands on experience to effectively run the system. It is accessible only through the DRI mainframe and is run through the DRI proprietary software package, Economic Programming System (EPS). At present, no one outside of DRI personnel runs the model. The expense of completing an integrated run in conjunction with a DRI macro forecast precludes extensive examination of alternative cases. In addition, because the regional model is so large, it requires a large amount of training in order to become familiar enough with its properties to use model results for policy analysis. The derivation of baseline regional forecasts consistent with a baseline macro forecast, is certainly feasible as is the limited investigation of specific policies or key economic growth paths.

Using the DRI RIS system directly as the regional macroeconomic model in NEMS is not feasible for several reasons. First, the size and specification of regional detail in the model makes it too large for NEMS uses, especially when the purpose of NEMS is to forecast regional energy variables as opposed to regional macroeconomic concepts. Second, it is possible to derive regional shares using forecasts from the DRI RIS model; however, the shares would not change as energy prices change. Third, the complexity and size of the DRI RIS model requires a substantial investment in training of EIA personnel to adequately incorporate the full RIS model into NEMS.

National-Regional Impact Evaluation System (NRIES II). NRIES II is an annual econometric project and impact model used to estimate the distribution of impacts of alternative policies and to provide short- to medium-term projections of state economic activity. The model is maintained by the Regional Economic Analysis Division within the BEA at the Department of Commerce.[13]

NRIES consists of 51 individual state econometric models, a national model, and a set of indexes that measure trade flows among states. The forecast horizon is ten years, through the year 2000. NRIES is structured so that (1) coefficients of equations pertaining to variables that differ little among states, such as Federal fiscal and monetary variables, are estimated within the national model, and (2) coefficients of equations pertaining to variables that differ substantially among states, such as industry product, employment, and income, are estimated within the individual state models.

Variables projected within the national model are termed "top-down" while those projected

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[13] J.R. Kort, J.V. Cartwright, R.M. Beemiller, "Linking Regional Economic Models for Policy Analysis," Regional Economic Analysis Division Bureau of Economic Analysis, Department of Commerce, July 1984.

within the state models are termed "bottom-up". When bottom-up variables are aggregated to national totals, they are termed "sum-of-states" and these aggregations are the national projections. Changes in individual state economics can both affect, and be affected by, changes in the national economy.

The 51 individual state models form the core of the system. Each state model forecasts output, employment, wage rates, nonwage sources of income, population, state and local government revenues and expenditures, investment, labor force, unemployment, and retail sales. The national model derives such variables as final demand components, Federal government receipts and expenditures, money supply, interest rates, consumer and producer prices, tax rates, and various Social Security variables. The model also captures interstate commodity flows.

The focus of the state models is on the derivation of output for the 20 two-digit SIC manufacturing sectors and 10 one-digit nonmanufacturing sectors. Manufacturing activity is mainly a function of relative costs of business, interstate flow transactions, and national model variables such as consumption, investment, and interest rates. Output in the nonmanufacturing sectors is mainly a function of local-demand variables such as state disposable income or population and national variables such as interest rates.

Employment is essentially derived as a function of industry output. Investment in nonresidential structures and equipment is specified as a function of interest rates and state total output, but not at the industry level.

The NRIES is particularly useful for evaluating the interregional distributional effects with its explicit representation of interregional flows. Also, NRIES derives a simultaneous solution at the regional and national levels. The bottom-up nature of the model assures complete consistency between the national and regional results. The national model on top provides needed control to assure that the simple summation of the state results does not yield a systematic over or understatement of the growth potential of the aggregate economy.

However, there are limits to its immediate usefulness. First, the model currently projects only through 2000. An extension to the year 2020 would be a major effort and could be done only through BEA. Model size is also a consideration. The bottom-up aggregation of 51-states nature of the model makes it large and cumbersome. But perhaps the most difficult methodological issue is consistency with the National Submodule results. The National Submodule, based on the structural DRI Model of the U.S. Economy, is capable of addressing a large variety of policy issues ranging from specific energy initiatives to accommodating monetary or fiscal policy to supply side effects related to capital formation. These issues cannot be adequately covered using the strict bottom-up approach as typified by NRIES.

Regional Input-Output Modeling System (RIMS II). RIMS is also developed and maintained by BEA. RIMS represents a set of regional input-output coefficients and multipliers for use in estimating the regional impacts of economic policies.[14] Coefficients and multipliers can be estimated for any county or group of counties in the U.S. and for all of the approximately 500 industries in the BEA set of benchmark input-output tables. RIMS can be used to estimate the impacts of project and program expenditures by industry on regional output, earnings, and employment.

The available detail, both in terms of the regional disaggregation and the industrial disaggregation, is the raison d'etre for the RIMS model. RIMS also has major limitations characteristic of other regional and national input/output models. The multipliers are derived from a linear Leontief production function which assumes constant returns to scale and no substitution among inputs. Also, RIMS does not identify the time paths of impacts, and does not take into account the interregional flows of goods and services. In addition, RIMS is a BEA model and is maintained and operated by BEA. The flexibility of a regional model that is directly linked to the NEMS system and operated by EIA personnel would be lost.

Regional Economic Models, Incorporated (REMI) Economic-Demographic Forecasting and Simulation (EDFS) Model. The REMI EDFS model, an annual regional forecasting and policy simulation of both the private and public sectors of the United States, has been publicly available since 1980. The model's forecast period extends to the year 2035 and the regions covered include the 50 states and Washington, D.C. Model runs from post sample period forecasts for these 51 regions indicate the model may be more successful in long-term forecasting.[15]

The REMI EDFS model, composed of five blocks, employs a highly simultaneous model structure where most interactions between blocks flow both ways. The structure of the model incorporates interindustry transactions and endogenous final demand feedbacks. The model includes substitution among factors of production in response to changes in relative cost factors, migration response to changes in expected income, wage response to changes in labor market conditions, and changes in the share of local and export markets in response to changes in regional profitability and production costs.

Block-1 of the model, output linkages, interacts extensively with the other blocks of the model. It includes output equations, consumption equations, real disposable income equations, investment equations, and government spending equations.

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[14] "Regional Multipliers: A User handbook for the Regional Input-Output Modeling System (RIMS II), Bureau of Economic Analysis, Department of Commerce, May 1986.

[15] The REMI EDFS analysis draws heavily from George I. Treyz, Dan S. Rickman, Gang Shao, "The REMI Economic-Demographic Forecasting and Simulation Model" International Regional Science Review, Vol. 14, No. 3, p. 251, 1992.

The output equations employ an input/output structure representing the interindustry and final demand linkages by industry. Outputs for 53 sectors (49 private non-farm industries and three government sectors) are calculated. Regional information is produced by applying regional purchase coefficients to historical and projected input/output tables from the Bureau of Labor and Statistics (BLS).

The consumption equations translate real disposable income into consumption demand. Real disposable income (personal income adjusted for taxes and the cost of living) data by sector is based on data from the BEA.

The investment equations are based on residential, non-residential, and equipment investment. Government spending is predicted for six components: federal civilian, federal military, state and local education, health and welfare, safety, and miscellaneous.

Block-2 of the model, factor demands, assumes industries demand profit-maximizing levels of factor inputs. The optimal choice of inputs demands two stages. First, industries demand fixed shares of composite value added and intermediate inputs and, second, industries choose optimal levels of the components of composite factors. Block-2 is composed of labor, capital, and fuel demands. While fuel demand is not explicit in the model, the cost of fuel enters the demands for labor and capital.

Block-3 of the model, regional population and labor supply, determines the interaction of the model's demographic and economic sections. The cohort algorithm applies fertility and survival rates from state-specific 1980 data trended backward and forward by the Bureau of Census (BC). The migrants category consists of international, retired, former military and their dependents, and economic migrants. International migration is calculated by applying a fixed regional share to BC data.

Block-4 of the model consists of production, labor, and capital costs, along with prices and profits. Relative labor cost is based on several BC Current Population Surveys and REMI data.

Block-5 of the model, market shares, is based on the effects of national and regional industries in the region. The model uses the Department of Commerce's 1977 Census of Transportation data for manufacturing industries and subjective estimates for non-manufacturing industries.

Summary of Regional Models Reviewed. Similar to requirements for the national macroeconomic model, three system requirements must be addressed by the Regional Submodule: (1) develop a baseline path for regional economic activity, (2) calculate regional economic feedbacks internal to the modeling system, and (3) evaluate detailed regional impacts. However, decisions about the regional economic modeling are directly tied to decisions about the macroeconomic system of models.

Regional consequences of energy actions and events are partially addressed through the supply and demand models directly. For example, energy production and energy price impacts are derived within the energy components of the system. The regional component of the macroeconomic model addresses the secondary effects which arise because of regional reactions to regional energy issues or regional effects caused by national impacts. For example, the regional macroeconomic model is intended to incorporate economic impacts of differences in regional energy prices and labor costs.

Based upon the above discussion, a system that fully integrates the interindustry structure into the aggregate economy has specific advantages. Bottom-up interindustry/macro modeling is attractive for numerous reasons, which may not apply to regional/interindustry bottom-up models (as in NRIES II). This assertion requires some critical design and segmentation considerations in the sectoral detail versus regional detail. In addition, bottom-up regional models may not be able to confront the type of detailed energy policy options that NEMS requires. For example, neither the imposition of a national tax policy nor the consideration of the disposition of the collected revenues can be addressed using a bottom-up regional economic model.

The ability to address the fundamental determinants of growth is critical to the macroeconomic modeling. The regional models to date are demand-driven systems that simply do not address the underlying supply constraints on the economy. The macroeconomic models address investment behavior in detail; in the regional models, investment behavior is handled poorly or not at all.

Size of the system is a critical constraint. Regional modeling, particularly if bottom-up, forces the entire system to grow rapidly to an unmanageable size.

Conclusions on Regional Submodule Structure. Based upon the discussion of alternative regional modeling considerations presented above, the following conclusions are advanced:

1. The MAM Regional Submodule is compatible with the National, Interindustry, and Employment Submodules and incorporates regional impacts by utilizing regional shares based on a smaller version of the DRI Regional Model estimated at the Interindustry Submodule level of aggregation.

2. Existing regional models have several drawbacks. First, the size and complexity of the DRI regional model is a major hindrance to direct incorporation within NEMS. The system of regional models maintained by BEA is unusable for NEMS because at least one of the following conditions holds: (1) the BEA system contains its own macroeconomic model (a simpler representation than what is required by NEMS analysis); (2) the BEA forecast periods do not match the NEMS requirements; (3) some BEA models are incapable of analyzing the stream of impacts over time. Using models that are maintained or updated

on schedules over which EIA has no control would not add to NEMS flexibility.

3. The share approach has three primary advantages: (1) direct linkage and consistency with the national, interindustry, and employment models used in NEMS analysis; (2) regional output corresponds to national aggregates; and (3) the ability to generate regional forecasts consistent with the NEMS energy models' forecasts of production in industries such as refining and mining.

Summary Rationale. Three considerations underlie the decision to adopt the kernel regression and response surface approaches for NEMS:

- o EIA time and project resource constraints eliminate the option of developing a complete system of structural models in-house for the AEO2001.
- o Incorporating an existing proprietary model as the MAM would have raised the issues of disclosure and inconsistencies between the MAM energy equations and the NEMS view of energy market behavior.
- o Removing the energy sector from an existing proprietary model and linking the remainder with NEMS would have raised disclosure issues and non-energy proprietary equations.

The kernel regression and response surface approaches have the advantage of being able to avoid the common econometric problems of multicollinearity, limited sample variability, and short run disequilibria. Also, there can be no simultaneous equation bias because the exogenous variables are controlled and an approximation to the reduced form equations is estimated. The usefulness of these approaches is determined by the closeness with which they are able to approximate a complex surface by using a hyperplane. This is more of a numerical analysis issue as opposed to a statistical consideration.

Response surface models have been in use since 1959 when G.E.P. Box and colleagues began publishing papers on the subject.[16] While response surface, or reduced form, models are widely used in the natural sciences, they have not been in common use among economists. A notable exception is the series of papers by James M. Griffin (1977a, 1977b, 1978, 1979) that estimate cost functions based on pseudo data generated by repeated runs of linear programming models. Other applications of pseudo data in economics include Attanasi and Green (1981), Sav (1984, 1987), and Kolstad and Wolak (1983). The use of pseudo data for the estimation of economic models has been criticized (Maddala and Roberts, 1980) but not without a spirited reply by Griffin (1980). Finally, because the purpose of this model is to reproduce the output of a larger model, the only possible data for this purpose is pseudo data.

Kernel regression modeling is similar to response surface modeling in that it uses

[16] See Box and Draper (1987) for an excellent history and discussion of the technique.

simulations from the structural model being approximated to create a pseudo database. However, instead of relying on the entire database to estimate the regression relationships, it uses a subset of data chosen based on the values of the input variables to estimate the relationships in that region. Appendix A will describe the specific form of the localized regression.

The Macroeconomic Activity Module (MAM) serves two functions within the National Energy Modeling System (NEMS). First, it provides consistent sets of baseline macroeconomic variables which are used by the supply, demand and conversion modules in reaching an energy market equilibrium. Second, it is designed to provide a feedback mechanism that alters the baseline variables during the course of an integrated NEMS run.

For the reasons discussed above, the MAM is not a structural model. Instead, the consistent sets of baseline variables are generated by running the full slate of DRI models (macroeconomic, input-output, employment, and regional). The macroeconomic variables required by NEMS are extracted for use as input by the NEMS. In order to provide the feedback mechanism within NEMS, numerous simulations of the DRI models are completed on a personal computer, and the solutions saved. A simplified representation of the relationship between the important inputs (provided by the NEMS) and the required outputs (provided back to NEMS) is then constructed.

Until recently (through the AEO98 version), the National Submodule of MAM relied upon a response surface version of the DRI US Quarterly model to incorporate energy price feedback into the macro economy. The response surface version of the model was an approximation of the larger model and was estimated on “pseudo data” generated by repeated simulations of the larger model. Energy prices, in particular the world oil price, were changed in the DRI model and results of many simulations were saved in a database. Linear equations were estimated that related a particular variable (such as percent changes in GDP) to percent changes in energy prices and lagged dependent variables in order to mimic the response of DRI’s Quarterly model to changes in energy prices.

This response surface model worked relatively well when the macroeconomic impacts were the result of changing energy prices when resource costs changed. The model was fast and relatively easy to maintain. However, in situations where energy prices were changing because of some policy tool, such as carbon tax or permit schemes, the results from the response surface version of the model became less accurate in mimicking the results obtained from the larger DRI model. In these instances, energy end-use prices would change by far more than the underlying energy resource costs. As a result, EIA began to search for alternate ways of capturing the response of the DRI model that would be useful in both an energy policy scenario as well as a situation that involved projecting different energy resource costs.

Prior to the Energy Information Administration's carbon stabilization analysis[17], the response surface model contained in the National submodule of the Macroeconomic Activity Module was replaced with a kernel regression model. The performance of the kernel regression model, in terms of mimicking the DRI US model, was judged superior in a variety of policy settings to that of the response surface model. As a result, the kernel regression has become, for now, the national macroeconomic model of the National Energy Modeling System. The kernel regression model has since been used to produce forecasts reported in the *Annual Energy Outlook 2001*.

[17] Energy Information Administration, *Service Report: Analysis of Carbon Stabilization Cases*, SR-OIAF/97-01 (Washington, DC, October 1997.)

3. Module Structure

Figure 1 graphically illustrates the design and flow of the MAM within the NEMS system. Figures 2 through 6 provide supporting illustrations of the submodule flows. Key computations and equations used in MAM are described following their graphic representation.

Figure 1 depicts MAM in the context of the NEMS system. The four primary submodules of MAM: the National, Interindustry, Employment, and Regional Submodules, are shown in the diagram. The National Submodule calculates the national level variables. The Interindustry Submodule creates the industrial gross output projections. The Employment Submodule determines the employment projections. The Regional Submodule generates the regionalized variable forecasts. The whole of Figure 1 illustrates the role of MAM within the NEMS system. MAM receives energy price and quantity forecasts, system information, and energy supply sector activity from the NEMS system and provides national and regional economic projections to the NEMS system.

Figure 2 illustrates the flow of the National Submodule. The system information (including the number of years, regions, and driver variables), the DRI macroeconomic baseline forecast generated externally to the NEMS system, and additional driver variable information are input to the National Submodule. The kernel regression algorithm that comprises the National Submodule estimates the solution macroeconomic variables based on the NEMS input values. Final demands are among the macroeconomic variables calculated using this algorithm.

Figure 3 illustrates the flow of the Interindustry Submodule. System information including the number of industries that are modeled and additional information, along with the final demands calculated in the National Submodule, are input to the Interindustry Submodule. Changes in interindustry activity are then calculated using the response surface approximation, followed by the calculation of industrial outputs, manufacturing outputs, service outputs, and total industrial output. Aggregations provide the composite industrial gross outputs for reporting purposes. The interindustry gross outputs are forecasted in this submodule.

Figure 4 illustrates the Growth Industry component of the Interindustry Submodule. This component models the industrial outputs from energy-producing industries that come from NEMS. These industries are: Coal Mining, Oil and Gas Extraction, Petroleum Refining, Gas Utilities, and Electric Utilities. This component draws upon industry-specific inputs to estimate growth paths for these five sectors, based upon historical gross output levels and the growth in the industry-specific inputs from the appropriate NEMS supply and conversion modules.

Figure 5 illustrates the Employment Submodule. System information along with the changes in gross output calculated by the Interindustry Submodule are input to the Employment Submodule. Changes in employment are then calculated using the response surface approximation. Employment by industry is forecasted in this submodule.

Figure 6 illustrates the Regional Submodule. The Regional Submodule operates upon a subset of the macroeconomic variables that are forecasted by the National, Employment, and Interindustry Submodules, specifically, the macroeconomic variables that are required by the NEMS demand modules at the Census Division level of detail. The inputs to the Regional Submodule are some of the national macroeconomic variables, the interindustry gross outputs, and employment by industry. The Regional Submodule applies regional shares to each input to calculate the Census Division levels.

Figure 1. MAM Calculational Flows within NEMS

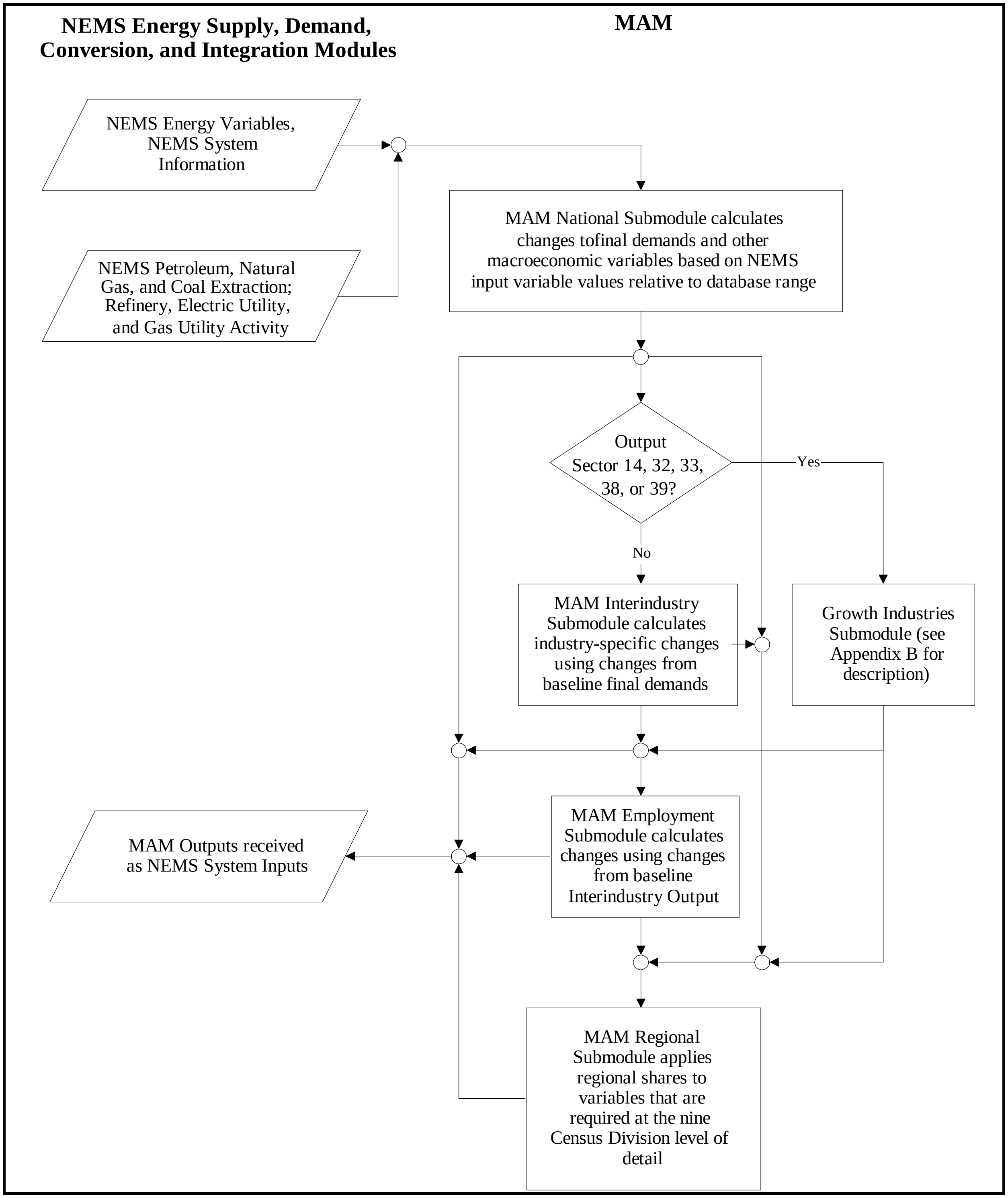
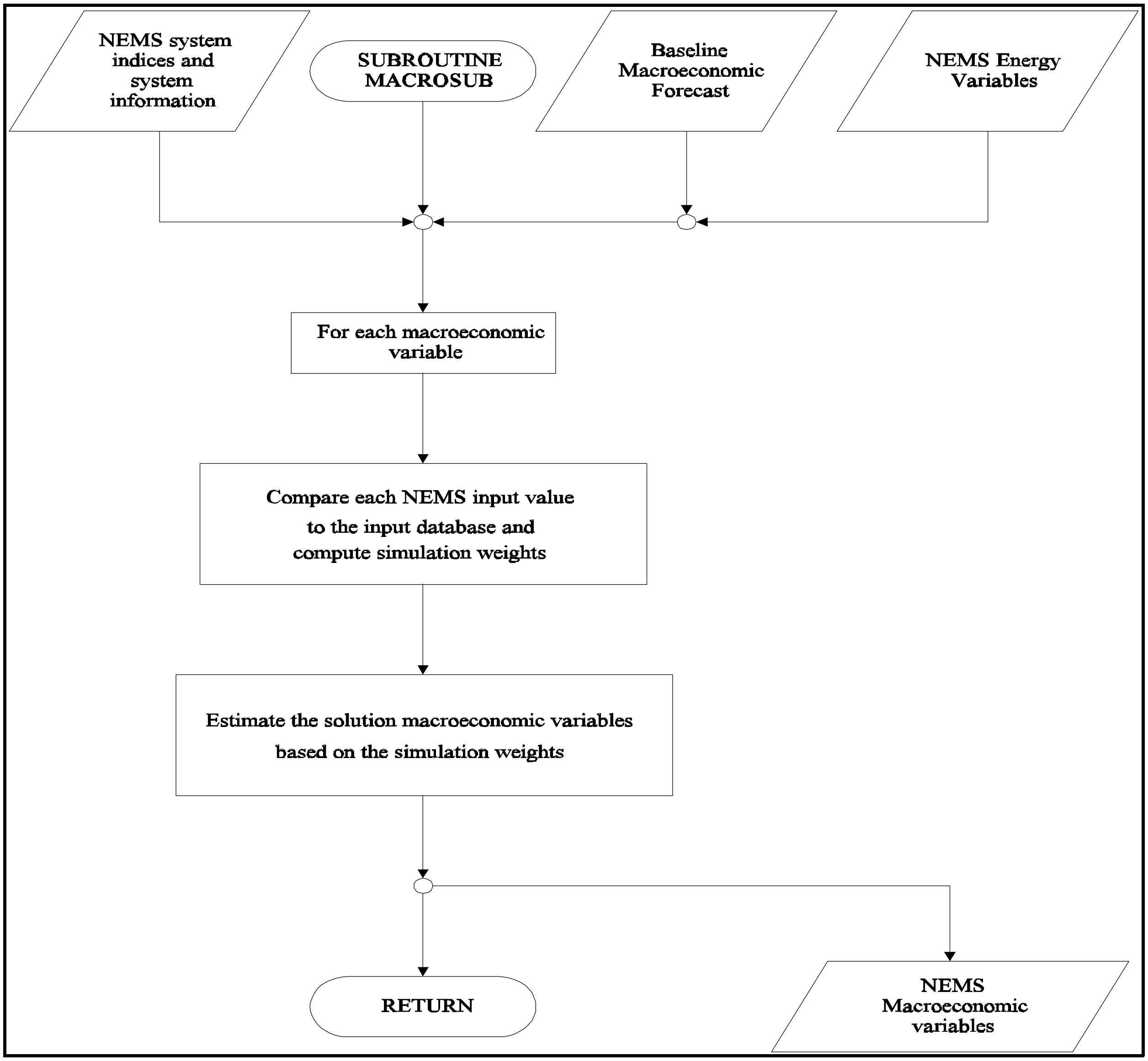
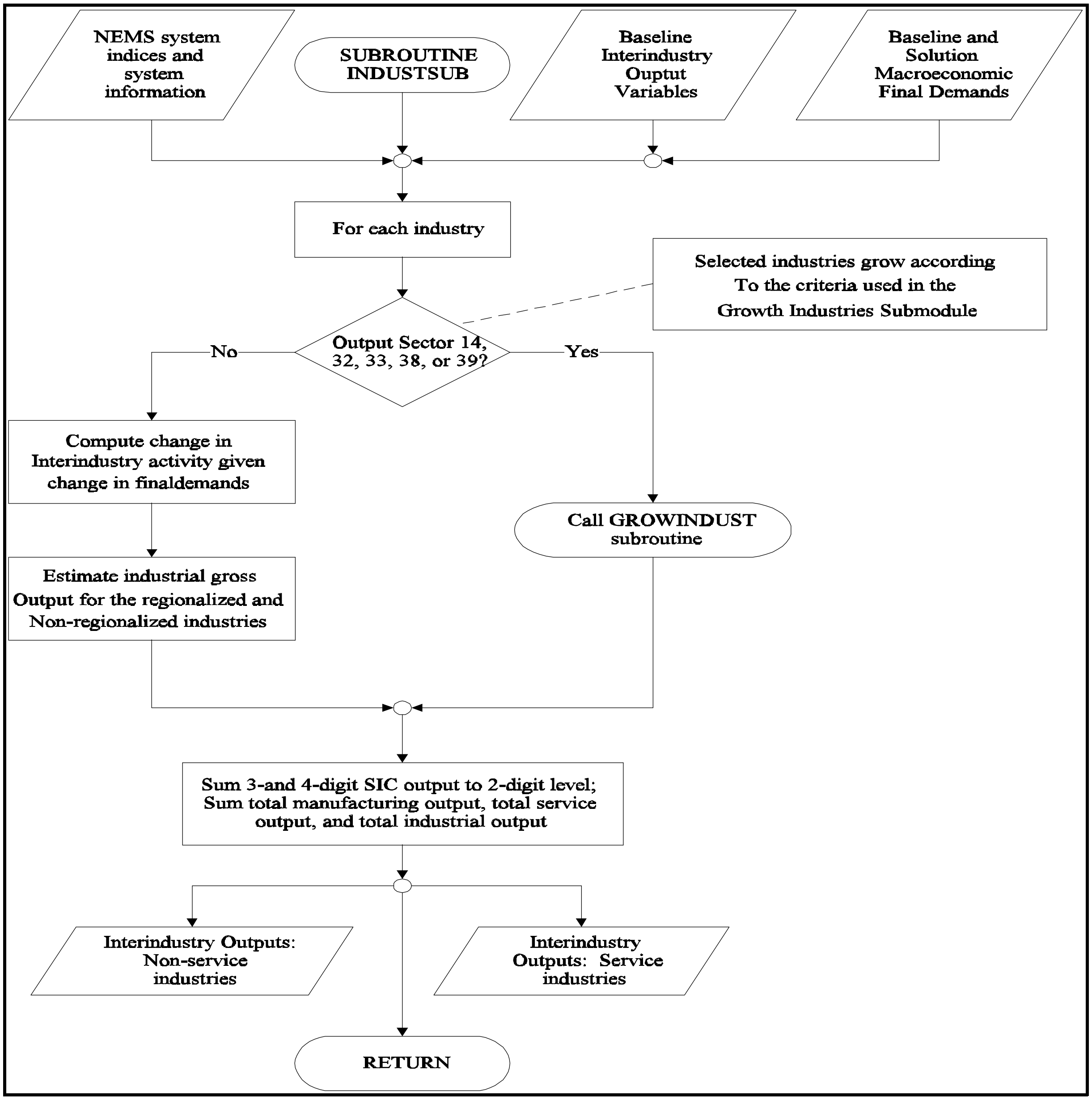


Figure 2. National Submodule Flow[18]



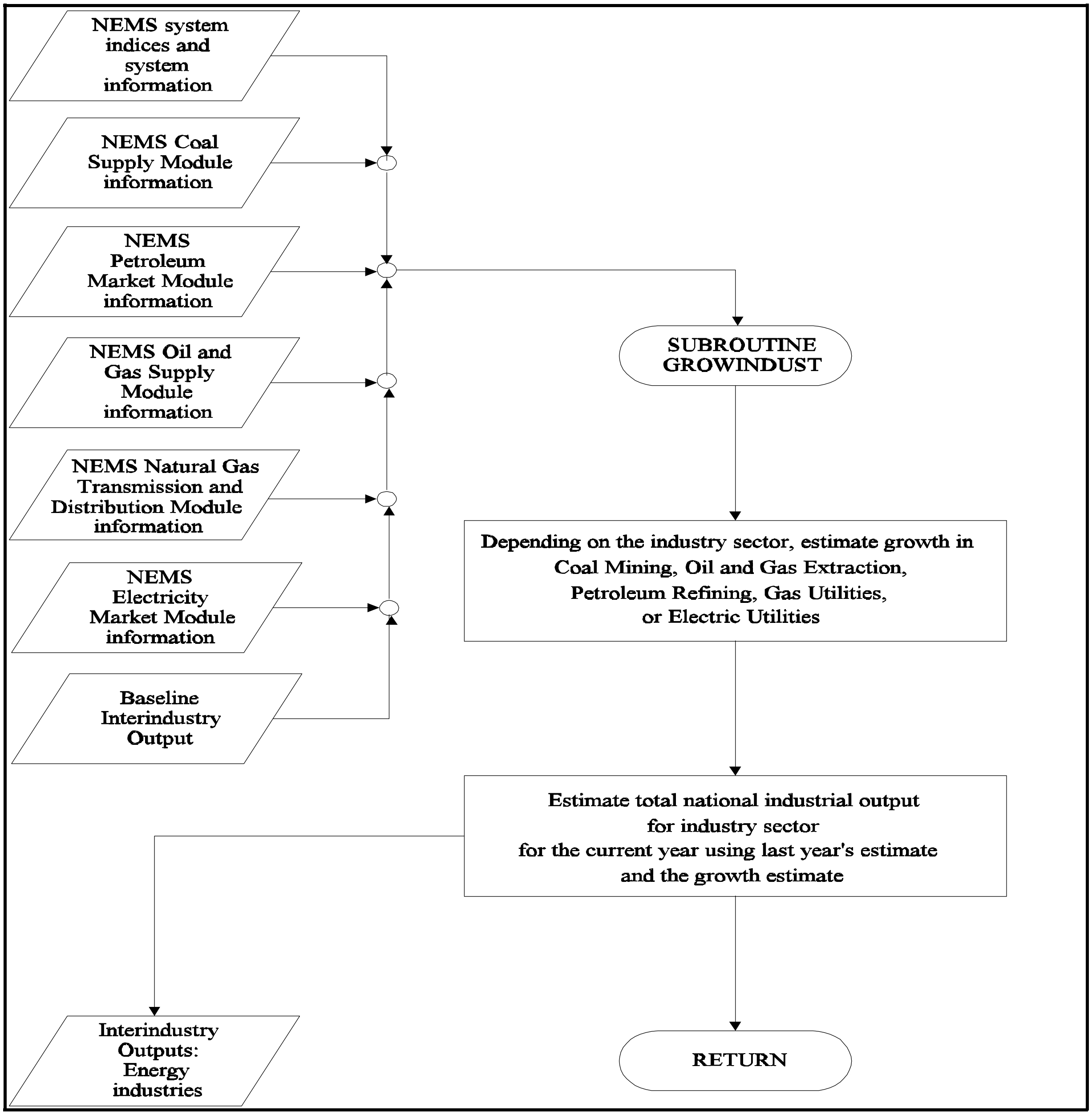
[18] Tables A-1, A-2, A-7, and A-8 of Appendix A to this report provide the definitions, usage, calculation, and dimensions of the items contained in the input/output blocks (rhombi) of this diagram. The process blocks (rectangles) of this diagram are further discussed in the second section of Appendix B, "The National Submodule".

Figure 3. Interindustry Submodule Flow[19]



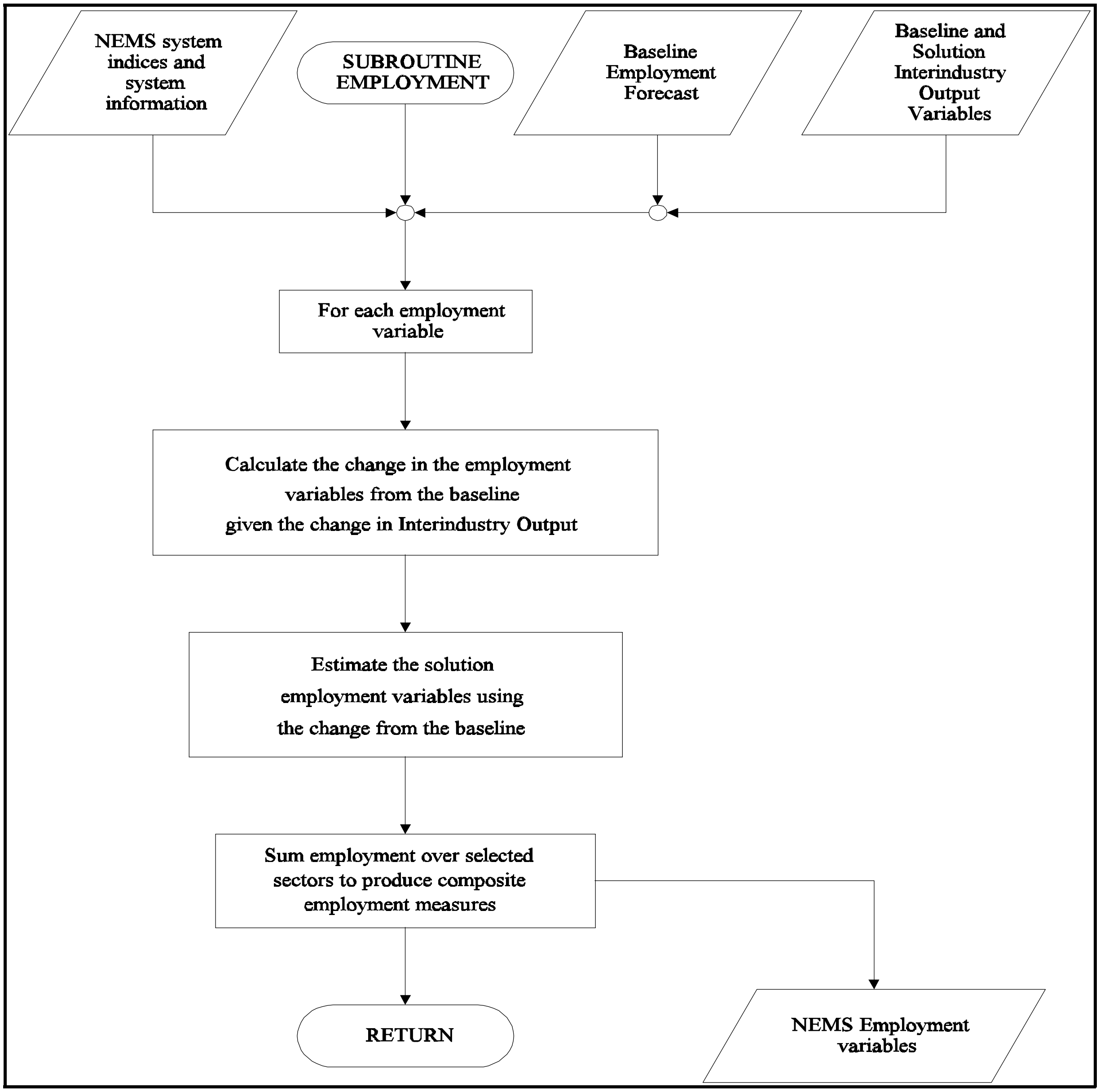
[19]Tables A-1, A-2, A-3, A-6, and A-8 of Appendix A to this report provide the definition, dimensions, and usage of the interindustry components contained in the input/output blocks (rhombi) of this diagram. The calculational steps illustrated in the rectangular blocks of this diagram are further described in the third section of Appendix B to this report, "The Interindustry Submodule".

Figure 4. Growth Industry Component of Interindustry Submodule [20]



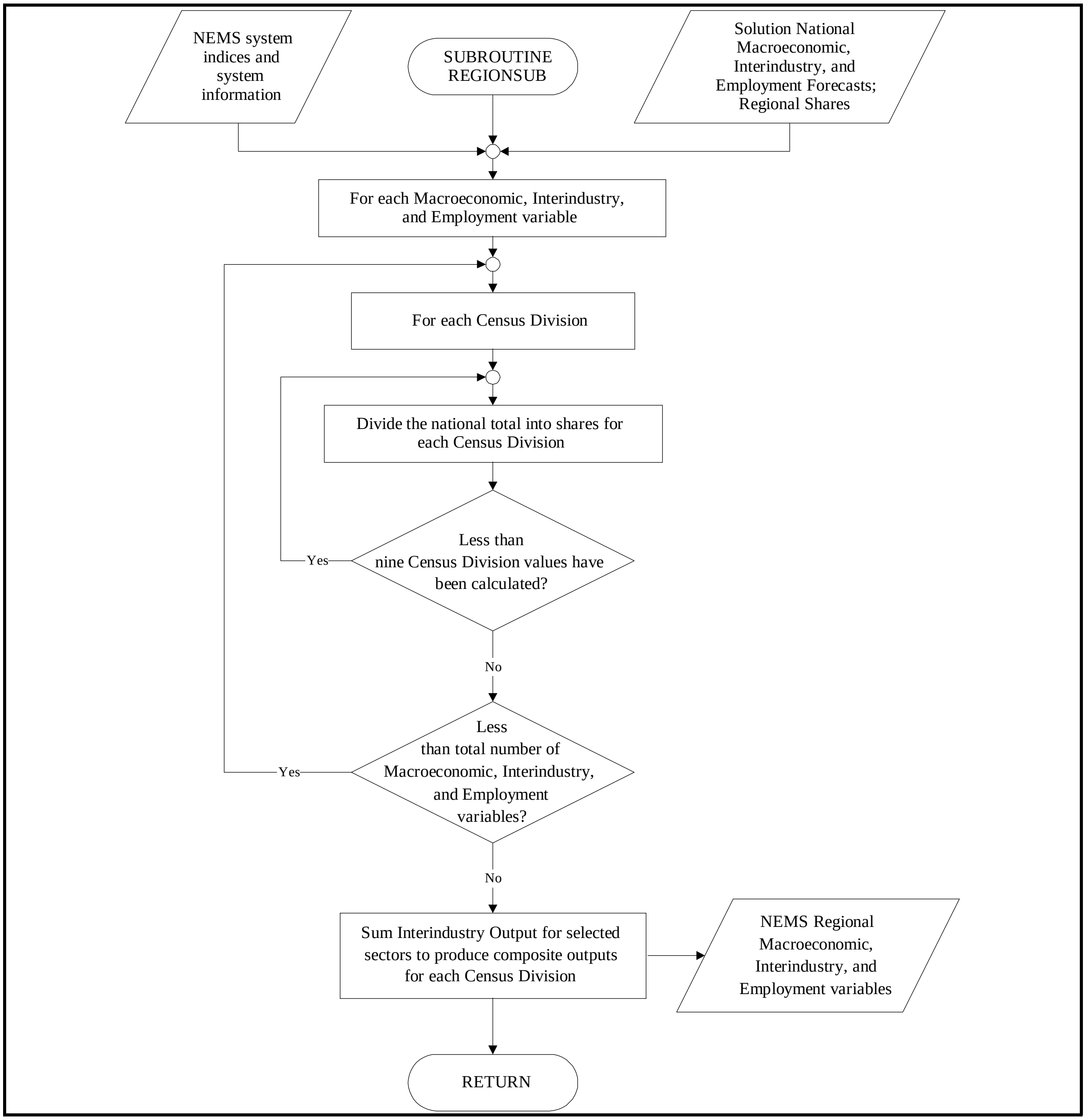
[20] Tables A-1, A-4, and A-8 of Appendix A to this report provide the definitions, dimensions, and usage of the Growth Industry Component items referenced in the input/output blocks (rhombi) of this flow diagram. The calculational processes provided in the rectangular blocks of this diagram are further described in the fourth section of Appendix B to this report, "The Growth Industry Submodule".

Figure 5. Employment Submodule Flow[21]



[21]Tables A-1, A-4, A-6, and A-8 of Appendix A to this report provide the definition, dimensions, and usage of the Employment Submodule as illustrated in the input/output blocks (rhombi) of this diagram. The calculational steps illustrated in the rectangular blocks of this diagram are further described in the second section of Appendix B to this report, "The Employment Submodule".

Figure 6. Regional Submodule Flow[22]



[22]Table A-1, A-2, A-3, A-4, A-5, and A-8 of Appendix A to this report defines the NEMS system information and indices required by the Regional Submodule as illustrated in the input/output blocks in the upper right corner of this flow diagram and the decision blocks (diamonds) appearing throughout the diagram. The calculations described in the rectangular blocks of the diagram are further detailed in the fifth section of Appendix B to this report, "The Regional Submodule".

Key Computations and Equations

MAM Approach

The goal of the MAM is to replicate the structural DRI models' impacts resulting from energy market changes. Four DRI models are used to create any macroeconomic baseline: the DRI U.S. Quarterly Macroeconomic Model, the DRI Personal Computer Input-Output Model (PCIO), the DRI Employment Model, and the DRI Personal Computer Regional Model. For the AEO2001, MAM uses a kernel regression approximation of the DRI US Quarterly model for the National Submodule, and response surface representations of the DRI PCIO and Employment Models for the Interindustry and Employment Submodules respectively. The Regional Submodule of MAM used for the AEO2001 is a set of regional shares developed through simulations of the full slate of DRI models.

MAM National Submodule

The National Submodule of the MAM is a kernel regression representation of the DRI U.S. Quarterly Macroeconomic Model. Kernel regression is a nonparametric approach to regression analysis that makes no assumptions regarding the functional form of the unknown function *m* in the following relationship:

$$Y_i = m(X_i) + \varepsilon_i \qquad \textbf{(7)}$$

The Y_i's are observed random variables, the X_i's are known constants and the ε_i's are independent random errors with mean zero and constant variance. In the Macroeconomic Activity Module, the Y's are the one hundred and nineteen national and regional macroeconomic concepts that the module forecasts. The X's are twelve inputs from the National Energy Modeling System. These inputs include tax collections and energy prices and quantities demanded. A full description of the kernel regression inputs and outputs is provided in Appendix A. To approximate the unknown function *m*, the kernel regression relies upon databases containing simulation results of the DRI U.S. Quarterly Macroeconomic Model. The simulations represent different assumptions about the price of crude oil and about policy instruments. The databases are linked so that the input variables (i.e. tax collections and energy prices and quantities) from each simulation are associated with their respective output variables (i.e. macroeconomic concepts.)

Policy questions are much more complicated in terms of the assumptions that must be made when running the larger DRI model. Consequently, constructing a surface that approximates the multiple dimensions becomes extremely complicated. Rather than attempt to uniformly define the space, we have chosen to describe the neighborhoods of likely input combinations more completely. This is both good and bad. Within the defined neighborhoods the approximation of the full DRI model solution is much more precise; but when the energy inputs from a particular NEMS simulation fall near the edge of a neighborhood, or between well defined neighborhoods, the kernel results are suspect.

The success of this kernel regression procedure relies upon including simulations in the database which are similar along the important dimensions to the energy policies analyzed (if using the kernel regression model in a policy mode) or the path of energy prices (if using the kernel model in an energy resource cost mode). In creating the database used for the carbon constraint study, repeated NEMS simulations of alternative carbon price scenarios were needed in order to better calibrate the response of the larger DRI model to changing energy prices and quantities predicted by the energy models in NEMS. If the analyzed NEMS scenarios have different starting times or alternative paths to attain carbon targets, then the DRI model had to be simulated again using the new starting times or paths to carbon attainment. The construction of the AEO world oil price portion of the database was much simpler. Twenty-two alternative world oil price paths, ranging from a 50% decrease to a 100% increase relative to the baseline path, were input to the DRI model. The simulation results make up the database.

One major concern for both the response surface version of MAM using linear estimation techniques and the kernel regression technique is how close both replicate the larger DRI model. An example is provided that compares the results using a kernel regression approach to a linear regression. This illustration, while a gross oversimplification of the application of the methodology in the MAM, does demonstrate the basics of performing kernel regression. Analogies to the MAM are made where possible. Table 1 contains data for an independent variable, X, and a dependent variable, Y.

Table 1. Data for Hypothetical Regression Analysis

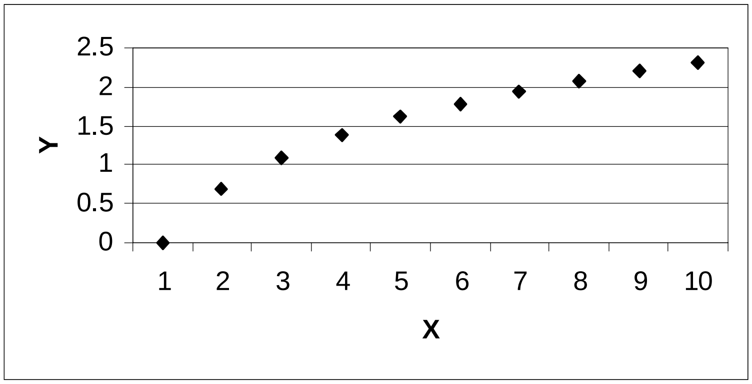
X	Y
1	0.000000
2	0.693147
3	1.098612
4	1.386294
5	1.609438
6	1.791759
7	1.945910
8	2.079442
9	2.197225
10	2.302585

The input and output variable databases in MAM are analogous to the data in Table 1. The explanatory variables, X, in the MAM include tax collections and energy prices and quantities demanded. In the MAM, the response variables, Y, are all the national macroeconomic variables forecasted by the module. The input databases contain samples of simulations that differ in both the type of policy and its degree of implementation. Results of simulations based upon these assumptions are placed in the output databases. The input and output databases are linked so that levels of tax collections and of energy prices and quantities demanded are related to their respective levels of the national and regional macroeconomic variables.

The data points in Table 1 are plotted in Figure 1. Ordinarily, the function *m* describing the relationship between Y and X is unknown. In this instance, the function *m* is known because the data for this illustration were invented. The true relationship is:

$$Y_i = m(X_i) + e_i = \ln(X_i) \qquad \textbf{(8)}$$

Figure 1: Plot of Data Points X and Y.

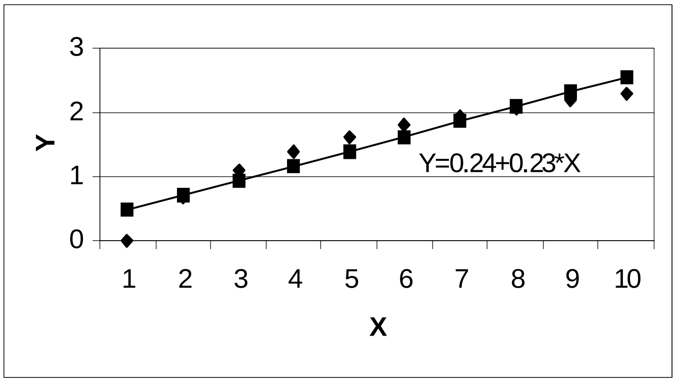


We will proceed with this illustration as though the function *m* is unknown and use regression analysis to approximate the function $\ln(X_i)$. The specific question this illustration answers is what is the value of Y given *X* equals 4.5. Since the function *m* is known, we know the true answer is 1.5. We proceed now to see what answer a parametric and a nonparametric approach would yield assuming *m* is not known.

Figure 2 contains a plot of the X and Y data points along with the regression line estimated using ordinary least squares. In order to use ordinary least squares, we must specify a functional form and make assumptions about the behavior of the residuals. Given this approximation to the function *m*, the value of Y given that *X* equals 4.5 is:

$$\begin{aligned} Y(X) &= \alpha + \beta X \\ Y(4.5) &= 0.24 + 0.23(4.5) = 1.28 \end{aligned} \qquad \textbf{(8)}$$

Figure 2: Ordinary Least Squares Regression of Y on X



The steps to solve the kernel estimator given *X* equals 4.5 are now given in more detail than that for the ordinary least squares estimator. We begin by normalizing values of the explanatory variable, X, using its mean, 5.5. Table 2 contains these values.

Table 2. Data for Kernel Regression Analysis

X	Normalized X (X_i/5.5)
1	0.181818
2	0.363636
3	0.545454
4	0.727272
5	0.909091
6	1.090909
7	1.272727
8	1.454545
9	1.636363
10	1.818182

This same transformation is done for all the inputs in the selected simulations contained in the input databases during a NEMS run. The values of tax collections and energy prices and quantities demanded supplied by NEMS are also transformed using the means of the inputs contained in the databases. In this example, the input value is 4.5 and its normalized value is 0.818182. While normalizing the input data is not necessary, the conversion to multiples of average units makes analysis of the input data easier particularly when there are a number of inputs measured in different units as in NEMS.

The kernel estimator computes for a function of X a weighted average of observations close to the i^{th} value of X. The kernel estimator used in the MAM is the Nadaraya-Watson estimator. This same nonparametric estimator is used in this illustration to approximate the function *m*. The Nadaraya-Watson estimator is:

$$m_h(X) = \frac{n^{-1}\sum K_h(X - X_i)Y_i}{n^{-1}\sum K_h(X - X_i)} \qquad \textbf{(10)}$$

where X is the normalized value of 4.5, n is the sample size 10, Y_i is the values of the observed response variable and $K_h(u)$ is the kernel with a scale factor h. The scale factor is also known as the bandwidth. The bandwidth determines the size of the weight sequence about the i^{th} value of X. The formula for the kernel, $K_h(u)$ is:

$$K_h(u) = h^{-1} * 0.75 * (1 - (u)^2) \text{ for } |u| \le 1, \text{else} \qquad \textbf{(11)}$$
$$K_h(u) = 0$$

Where u = (X-X_i)/h and
h = a scale factor

"u" is the scaled difference between X, the normalized value of 4.5, and that of the normalized values of the explanatory variable, X_i. The kernel determines the shape of the weights. The kernel used in MAM is known as the Epanechnikov kernel. This kernel is of parabolic shape. It is one of several kernels that could be used in an estimator. It was selected because it is considered "optimal" in terms of minimizing certain measures of error. Actually, the choice of a kernel is not as important as is the selection of a bandwidth. The value of the bandwidth, h, is arbitrarily selected as 0.5 in this illustration. In the MAM, the bandwidth is computed as a function of the sample size and the standard deviation of the explanatory variables. Table 3 contains the values of u and of the kernel for X_i.

Table 3. Computed Values of the Scaled Differences From the Normalized Value of 4.5 and of the Kernel

X	Normalized X (X_i/5.5)	U ((4.5/5.5)-X_i)/h	Kernel
1	0.181818	1.272727	0.000000
2	0.363636	0.909091	0.260331
3	0.545454	0.545455	1.053719
4	0.727272	0.181818	1.450413
5	0.909091	-0.181818	1.450413
6	1.090909	-0.545454	1.053719
7	1.272727	-0.909091	0.260331
8	1.454545	-1.272727	0.000000
9	1.636363	-1.636363	0.000000
10	1.818182	-2.000000	0.000000

All the data required by the Nadaraya-Watson estimator has now been computed. Plugging it in and solving yields the nonparametric solution for the function *m* given that *X* is 4.5:

$$m_h(4.5/5.5) = 1.460992$$

In this illustration, the nonparametric estimator yielded a solution closer to the actual value of 1.5 as compared to that of the ordinary least squares estimator, 1.28. Nonparametric regression estimators are more robust in regression analysis problems given uncertainties about the functional form of relationships and given violations in assumptions regarding the least squares residuals.

Database Description

Before the kernel regression version of MAM was developed, macroeconomic analysis of carbon emission restriction policies was conducted outside the NEMS using the full DRI models. While it is still true that a full DRI model simulation is the basis for the final macroeconomic analysis of policy, the kernel regression model provides an approximation of the macroeconomic response <u>during</u> an integrated NEMS run, leading to a more complete equilibrium solution for the energy markets.

In order to run a full DRI model simulation of a policy such as an auctioned carbon permit system 26 energy variables within the DRI model are altered to replicate the NEMS solution. These energy variables include energy prices, energy quantities produced, and energy quantities consumed. The total amount of money collected by the Federal Government through the permit auction is also input to the DRI model. This is the extent of the information provided by NEMS energy models. However, additional assumptions must be made in order to perform the DRI simulation. These assumptions include fiscal policy (what the Federal Government does with the permit revenue), and monetary policy (how the Federal Reserve is assumed to react to changes in inflation and the unemployment rate). With this information, the simulation can be performed and the macroeconomic impact of the policy reported.

To construct the database for the carbon policy kernel regression model, consistent sets of the energy inputs and revenue collections representative of the policy of interest must be provided to run the DRI model. The inputs must be internally consistent because they are jointly determined (price and quantity combinations are determined by the NEMS equilibrium solution). Populating the database with DRI simulation results based on actual NEMS energy inputs leads to more accurate approximations of the macroeconomic impacts during an integrated NEMS run. The input sets are created either by setting a target emission level as the objective in the NEMS solution, or by directly setting the permit price.

NEMS is a complex modeling system that requires several iterations of integrated runs before a converged solution is reached. Preliminary NEMS runs of the scenarios considered in Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity provided the inputs used to construct the carbon policy portion of the kernel regression database.

The solution algorithm of the kernel regression model can be described as a two-stage selection process. The first stage determines the portion of the database to consider when reaching a solution. The restriction is based on several parameters that are set at the time the NEMS run is submitted. The first decision point is whether macroeconomic feedback should be turned on for the integrated NEMS run. Feedback should only be turned on if the current policy under consideration is adequately represented within the database (the current database was constructed to analyze world oil price scenarios and carbon emission restriction policies involving permits or taxes). If feedback is deemed appropriate, the second parameter determines whether the NEMS run represents a change to the world oil price, or a carbon emission restriction policy. For a carbon emission restriction policy, two additional parameters must be provided: the first year of the emissions restriction and the assumed disposition of the carbon revenues (used by the Federal Government to reduce the debt, returned to consumers through a lump-sum reduction in personal income taxes, returned to business through a lump-sum reduction in corporate income taxes, or returned to both consumers and business through a reduction in both the employee and employer shares of social security contributions). Each combination of parameters defines the segment of the database to be considered for the integrated NEMS run.

Once the relevant segment of the database has been determined, the values of the energy prices and quantities, and the carbon revenue are used to reach the kernel solution. Although 27 variables are input to the DRI model when analyzing a carbon emission reduction policy, the kernel regression model uses a subset of twelve of the variables when determining the solution. The variables included in the subset were chosen because they sufficiently identify the appropriate neighborhood for the solution. Appendix A contains a list and description of the twelve input variables.

The selection process for a world oil price scenario is similar, but simpler. The only two parameter settings required before the kernel regression model can be solved are that the current NEMS run should include macro feedback, and that the run is a world oil price scenario. The same twelve variables are then used to determine the kernel regression solution.

MAM Interindustry Submodule

The Interindustry Submodule of the NEMS MAM is a response surface representation of the DRI Input-Output Model for the Personal Computer (PCIO)[23]. The Interindustry Submodule of the NEMS MAM does not generate baseline forecasts of Industrial Gross Output. PCIO is used for this purpose. The role of the Interindustry Submodule is to calculate how Industrial Gross Outputs change when macroeconomic final demands change. Changes to macroeconomic final demands are determined within the National Submodule of MAM.

As described previously in this report, consistency between the National and Interindustry Submodules is critical to ensuring meaningful macroeconomic and interindustry results. The DRI Model on which the response surface Interindustry Submodule is based, DRI's PCIO, is a standard input-output model. DRI's PCIO takes as inputs final demand components from the DRI U.S. Quarterly Model and determines the level of interindustry activity. The MAM National and Interindustry Submodules are joined similarly, with the main difference that <u>changes</u> in interindustry activity are determined by <u>changes</u> in final demand components in MAM.

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[23] The calculations performed by a standard input-output model, of which PCIO is an example, are described in the Alternative Macroeconomic Modeling Approaches section of this report.

This type of input-output model represents a top-down approach to interindustry modeling. Aggregate demand, in the form of the final demand components, is calculated first by the macroeconomic module, and is used in determining the detailed output required of the interindustry sectors to achieve this level of aggregate demand. The disaggregation can be made along several lines which have theoretical appeal: homogeneity of product, homogeneity of process, homogeneity of energy service, etc. From a practical standpoint however, the choice of disaggregation is limited by the availability of data. The PCIO input-output model is disaggregated into 106 output sectors. The output groupings are listed in Table 1. The Industrial Sector Demand Module does not require this level of detail. Therefore, interindustry projections provided to the NEMS system are an aggregation of the PCIO input-output sectors to the level requested by the Industrial Sector Demand Module. Because of the structure of the input-output model, and of input-output modeling in general, it is not necessary to directly link the full DRI-PCIO model with NEMS in order to capture meaningful changes in interindustry activity.

Table 1. Output Groupings within full DRI-PCIO Model

Real Gross Output	SIC Coverage	Number of Output Sectors
Agriculture	01,02,07,08,09	4
Mining	10-14	7
Construction	15,16,17	2
Manufacturing	20-39	69
Transportation	40-42,44-47	7
Communications	48	2
Utilities	49	3
Wholesale Trade	50,51	1
Retail Trade	52-59	2
Finance, Insurance, and Real Estate	60-67	2
Services	70-87,89	5
Government	N/A	2
Note: SIC is Standard Industrial Classification		

The Interindustry Submodule operates in a manner slightly different from a standard input-output model. The ways in which the two differ are fourfold:

1) The exogenous driver for a standard Input-Output model is a matrix of forecasted final demands. For PCIO the matrix consists of 56 final demands forecasted annually through the year 2020. The exogenous driver for the Interindustry Submodule is a matrix of forecasted changes from baseline levels in final demands. For the Interindustry Submodule the matrix consists of changes from baseline levels for 46 final demands forecasted through the year 2020.

2) The A matrix (direct requirements matrix) in the PCIO model is replaced by the α matrix. The α matrix shows the amount by which each industry's gross output changes for a change of $1 in each final demand in the base year (1996) of the Interindustry Submodule.

3) There is no row scalar matrix, nor is there a bridge matrix, in the Interindustry Submodule. Instead a second matrix of coefficients (the β matrix) is included which

describes the way in which the relationships between industrial gross outputs and macroeconomic final demands change over time in the PCIO model. It represents the combined effect of both the changing bridge matrix and the changing row scalars in PCIO.

4) The output from a standard Input-Output model is a matrix of forecasted gross output levels by industry. For PCIO the matrix consists of gross output for 106 industries forecasted annually through the year 2020. The output from the Interindustry Submodule is a matrix of forecasted changes from baseline levels in final demand. For the Interindustry Submodule the matrix consists of changes from baseline levels for 45 industries forecasted through the year 2020. These solution changes from baseline levels are then added to the baseline levels and passed to the NEMS integrating system for use by the energy modules and for report-writing purposes.

The response surface model responds to changes from baseline levels in macroeconomic final demand components and calculates consistent changes in interindustry activity. Each of the equations in the Interindustry Submodule has the same generic specification relating change in interindustry activity *i* to change in final demand *j*:

$$\Delta IO_i = \left(\sum_{j=1}^{46} \left[\alpha_{i,j} + (\beta_{i,j} * time_t)\right] * \Delta FD_j\right) \quad \textbf{(12)}$$

where

- ΔIO_i is the change from baseline level in industrial gross output for sector *i*,
- α_{ij} is the base-year coefficient which relates changes in final demand component *j* to changes in industrial gross output for sector *i*, (*i* not necessarily equal to *j*),
- β_{ij} is the time-dependent coefficient of change for translating changes in final demand component *j* into changes in interindustry activity for sector *i*,
- $time_t$ is an annual time counter which equals 0 in the base year (1996), and
- ΔFD_j is the change from baseline level in final demand component *j*

In order to estimate the two coefficient matrices α and β, the first final demand component in the macroeconomic model was increased 1000 million dollars ($1992) throughout the forecast period of PCIO while holding all other final demands constant. The resulting change from baseline levels of gross output for each of the 106 industries of PCIO was then calculated, and the changes aggregated to the level of industrial detail required for the Interindustry Submodule (45 sectors). The mapping of PCIO sectors to Interindustry Submodule sectors is shown in the following table. This process was repeated for each of the macroeconomic final demand categories of the National Submodule. The result of these controlled simulations of PCIO was 2610 time series of interindustry impacts, each relating change in gross output of a specific industrial sector to change in a particular final demand component.

Each of the 2610 output time series was divided by 1000, the amount by which each macroeconomic final demand was incremented when running the PCIO model, resulting in multipliers relating change in industrial gross output to change in final demand. A linear regression was then performed on each of the multiplier time series, with time as the independent variable. The α_{ij} coefficients represent the amount that sector *i*'s output would change for a unit change in final demand *j*, for the base year of the simulation. Since the PCIO model is not static, time is included in the regressions. The β_{ij} coefficients are designed to capture the effects of both the changing row scalars and the changing bridge matrix within PCIO. A linear time specification was chosen for the initial estimation of the Interindustry Submodule.

Table 3. Mapping of PCIO Sectors to MAM Interindustry Submodule Sectors, p. 1

PCIO Sector	Interindustry Submodule Sector
Other Agricultural Products	Agricultural Production - Crops (SIC 01)
Livestock and Products Forestry and Fishery Products Ag., Forestry, and Fishery Services	Other Agriculture Including Livestock (SIC 02,07-09)
Iron Ore Mining Nonferrous Metals Mining Stone/Clay Mining & Quarrying Chem. and Fertilizer Mineral Mining	Metal & Other Non-metallic Mining (SIC 10,14)
Coal Mining	Coal Mining (SIC 11, 12)
Crude Petroleum Natural Gas	Oil & Gas Mining (SIC 13)
New Construction Maintenance & Repair Construction	Construction (SIC 15-17)
Food & Kindred Products	Food & Kindred Products (SIC 20)
Tobacco Manufactures	Tobacco Products (SIC 21)
Fabric, Yarn & Thread Mills Miscellaneous Textile Goods	Textile Mill Products (SIC 22)
Apparel Misc. Fabricated Textile Products	Apparel & Other Textile Products (SIC 23)
Lumber & Wood Products Wood Containers	Lumber & Wood Products (SIC 24)
Household Furniture Other Furniture & Fixtures	Furniture & Fixtures (SIC 25)

Table 3. Mapping of PCIO Sectors to MAM Interindustry Submodule Sectors, p. 2

Paper Mills, Exc. Building Paper Paper & Allied Products Paperboard Containers & Boxes	Paper & Allied Industries (SIC 26)
Printing & Publishing	Printing & Publishing (SIC 27)
Inorganic & Organic Chemicals	Inorganic Chemicals (SIC 281) -- 29% Organic Chemicals (SIC 286) -- 71%
Plastic Materials & Resins Synthetic Rubber Cellulosic & Noncellulosic Fibers	Plastic Materials & Synthetics (SIC 282)
Fertilizers Agricultural Chemicals, NEC	Agricultural Chemicals (SIC 287)
Miscellaneous Chemical Products Drugs, Cleaning and Toilet Prep. Paints & Allied Products	Other Chemicals & Allied (SIC 28, NEC)
Petroleum Refining	Petroleum Refining (SIC 291)
Misc. Petroleum & Coal Products Paving Mixtures, Asphalt	Asphalt, Coal & Miscellaneous Products (SIC 295,299)
Rubber Products Miscellaneous Plastic Products	Rubber & Miscellaneous Plastic Products (SIC 30)
Leather & Footwear	Leather & Leather Products (SIC 31)
Glass & Glass Products	Glass & Glass Products (SIC 321-323)
Hydraulic Cement	Cement, Hydraulic (SIC 324)
Stone & Clay Products	Other Stone, Clay & Glass (SIC 32, NEC)
Coke Oven Products Blast Furnaces & Basic Steel	Blast Furnace & Basic Steel (SIC 331)
Primary Aluminum	Primary Aluminum (SIC 3334)
Steel Foundries, Heat Treating Primary and Basic Nonferrous Metals	Other Primary Metals (SIC 33, NEC)
Ferrous and Nonferrous Forgings Metal Containers Fabricated Structural Metal Products Screw Machine Products & Fasteners Automotive and Other Stampings Other Fabricated Metal Products	Fabricated Metal Products (SIC 34)

Table 3. Mapping of PCIO Sectors to MAM Interindustry Submodule Sectors, p. 3

Engines & Turbines Farm & Garden Machinery Construction & Mining Machinery Oil Field Machinery Materials Handling Machinery Metalworking Machinery & Equipment Special Industry Machinery General Industrial Machinery Miscellaneous Nonelectrical Machinery Office, Computing & Account. Machinery Service Industry Machinery	Industrial Machinery & Equipment (SIC 35)
Electrical Machinery Household Appliances Electrical Lighting & Wiring Equipment Radio, TV, and Communications Equipment Electronic Comp. & Accessories Misc. Electrical Machinery & Equipment	Electronic & Other Electric Equipment (SIC 36)
Motor Vehicles & Equipment Aircraft & Parts Ship & Boat Building & Repairing Railroad Equipment Miscellaneous Transportation Equipment Ordnance & Accessories	Transportation Equipment (SIC 37)
Instruments & Supplies Optical, Ophthalmic & Photo Equipment	Instruments & Related Products (SIC 38)
Miscellaneous Manufacturing	Miscellaneous Manufacturing Industries (SIC 39)
Railroads & Related Services Passenger Transportation, NEC Motor Freight Water Transport. & Related Services Air Carriers & Related Services Pipelines, Except Natural Gas Transportation Services, NEC	Transportation Services (SIC 40-47)
Communications, Exc. Radio & TV Radio & TV Broadcasting	Communications (SIC 48)
Electric Utilities	Electric Utilities (SIC 491, pt 493)
Gas Utilities	Gas Utilities (SIC 492, pt 493)
Water & Sewer Services	Water & Sewer Services (SIC 494-497, pt 493)

Table 3. Mapping of PCIO Sectors to MAM Interindustry Submodule Sectors, p. 4

Wholesale Trade	Wholesale Trade (SIC 50,51)
Retail Trade Eating & Drinking Places	Retail Trade (SIC 52-59, 739)
Finance & Insurance Real Estate & Rentals	F.I.R.E. (SIC 60-63, 65-66, 153)
Personal Services, Exc. Automotive Business Services Automobile Repair & Service Movies & Amusements Medical, Educational Services, NPO	Services (SIC 70, 73, 75, 76, 78-80, 82-84, 86, 89)
Federal Government Enterprises State & Local Government	Government Enterprises (SIC pt 41, 431)

MAM Employment Submodule

The response surface Employment Submodule characterizes employment changes for inclusion in NEMS. These changes are added to, or subtracted from, the baseline projections provided by the structural employment model to derive new employment levels. The response surface employment equations previously contained in the National Submodule of MAM related changes in employment directly to changes in energy prices from the integrating module of NEMS. The revised response surface Employment Submodule relates changes in employment to changes in gross output from the Interindustry Submodule of MAM. This change makes the model more intuitive -- when an industry's output demand increases, its input usage generally increases as well. Labor is one input to the production process.

The Employment Submodule is constructed similarly to the Interindustry Submodule of MAM. Within MAM <u>changes</u> in employment are determined by <u>changes</u> in gross output. The response surface Employment Submodule is specified as a partial adjustment model. Increasing and decreasing employment is costly for businesses. Firms will not adjust employment to the ultimately desired level immediately when output demand changes, but will wait to see whether the demand change persists. For each sector, the equation for change in employment is:

$$\Delta E_{i,t} = ((\beta_1 + (\beta_2 * time)) * \Delta GO_{i,t}) + (\beta_3 * \Delta E_{i,t-1}) \qquad \textbf{(13)}$$

where:

$\Delta E_{i,t}$	=	change in employment for industry *i* in period *t*, in millions of persons
time	=	a time counter, which equals 1 in 1995
$\Delta GO_{i,t}$	=	change in gross output for industry *i* in period *t*, in millions of \$1992
$\Delta E_{i,t-1}$	=	change in employment for industry *i* in the previous period, in millions of persons

In order to estimate the coefficient matrices β_1, β_2, and β_3, each of the output aggregates contained in the Interindustry Submodule was increased within PCIO by 1 million dollars (\$1992) throughout the forecast period of the employment model while holding all other gross outputs constant. The resulting change from baseline levels of employment as projected by the structural employment model were regressed against the change in gross output and lagged change in employment.

Although only 30 disaggregated employment sectors are reported, the response surface model operates at the Interindustry Submodule level of disaggregation (45 sectors). Except for two employment sectors, each sector's change in employment is related to that sector's change in gross output only. Because of differences between the response surface and structural modeling systems, two of the 45 employment sectors (Agricultural Production -- Crops, and Retail Trade) are each related to two gross output categories. Employment in the Agricultural Production -- Crops sector is based on gross output in both the Agricultural Production -- Crops sector (equation 30) and the Other Agriculture including Livestock sector (equation 31). Employment in the Retail Trade sector is based on gross output in both the Retail Trade sector (equation 43) and the Services sector (equation 45).

The β_1 coefficient, which can be viewed as the base year (or constant) coefficient relating employment change to a 1 million dollar ($1992) output change, is positive for all industries, as would be expected. The purpose for the time counter is to capture the productivity trends contained in the structural employment model. The β_2 coefficient is generally negative, indicating that productivity increases over time for most industries. The β_3 coefficient is generally positive, indicating that most industries do not immediately adjust employment fully to the desired level when output demand changes.

MAM Regional Submodule

The Regional Submodule disaggregates the results of the National and Interindustry Submodules to the nine Census Division level of detail. AEO2001 uses regional shares derived from simulations of the DRI Personal Computer Regional Model designed to be compatible with both the DRI U.S. Quarterly and PCIO models. Regional shares that vary over time for each macroeconomic growth case are included in NEMS for the AEO2001 production runs. These regional shares are developed from simulations of the three full DRI models in integrated mode, then applying the appropriate regional shares to the macroeconomic growth case.

Some limitations to the Regional Submodule exist. Regional variations in capital costs are not generated, and all regions are assumed to react to the same national set of interest rates. Technology change influences total factor productivity, and is captured through the derivation of potential GDP at the national level only. However, the various energy modules within NEMS capture the entry of new technology at the regional level. Last, MAM addresses only national decisions on fiscal policy through the National Submodule. *State* tax policy, such as a changes in state gasoline taxes, is not directly considered.

Appendix A: Model Input and Output Inventory

Introduction

This Appendix describes the input data, parameters, variables, and data calibrations that are currently required for the execution of the National, Interindustry (including the Growth Industry Component of the Interindustry Submodule), Employment, and Regional Submodules of the Macroeconomic Activity Module (MAM). These data provide a detailed representation of drivers required to support macroeconomic activity forecasting in support of MAM. Appendix A also presents the primary outputs generated by MAM, and the MAM filenames required for the generation of NEMS scenarios. As described in the main text of this Volume, the National Submodule of MAM is a kernel regression representation, and the Interindustry and Employment Submodules of MAM are response surface approximations of large, proprietary econometric models developed by Data Resources, Inc./McGraw-Hill (DRI). Accordingly, the DRI modeling variables that are used to implement the kernel regression and response surface approximations are presented in this Appendix, along with the MAM output variables that are ultimately produced.

Table A-1 identifies the controlling MAM input data, including user-specified modeling switches and variable subscripts used in the MAM FORTRAN source code. The user-specified switches presented in Table A-1 enable the modeler to choose between alternative growth path assumptions in the scenario development process.

Table A-2 defines the macroeconomic variables contained within the National Submodule of MAM. All the numbered variables in Table A-2 are both inputs to, as well as outputs from, the National Submodule. The index *i* in Table A-2 indexes the NEMS variable that appears in the *i*th row of the array. The unnumbered variables are calculated outputs from the National Submodule. The DRI Name column in Table A-2 gives the DRI variable names that are used in the full DRI models from which the MAM is developed. The variables which have an entry in the third column are also made available to the other NEMS modules through the MACOUT common block.

Table A-3 defines industrial gross output variables contained within the Interindustry Submodule of MAM. All the variables in Table A-3 are both inputs to, as well as outputs from, the Interindustry Submodule and are also made available to the other NEMS modules through the MACOUT common block.

The Growth Industries Component of the Interindustry Submodule calculates industrial gross output growth rates for the energy sectors (Petroleum Refining, Coal Mining, Oil & Gas Extraction, Electric Utilities, and Gas Utilities) based on physical activity for the appropriate NEMS supply or conversion modules. Table A-4 describes the NEMS variables used to calculate the growth rates for each sector.

Table A-5 defines the employment levels aggregated to the 2-digit SIC category which are passed as solution values to the NEMS common block. The Employment Submodule operates at a more disaggregated level (the same level as the Interindustry Submodule) but the projections are aggregated to provide employment at the 2-digit SIC category level.

The estimated coefficients used by the Interindustry and Employment Submodules of MAM are presented in Table A-6. Table A-6 provides descriptions of each set of coefficients, including the dimensions of each set.

Before computing the National Submodule kernel regression solution, MAM must calculate the input value for the fourteen selection variables, $MCKCOMM_i$. Table A-7 defines the kernel regression selection variables. For each, the DRI model mnemonic is given along with its definition. The final column of Table A-7 lists the NEMS variables which are used to calculate the corresponding DRI selection variable.

Table A-8 identifies the files used by MAM during the NEMS execution process. Table A-8 indicates whether each file is an input or an output file, and describes the general contents of each file.

Table A-9 lists the layout of the MCBASS input file, which is especially important because it is the basis for any MAM run. The NEMS user chooses one of the three macroeconomic growth cases (low, mid, or high) contained in MCBASS to drive the energy market solution. Because the MCBASS file contains no labels, Table A-9 is critical to understanding the order of the inputs. MCBASS is a partitioned dataset , with the entire set of consistent variables listed in Table A-9 provided for each growth case. Each growth case is labeled in the row preceding the variable values. The values contained in the MCBASS file are developed by simulating the four large scale DRI models sequentially in the following order: U.S. Quarterly Model of the Macroeconomy, PCIO, Employment Model, Regional Model. The required variables from each model are extracted to create MCBASS. The third column of Table A-9 indicates the source model for each variable. The variables in the MCBASS file are national in scope, and cover the period from 1990 through 2020, annually. The fifteen variables derived by the Regional Model are national aggregates of regional model results.

Table A-10 provides a listing of the MACOUT common block variables referenced by other NEMS modules. The entries in the first column indicate the variable row number within each MCBASS growth case as in Table A-9. The final column lists the referencing NEMS modules, with a description of the module abbreviations following Table A-10. As indicated in the first column, the final four entries refer to a range of variables. Table A-9 lists the row descriptions within each range.

Table A-1. Controlling MAM Input Data

Input Name	Input Type (filename)	Input Description
EXM	Run-time option (SCEDES)	MAM Model Switch, 1 = on, 0 = off
MNUMYR = 31	System parameter (PARAMETR)	Number of solution years, 1990 - 2020
CURIYR	System parameter (Integrating Module)	Current solution year, index, 1990 = 1
CURITR	System parameter (Integrating Module)	Current solution iteration
MMAC	Run-time option (SCEDES)	Macroeconomic growth scenario: 1 = Low, 2 = Mid, 3 = High
WWOP	Run-time option (SCEDES)	World Oil Price scenario: 1 = Low, 2 = Mid, 3 = High
MACTAX	Run-time option (SCEDES)	Carbon tax scenario: 0 = none (i.e., AEO case), 1 = Deficit Reduction, 2 = Personal Tax Rebate, 3 = Corporate Tax Rebate, 4 = Social Security Tax Rebate
MACTXYR	Run-time option (SCEDES)	First year of carbon tax
MACFDBK	Run-time option (SCEDES)	Macroeconomic feedback lever, 1 = on
MCNMFDVARS = 59	MAM parameter (MACPARMS)	Number of macroeconomic final demand variables
MCNMIND = 35	MAM parameter (MACPARMS)	Number of regionalized interindustry output variables
MCNMSERV = 10	MAM parameter (MACPARMS)	Number of non-regionalized service output variables
MCLHISYR = 1999	MAM parameter (MACPARMS)	Last historical year in the forecast
MCNMMAC = 92	MAM parameter (MACPARMS)	Number of non-regionalized macroeconomic variables in the baseline
MCNMMACREG = 57	MAM parameter (MACPARMS)	Number of regionalized macroeconomic variables in the baseline
MCNUMMNF = 29	MAM parameter (MACPARMS)	Number of manufacturing interindustry variables in the baseline
MCNUMREGS = 11	MAM parameter (MACPARMS)	The nine Census Divisions, a placeholder for California (currently not in use), and the national total of all Census Divisions
MCNMFLTYPE=14	MAM parameter (MACPARMS)	Number of commercial floorspace types, including total
NUMEMPL = 46	MAM parameter (MACPARMS)	Number of Industrial Employment categories
MCBIMPRD9(I), I =1 to 11	MAM parameter (MACPARMS)	Base year (1987) manufacturing gross output by Census Division
OVARS = 119	MAM parameter (MACPARMS)	Number of Kernel Regression output variables
NOBS = 23	MAM parameter (MACPARMS)	Number of years in each Kernel Regression simulation
KSTYR = 1998	MAM parameter (MACPARMS)	First year of Kernel Regression simulations

Table A-2. MAM National Submodule Variable Description

i	DRI Name	MACOUT Common Block Name	Macroeconomic Variable Description
1	CDMV&P92C		Consumption of Motor Vehicles and Parts, billions of chained 96$
2	CDFURN@CMP92C		Consumption of Furniture and Household Equipment, excl Computers, billions of chained 96$
3	CDCMP		Consumption of Furniture and Household Equipment, Computers, billions of nominal $
4	CDO92C		Consumption of Other Durables, billions of chained 96$
5	CNCS92C		Consumption of Clothing and Shoes, billions of chained 96$
6	CNFOOD92C		Consumption of Food, billions of chained 96$
7	CNFUEL92C		Consumption of Fuel Oil and Coal, billions of chained 96$
8	CNGAS92C		Consumption of Gasoline & Oil, billions of chained 96$
9	CNOO92C		Consumption of Other Nondurables, billions of chained 96$
10	CSHOUS92C		Consumption of Housing, billions of chained 96$
11	CSHHOPE92C		Consumption of Electricity, billions of chained 96$
12	CSHHOPG92C		Consumption of Natural Gas, billions of chained 96$
13	CSHHOPO92C		Consumption of Other Household Operation, billions of chained 96$
14	CSTRANS92C		Consumption of Transportation Services, billions of chained 96$
15	CSO92C		Consumption of Other Services, billions of chained 96$
16	CSMED92C		Consumption of Medical Care, billions of chained 96$
17	IPDENRAUTO92C		Investment in Non-Residential Producers' Durable Equipment, Automobiles, billions of chained 96$
18	IPDENRMCOF		Investment in Non-Residential Producers' Durable Equipment, Computers, billions of nominal $
19	IPDENROTHR92C		Investment in Non-Residential Producers' Durable Equipment, Other, billions of chained 96$
20	ICNRB&O92C		Investment in Non-Residential Structures, Buildings and Other, billions of chained 96$
21	ICNRMI&PET92C		Investment in Non-Residential Structures, Mining and Exploration, billions of chained 96$
22	ICNRPU92C		Investment in Non-Residential Structures, Public Utilities, billions of chained 96$
23	IPDER92C		Investment in Residential Producers' Durable Equipment, billions of chained 96$
24	ICR92C		Investment in Residential Structures, billions of chained 96$
25	GFMLCFC92C		National Defense Consumption Expenditures, Consumption of General Government Fixed Capital, billions of chained 96$

26	GFMLCO92C		National Defense Consumption Expenditures, Other, billions of chained 96$
27	GFMLGI92C		National Defense Gross Investment, billions of chained 96$
28	GFML92C	MC_GFML92C [1]	Federal Government Purchases, Defense, billions of chained 96$
29	GFMLWSS@FAC92C		National Defense Consumption Expenditures, Compensation of General Government Employees excl Force-Account, billions of chained 96$
30	GFOCFC92C		Nondefense Consumption Expenditures, Consumption of General Government Fixed Capital, billions of chained 96$
31	GFOCO92C		Nondefense Consumption Expenditures, Other, billions of chained 96$
32	GFOGI92C		Federal Nondefense Gross Investment, billions of chained 96$
33	GSLGIIC92C		State & Local Gross Investment, Structures, billions of chained 96$
34	M92CNIA2AC		Imports, Civilian Aircraft, Engines & Parts, billions of chained 96$
35	GFOWSS@FAC92C		Nondefense Consumption Expenditures, Compensation of General Government Employees excl. Force-Account, billions of chained 96$
36	GFONINV92CCH		Nondefense Consumption Expenditures, Nondurables, CCC Inventory Change, billions of chained 96$
37	GSLCFC92C		State & Local Consumption Expenditures, Consumption of General Government Fixed Capital, billions of chained 96$
38	GSLCO92C		State & Local Consumption Expenditures, Other, billions of chained 96$
39	GSLGIEQP92C		State & Local Gross Investment, Equipment, billions of chained 96$
40	GSLWSS@FAC92C		State & Local Consumption Expenditures, Compensation of General Government Employees excl. Force-Account, billions of chained 96$
41	EX92CNIA0		Exports, Food Goods, Feeds, & Beverages, billions of chained 96$
42	EX92CNIA1		Exports, Industrial Supplies & Materials, billions of chained 96$
43	EX92CNIA2O		Exports, Capital Goods excl. Autos, Aircraft, & Computers, billions of chained 96$
44	EXNIA2BM		Exports, Computers & Peripherals, billions of nominal $
45	EX92CNIA2AC		Exports, Civilian Aircraft, Engines & Parts, billions of chained 96$
46	EX92CNIA3		Exports, Automotive Vehicles, Engines & Parts, billions of chained 96$
47	EX92CNIA4		Exports, Consumer Goods except Automotive, billions of chained 96$
48	EXD&N92C	MC_EXDnN92C [1]	Exports, Goods, billions of chained 96$
49	EXS92C		Exports, Services, billions of chained 96$
50	TYF92C		Receipts of Factor Income, billions of chained 96$
51	M92CNIA0		Imports, Food Goods, Feeds, and Beverages, billions of chained 96$

52	M92CNIA1@PET		Imports, Industrial Supplies & Materials excluding Petroleum, billions of chained 96$
53	M92CNIA100		Imports, Petroleum & Products, billions of chained 96$
54	M92CNIA2O		Imports, Capital Goods excl. Autos, Aircraft, & Computers, billions of chained 96$
55	MNIA2BM		Imports, Computers & Peripherals, billions of nominal $
56	M92CNIA3		Imports, Automotive Vehicles, Engines & Parts, billions of chained 96$
57	M92CNIA4		Imports, Consumer Goods except Automotive, billions of chained 96$
58	MS92C		Imports, Services, billions of chained 96$
59	PAYYF92C		Payments of Factor Income, billions of chained 96$
60	INV92CCH	MC_INV92CCH [1]	Change in Business Inventories, billions of chained 96$
61	GDP92C	MC_GDP92C [1]	Gross Domestic Product, billions of chained 96$
62	GDP		Gross Domestic Product, billions of nominal $
63	C92C	MC_C92C [1]	Personal Consumption Expenditures, Total, billions of chained 96$
64	C		Personal Consumption Expenditures, Total, billions of nominal $
65	I92C	MC_I92C [1]	Gross Private Domestic Investment, billions of chained 96$
66	I		Gross Private Domestic Investment, billions of nominal $
67	IFIXNR92C		Fixed Investment, Nonresidential, billions of chained 96$
68	IFIX92C	MC_IFIX92C [1]	Fixed Investment, Total, billions of chained 96$
69	G92C	MC_G92C [1]	Government Consumption Expenditures & Gross Investment, billions of chained 96$
70	EX92C	MC_EX92C [1]	Exports of Goods & Services, billions of chained 96$
71	M92C	MC_M92C [1]	Imports of Goods & Services, billions of chained 96$
72	GNP92C	MC_GNP92C [1]	Gross National Product, billions of chained 96$
73	PCWGDP	MC_PCWGDP [1]	Chain-Type Price Index, GDP, 1996 = 1.0 (1987 = 1.0 in MACOUT)
74	GDP92CFE		Full Employment Level of Real Gross Domestic Product, billions of chained 96$
75	PCWEX		Chain-Type Price Index, Exports of Goods & Services, 1996 = 1.0
76	PCWM		Chain-Type Price Index, Imports of Goods & Services, 1996 = 1.0
77	RMGBS3NS	MC_RMGBS3NS [1]	Discount Rate on 3-Month U.S. Treasury Bills
		MC_RLRMGBS3NS [1]	Real Discount Rate on 3-Month U.S. Treasury Bills
78	RMMTGCCNS	MC_RMMTGCCNS [1]	Conventional 30-Year Mortgage Commitment Rate
79	RMPUAANS	MC_RMPUAANS [1]	Yield on AA Utility Bonds
		MC_RLRMPUAANS [1]	Real Yield on AA Utility Bonds
80	REALRMGBLUS	MC_REALRMGBLUS [1]	Real Average Yield on 10-Year U.S. Government Bonds, Constant Maturity

81	ECIWSP	MC_ECIWSP [1]	Employment Cost Index, Wages & Salaries, Private Sector, June 1989 = 1.0
82	JULCNF	MC_JULCNF [1]	Unit Labor Costs Index, Non-Farming Business Sector, 1992 = 1.0
83	SQTRCARSIMP	MC_SQTRCARSIMP [1]	Unit Sales of Automobiles, Foreign, millions of units
84	SQTRCARS	MC_SQTRCARS [1]	Unit Sales of Automobiles, Total, millions of units
		MC_SQTRCARSDOM [1]	Unit Sales of Automobiles, Domestic, millions of units
85	SQDTRUCKSL	MC_SQDTRUCKSL [1]	Truck Deliveries, Light Duty, millions of units
86	SQDTRUCKSH&M	MC_SQDTRUCKSH&M [1]	Truck Deliveries, Heavy and Medium Duty, millions of units
87	RUC	MC_RUC [1]	Unemployment Rate, All Civilian Workers
88	WPI	MC_WPI [1]	Producer Price Index, All Commodities, 1982 = 1.0
89	WPI14	MC_WPI14 [1]	Producer Price Index, Transportation Equipment, 1982 = 1.0
90	WPI11	MC_WPI11 [1]	Producer Price Index, Machinery & Equipment, 1982 = 1.0
91	LC	MC_LC [1]	Civilian Labor Force, millions of persons
92	RMFEDFUNDNS		Effective Rate on Federal Funds
93	CPI	MC_CPI [2]	Consumer Price Index (All Urban) - All Items, 1982-84 = 1.0
94	YD92C	MC_YD92C [2]	Disposable Personal Income, billions of chained 96$
95	WSD	MC_WSD [2]	Wage & Salary Disbursements, billions of nominal $
96	YP92C	MC_YP92C [2]	Personal Income, billions of chained 96$
97	SHUMBL	MC_SHUMBL [2]	Mobile Homes Shipments, millions of units
98	HUSTS1	MC_HUSTS1 [2]	Single-Family Housing Starts, Private including Farm, millions of units
99	HUSTS2&	MC_HUSTS2n [2]	Multi-Family Housing Starts, Private including Farm, millions of units
100	KQMH	MC_KQMH [2]	Stock of Mobile Homes, millions of units
101	KQHUSTS1	MC_KQHUSTS1 [2]	Stock of Single-Family Housing, millions of units
102	KQHUSTS2&	MC_KQHUSTS2n [2]	Stock of Multi-Family Housing, millions of units
103	N	MC_N [2]	Population Including Armed Forces Overseas, millions of persons
104	N16&	MC_N16n [2]	Population Aged 16 and Over, millions of persons
105	RWM@SUM	MC_MFGWGRT [2]	Average Annual Manufacturing Wages, nominal $
106	RWNM@SUM	MC_NMFGWGRT [2]	Average Annual Non-Manufacturing Wages, nominal $
		MC_COMMFLSP(1) [2]	Commercial Floor Space, Total, billion square feet
107	KAMUSE@SUM	MC_COMMFLSP(2) [2]	Commercial Floor Space, Amusement, billion square feet
108	KAUTO@SUM	MC_COMMFLSP(3) [2]	Commercial Floor Space, Automobile Sales, billion square feet
109	KDORM@SUM	MC_COMMFLSP(4) [2]	Commercial Floor Space, Dormitories, billion square feet
110	KEDUC@SUM	MC_COMMFLSP(5) [2]	Commercial Floor Space, Education, billion square feet
111	KHEALTH@SUM	MC_COMMFLSP(6) [2]	Commercial Floor Space, Health, billion square feet
112	KHOTEL@SUM	MC_COMMFLSP(7) [2]	Commercial Floor Space, Hotel, billion square feet
113	KMFG@SUM	MC_COMMFLSP(8) [2]	Commercial Floor Space, Manufacturing, billion square feet

114	KMISCNR@SUM	MC_COMMFLSP(9) [2]	Commercial Floor Space, Miscellaneous Non-Residential, billion square feet
115	KOFFICE@SUM	MC_COMMFLSP(10) [2]	Commercial Floor Space, Office, billion square feet
116	KPUB@SUM	MC_COMMFLSP(11) [2]	Commercial Floor Space, Public, billion square feet
117	KREL@SUM	MC_COMMFLSP(12) [2]	Commercial Floor Space, Religion, billion square feet
118	KSTORES@SUM	MC_COMMFLSP(13) [2]	Commercial Floor Space, Stores, billion square feet
119	KWARE@SUM	MC_COMMFLSP(14) [2]	Commercial Floor Space, Warehouse, billion square feet

[1] MACOUT Common Block Variables provided only at the National level

[2] MACOUT Common Block Variables provided at the National and Census Division level

Table A-3. MAM Interindustry Submodule Variable Description

MACOUT Common Block Name	Industrial Gross Output Variable Description (millions of fixed 92$)
MC_MFGO(1) [2]	Food & Kindred Products (SIC 20)
MC_MFGO(2) [2]	Tobacco Products (SIC 21)
MC_MFGO(3) [2]	Textile Mill Products (SIC 22)
MC_MFGO(4) [2]	Apparel & Other Textiles (SIC 23)
MC_MFGO(5) [2]	Lumber & Wood Products (SIC 24)
MC_MFGO(6) [2]	Furniture & Fixtures (SIC 25)
MC_MFGO(7) [2]	Paper & Allied Industries (SIC 26)
MC_MFGO(8) [2]	Printing & Publishing (SIC 27)
MC_MFGO(9) [2]	Inorganic Chemicals (SIC 281)
MC_MFGO(10) [2]	Organic Chemicals (SIC 286)
MC_MFGO(11) [2]	Plastic Materials & Synthetics (SIC 282)
MC_MFGO(12) [2]	Agricultural Chemicals (SIC 287)
MC_MFGO(13) [2]	Other Chemicals & Allied (SIC 28, nec)
MC_MFGO(14) [2]	Petroleum Refining (SIC 291)
MC_MFGO(15) [2]	Asphalt, Coal, & Miscellaneous Products (SIC 295, 299)
MC_MFGO(16) [2]	Rubber & Miscellaneous Plastic Products (SIC 30)
MC_MFGO(17) [2]	Leather & Leather Products (SIC 31)
MC_MFGO(18) [2]	Glass & Glass Products (SIC 321, 322, 323)
MC_MFGO(19) [2]	Cement, Hydraulic (SIC 324)
MC_MFGO(20) [2]	Other Stone, Clay, & Glass Products (SIC 32, nec)
MC_MFGO(21) [2]	Blast Furnace & Basic Steel (SIC 331)
MC_MFGO(22) [2]	Aluminum (SIC 3334, pt 3341, 3353-5, 3363, 3365)
MC_MFGO(23) [2]	Other Primary Metals (SIC 33, nec)
MC_MFGO(24) [2]	Fabricated Metal Products (SIC 34)
MC_MFGO(25) [2]	Industrial Machinery & Equipment (SIC 35)
MC_MFGO(26) [2]	Electronic & Other Electric Equipment (SIC 36)
MC_MFGO(27) [2]	Transportation Equipment (SIC 37)
MC_MFGO(28) [2]	Instruments & Related Products (SIC 38)
MC_MFGO(29) [2]	Miscellaneous Manufacturing Industries (SIC 39)

MC_MFGO(30) [2]	Agricultural Production, Crops (SIC 01)
MC_MFGO(31) [2]	Other Agricultural Production Including Livestock (SIC 02, 07, 08, 09)
MC_MFGO(32) [2]	Coal Mining (SIC 12)
MC_MFGO(33) [2]	Oil & Gas Extraction (SIC 13)
MC_MFGO(34) [2]	Metal & Other Mining (SIC 10, 14)
MC_MFGO(35) [2]	Construction (SIC 15, 16, 17)
MC_MFGO(36) [2]	Chemicals & Allied Products(SIC 28)
MC_MFGO(37) [2]	Petroleum Refining & Related Industries (SIC 29)
MC_MFGO(38) [2]	Stone, Clay, Glass, & Concrete Products (SIC 32)
MC_MFGO(39) [2]	Primary Metal Industries (SIC 33)
MC_NMFGO(1) [1]	Transportation Services (SIC 40, 41, 42, 43, 44, 45, 46, 47)
MC_NMFGO(2) [1]	Communications (SIC 48)
MC_NMFGO(3) [1]	Electric Utilities (SIC 491, part of 493)
MC_NMFGO(4) [1]	Gas Utilities (SIC 492, part of 493)
MC_NMFGO(5) [1]	Water & Sewer Services (SIC 494, 495, 496, 497, part of 493)
MC_NMFGO(6) [1]	Wholesale Trade (SIC 50,51)
MC_NMFGO(7) [1]	Retail Trade (SIC 52, 53, 54, 55, 56, 57, 59, 739)
MC_NMFGO(8) [1]	Finance, Insurance, Real Estate (SIC 60, 61, 62, 63, 65, 66, 153)
MC_NMFGO(9) [1]	Services (SIC 58, 70, 73, 75, 76, 78, 79, 80, 82, 83, 84, 86, 89)
MC_NMFGO(10) [1]	Government Enterprises (SIC part of 41, 431)
MC_NMFGO(11) [1]	Total Services Output (SIC 40 - 99)

[1] MACOUT Common Block Variables provided only at the National level

[2] MACOUT Common Block Variables provided at the National and Census Division level

Table A-4. Interindustry Growth Determined by NEMS Quantities

j	MACOUT Common Block Name	Interindustry Sector Definition	NEMS source
1	MC_MFGO(32)	Coal Mining (SIC 11, 12)	COALOUT Common Block: CQSBB - Total Coal Production
2	MC_MFGO(33)	Oil and Gas Extraction (SIC 13)	PMMOUT Common Block: RFQTDCRD - Total Crude Oil Production RFPQNGL - Total Natural Gas Plant Liquids Production OGPRDNG - Total Dry Natural Gas Production OGPRSUP - Supplemental Natural Gas Production
3	MC_MFGO(14)	Petroleum Refining (SIC 291)	PMMOUT Common Block: RFQPRDT - Total Petroleum Product Supplied PMMRPT Common Block: RFQPRDT - Total Imported Petroleum Products
4	MC_NMFGO(4)	Gas Utilities (SIC 492, part of 493)	PMMOUT Common Block: OGPRDNG - Total Dry Natural Gas Production
5	MC_NMFGO(3)	Electric Utilities (SIC 491, part of 493)	UEFDOUT Common Block: UGNTLNR - Total Electricity Generation

Table A-5. MAM Employment Submodule Variable Description

DRI Variable Name	MACOUT Common Block Name	Variable Description (millions of persons)
EEA	MC_EMPNA(1) [2]	Total Non-Agricultural Employment
EC	MC_EMPNA(2) [2]	Construction (SIC 15-17) Employment
EGF	MC_EMPNA(3) [2]	Federal Government Employment
EFIR	MC_EMPNA(4) [2]	Finance, Insurance, and Real Estate (SIC 60-67)Employment
EMI	MC_EMPNA(5) [2]	Mining (SIC 10-14) Employment
ESV	MC_EMPNA(6) [2]	Services (SIC 70-89) Employment
EGSL	MC_EMPNA(7) [2]	State & Local Government Employment
ER	MC_EMPNA(8) [2]	Transportation, Communications, Public Utilities (SIC 40-49) Employment
ETR	MC_EMPNA(9) [2]	Retail Trade (SIC 52-59) Employment
ETW	MC_EMPNA(10) [2]	Wholesale Trade (SIC 50-51) Employment
E24	MC_EMPNA(11) [2]	Lumber & Wood Products (SIC 24) Employment
E25	MC_EMPNA(12) [2]	Furniture & Fixtures (SIC 25) Employment
E32	MC_EMPNA(13) [2]	Stone, Clay, & Glass (SIC 32) Employment
E33	MC_EMPNA(14) [2]	Primary Metals (SIC 33) Employment
E34	MC_EMPNA(15) [2]	Fabricated Metal Products (SIC 34) Employment
E35	MC_EMPNA(16) [2]	Industrial Machinery and Equipment (SIC 35) Employment
E36	MC_EMPNA(17) [2]	Electronic and other Electrical Equipment (SIC 36) Employment
E37	MC_EMPNA(18) [2]	Transportation Equipment (SIC 37) Employment
E38	MC_EMPNA(19) [2]	Instruments (SIC 38) Employment
E39	MC_EMPNA(20) [2]	Miscellaneous Manufacturing (SIC 39) Employment
E20	MC_EMPNA(21) [2]	Food & Kindred Products (SIC 20) Employment
E21	MC_EMPNA(22) [2]	Tobacco Products (SIC 21) Employment
E22	MC_EMPNA(23) [2]	Textile Mill Products (SIC 22) Employment
E23	MC_EMPNA(24) [2]	Apparel & Other Textile Products (SIC 23) Employment
E26	MC_EMPNA(25) [2]	Paper & Allied Products (SIC 26) Employment
E27	MC_EMPNA(26) [2]	Printing & Publishing (SIC 27) Employment
E28	MC_EMPNA(27) [2]	Chemicals & Allied Products (SIC 28) Employment
E29	MC_EMPNA(28) [2]	Petroleum & CoalProducts (SIC 29) Employment
E30	MC_EMPNA(29) [2]	Rubber & Miscellaneous Plastics Products (SIC 30) Employment
E31	MC_EMPNA(30) [2]	Leather & Leather Products (SIC 31) Employment
EAG	MC_EMPNA(31) [1]	Agricultural (SIC 01, 02, 07-09) Employment

[1] MACOUT Common Block Variables provided only at the National level

[2] MACOUT Common Block Variables provided at the National and Census Division level

Table A-6. Estimated Coefficients used in MAM

Coefficient Name	Coefficient Description
$ECIND_{i,j}$	Base year (1996) coefficients which translate changes in the final demand component j into changes in interindustry gross output for sector i (for i = 1, 2, 3, ... MCNMIND + MCNMSERV and j = 1, 2, 3, ... MCNMFDVARS)
$ECNDCH_{i,j}$	Time-dependent coefficients of change which alter $ECIND_{i,j}$ when translating changes in the final demand component j into changes in interindustry gross output for sector i (for i and j as in ECIND above); t = 1 in 1997
$ECEMP_{ij}$	Predictor coefficients for translating changes in interindustry gross output for sector i and the jth explanatory variable (j=1..3)

Table A-7. MAM Kernel Regression Input Variables

i	DRI Variable	DRI Variable Definition	NEMS source
1	&TXGF	Carbon Tax Revenue	EMISSION Common Block: EMREV(I) for I = 1 to 5 - Emission Revenue by Demand Sector
2	WPI051	Producer Price Index - Coal	AMPBLK Common Block: PCLEL - Coal Price to Electric Generators
3	WPI053	Producer Price Index - Gas Fuels	NGTDMREP Common Block: OGWPRNG - Natural Gas Wellhead Price
4	WPI054	Producer Price Index - Electric Power	AMPBLK Common Block: PELRS - Residential Purchased Electricity Price PELCM - Commercial Purchased Electricity Price PELIN - Industrial Purchased Electricity Price PELTR - Transportation Purchased Electricity Price
5	WPI055	Producer Price Index - Utility Natural Gas	AMPBLK Common Block: PNGRS - Residential Natural Gas Price PNGCM - Commercial Natural Gas Price PNGIN - Industrial Natural Gas Price PNGTR - Transportation Natural Gas Price PNGEL - Natural Gas Price to Electric Generators
6	WPI0561	Producer Price Index - Crude Petroleum	INTOUT Common Block: IT_WOP - World Oil Price
7	WPI057	Producer Price Index - Refined Petroleum Products	AMPBLK Common Block: PTPRS - Residential Total Petroleum Price PDSCM - Commercial Distillate Price PRSCM - Commercial Residual Fuel Price PDSIN - Industrial Distillate Price PRSIN - Industrial Residual Fuel Price PDSTR - Transportation Distillate Price PJFTR - Transportation Jet Fuel Price PMGTR - Transportation Motor Gasoline Price PRSTR - Transportation Residual Fuel Price

8	DTFUELSALLB	Demand for All Fuels - All Sectors	QBLK Common Block: QTPAS - Petroleum Consumption, All Sectors QNGAS - Natural Gas Consumption, All Sectors QGPTR - Natural Gas Pipeline Consumption QLPIN - Lease and Plant Fuel Consumption QCLAS - Coal Consumption, All Sectors QMCIN - Metallurgical Coal Consumption, Industrial QCIIN - Net Coal Coke Imports, Industrial QUREL - Uranium Consumption, Electricity Generation QTRAS - Renewables Consumption, All Sectors QSTRS - Solar Thermal Consumption, Residential QSTCM - Solar Thermal Consumption, Commercial QEIEL - Net Electricity Imports QMETR - Methanol Consumption, Transportation QHYTR - Liquid Hydrogen Consumption, Transportation QTREL - Total Renewables, Electricity Generation QPCEL - Petroleum Coke, Electricity Generation RESDREP Common Block: QGERS - Geothermal Consumption, Residential
9	DENDUSE@COAL	End-Use Demand for Coal	QBLK Common Block: QMCIN - Metallurgical Coal Consumption, Industrial QCLAS - Coal Consumption, All Sectors QCLEL - Coal Consumption, Electricity Generation QCIIN - Net Coal Coke Imports, Industrial
10	DENDUSE@ELC	Electricity Sales to Ultimate Consumers	QBLK Common Block: QELAS - Purchased Electricity, All Sectors

11	DENDUSE@PET	End-Use Demand for Petroleum	QBLK Common Block: QDSAS - Distillate Consumption, All Sectors QDSEL - Distillate Consumption, Electricity Generation QKSAS - Kerosene Consumption, All Sectors QJFTR - Jet Fuel Consumption, Transportation QLGAS - Liquified Petroleum Gases, All Sectors QMGAS - Motor Gasoline Consumption, All Sectors QPFIN - Petrochemical Feedstocks, Industrial QRSAS - Residual Fuel Consumption, All Sectors QRSEL - Residual Fuel Cons., Electricity Generation QOTAS - Other Petroleum Consumption, All Sectors QSGIN - Still Gas Consumption, Industrial QPCIN - Petroleum Coke Consumption, Industrial QASIN - Asphalt and Road Oil Consumption, Industrial
12	DENDUSE@NG	End-Use Demand for Natural Gas	QBLK Common Block: QNGAS - Natural Gas Consumption, All Sectors QGPTR - Natural Gas Pipeline Consumption QLPIN - Lease and Plant Fuel Consumption QNGEL - Natural Gas Consumption, Electricity Gen.
13	WPI05	Producer Price Index - Fuels and Related Products and Power	Calculated from MCKCOMM inputs 2 through 7
14	QENG	Index of Domestic Energy Demand	Calculated from MCKCOMM inputs 9 through 12

Table A-8. MAM Input and Output File Specification

Filename	File Description	Input or Output
MCPARMS	Parameter file	Input
MCECIND	Interindustry submodule coefficient file	Input
MCECEMP	Employment submodule coefficient file	Input
MCBASS(LOW, MID, or HIGH)	Macroeconomic (including Interindustry and Employment) variable file (scenario specific)	Input
MCRGBAS(LOW, MID, or HIGH)	Regional variable file (scenario specific)	Input
MCWPIBAS	Initial values for MCKCOMM variables	Input
MCDRII	Kernel Regression baseline input variable values	Input
MCDRIO	Kernel Regression baseline output variable values	Input
MCPCOFI	Kernel Regression database input variable values for World Oil Price scenarios	Input
MCDRI	Kernel Regression database input variable values for Carbon Tax scenarios, Deficit Reduction mode	Input
MCPTI	Kernel Regression database input variable values for Carbon Tax scenarios, Personal Income Tax Rebate mode	Input
MCCTI	Kernel Regression database input variable values for Carbon Tax scenarios, Corporate Income Tax Rebate mode	Input
MCSSI	Kernel Regression database input variable values for Carbon Tax scenarios, Social Security Tax Rebate mode	Input
MCPCOFO	Kernel Regression database output variable values for World Oil Price scenarios	Input
MCDRO	Kernel Regression database output variable values for Carbon Tax scenarios, Deficit Reduction mode	Input
MCPTO	Kernel Regression database output variable values for Carbon Tax scenarios, Personal Income Tax Rebate mode	Input
MCCTO	Kernel Regression database output variable values for Carbon Tax scenarios, Corporate Income Tax Rebate mode	Input
MCSSO	Kernel Regression database output variable values for Carbon Tax scenarios, Social Security Tax Rebate mode	Input
MCKBASE(LOW, MID, or HIGH)	World Oil Price scenario input variable values for Kernel Regression	Input
MACOUT1	National, Interindustry, Employment, and Regional variable solution results	Output
MACOUT2	National, Interindustry, Employment, and Regional variable baseline values	Output

MACOUT4	Kernel Regression Inputs, Computations, Statistics, and Outputs	Output
MACOUT5	Kernel Regression Inputs, Computations, Statistics, and Outputs	Output

Table A-9. MCBASS Input File Layout

i	DRI Name	DRI Source Model	Variable Description
1	CDMV&P92C	Macroeconomic [1]	Personal Consumption Expenditures, Motor Vehicles and Parts, billions of chained 96$
2	CDFURN@CMP92C	Macroeconomic [1]	Personal Consumption Expenditures, Furniture and Household Equipment, excluding Computers, billions of chained 96$
3	CDCMP	Macroeconomic [1]	Personal Consumption Expenditures, Furniture and Household Equipment, Computers, billions of nominal $
4	CDO92C	Macroeconomic [1]	Personal Consumption Expenditures, Other Durables, billions of chained 96$
5	CNCS92C	Macroeconomic [1]	Personal Consumption Expenditures, Clothing and Shoes, billions of chained 96$
6	CNFOOD92C	Macroeconomic [1]	Personal Consumption Expenditures, Food, billions of chained 96$
7	CNFUEL92C	Macroeconomic [1]	Personal Consumption Expenditures, Fuel Oil and Coal, billions of chained 96$
8	CNGAS92C	Macroeconomic [1]	Personal Consumption Expenditures, Gasoline & Oil, billions of chained 96$
9	CNOO92C	Macroeconomic [1]	Personal Consumption Expenditures, Other Nondurables, billions of chained 96$
10	CSHOUS92C	Macroeconomic [1]	Personal Consumption Expenditures, Housing, billions of chained 96$
11	CSHHOPE92C	Macroeconomic [1]	Personal Consumption Expenditures, Electricity, billions of chained 96$
12	CSHHOPG92C	Macroeconomic [1]	Personal Consumption Expenditures, Natural Gas, billions of chained 96$
13	CSHHOPO92C	Macroeconomic [1]	Personal Consumption Expenditures, Other Household Operation, billions of chained 96$
14	CSTRANS92C	Macroeconomic [1]	Personal Consumption Expenditures, Transportation Services, billions of chained 96$
15	CSO92C	Macroeconomic [1]	Personal Consumption Expenditures, Other Services, billions of chained 96$
16	CSMED92C	Macroeconomic [1]	Personal Consumption Expenditures, Medical Care, billions of chained 96$
17	IPDENRAUTO92C	Macroeconomic [1]	Investment in Non-Residential Producers' Durable Equipment, Automobiles, billions of chained 96$

18	IPDENRMCOF	Macroeconomic [1]	Investment in Non-Residential Producers' Durable Equipment, Computers, billions of nominal $
19	IPDENROTHR92C	Macroeconomic [1]	Investment in Non-Residential Producers' Durable Equipment, Other, billions of chained 96$
20	ICNRB&O92C	Macroeconomic [1]	Investment in Non-Residential Structures, Buildings and Other, billions of chained 96$
21	ICNRMI&PET92C	Macroeconomic [1]	Investment in Non-Residential Structures, Mining and Exploration, billions of chained 96$
22	ICNRPU92C	Macroeconomic [1]	Investment in Non-Residential Structures, Public Utilities, billions of chained 96$
23	IPDER92C	Macroeconomic [1]	Investment in Residential Producers' Durable Equipment, billions of chained 96$
24	ICR92C	Macroeconomic [1]	Investment in Residential Structures, billions of chained 96$
25	GFMLCFC92C	Macroeconomic [1]	National Defense Consumption Expenditures, Consumption of General Government Fixed Capital, billions of chained 96$
26	GFMLCO92C	Macroeconomic [1]	National Defense Consumption Expenditures, Other, billions of chained 96$
27	GFMLGI92C	Macroeconomic [1]	National Defense Gross Investment, billions of chained 96$
28	GFML92C	Macroeconomic [1]	Federal Government Purchases, Defense, billions of chained 96$
29	GFMLWSS@FAC92C	Macroeconomic [1]	National Defense Consumption Expenditures, Compensation of General Government Employees excl. Force-Account, billions of chained 96$
30	GFOCFC92C	Macroeconomic [1]	Nondefense Consumption Expenditures, Consumption of General Government Fixed Capital, billions of chained 96$
31	GFOCO92C	Macroeconomic [1]	Nondefense Consumption Expenditures, Other, billions of chained 96$
32	GFOGI92C	Macroeconomic [1]	Federal Nondefense Gross Investment, billions of chained 96$
33	GSLGIIC92C	Macroeconomic [1]	State & Local Gross Investment, Structures, billions of chained 96$
34	M92CNIA2AC	Macroeconomic [1]	Imports, Civilian Aircraft, Engines & Parts, billions of chained 96$
35	GFOWSS@FAC92C	Macroeconomic [1]	Nondefense Consumption Expenditures, Compensation of General Government Employees excl. Force-Account, billions of chained 96$
36	GFONINV92CCH	Macroeconomic [1]	Nondefense Consumption Expenditures, Nondurables, CCC Inventory Change, billions of chained 96$
37	GSLCFC92C	Macroeconomic [1]	State & Local Consumption Expenditures, Consumption of General Government Fixed Capital, billions of chained 96$
38	GSLCO92C	Macroeconomic [1]	State & Local Consumption Expenditures, Other, billions of chained 96$

39	GSLGIEQP92C	Macroeconomic [1]	State & Local Gross Investment, Equipment, billions of chained 96$
40	GSLWSS@FAC92C	Macroeconomic [1]	State & Local Consumption Expenditures, Compensation of General Government Employees excl. Force-Account, billions of chained 96$
41	EX92CNIA0	Macroeconomic [1]	Exports, Food Goods, Feeds, & Beverages, billions of chained 96$
42	EX92CNIA1	Macroeconomic [1]	Exports, Industrial Supplies & Materials, billions of chained 96$
43	EX92CNIA2O	Macroeconomic [1]	Exports, Capital Goods excl. Autos, Aircraft, & Computers, billions of chained 96$
44	EXNIA2BM	Macroeconomic [1]	Exports, Computers & Peripherals, billions of nominal $
45	EX92CNIA2AC	Macroeconomic [1]	Exports, Civilian Aircraft, Engines & Parts, billions of chained 96$
46	EX92CNIA3	Macroeconomic [1]	Exports, Automotive Vehicles, Engines & Parts, billions of chained 96$
47	EX92CNIA4	Macroeconomic [1]	Exports, Consumer Goods except Automotive, billions of chained 96$
48	EXD&N92C	Macroeconomic [1]	Exports, Goods, billions of chained 96$
49	EXS92C	Macroeconomic [1]	Exports, Services, billions of chained 96$
50	TYF92C	Macroeconomic [1]	Receipts of Factor Income, billions of chained 96$
51	M92CNIA0	Macroeconomic [1]	Imports, Food Goods, Feeds, and Beverages, billions of chained 96$
52	M92CNIA1@PET	Macroeconomic [1]	Imports, Industrial Supplies & Materials excluding Petroleum, billions of chained 96$
53	M92CNIA100	Macroeconomic [1]	Imports, Petroleum & Products, billions of chained 96$
54	M92CNIA2O	Macroeconomic [1]	Imports, Capital Goods excl. Autos, Aircraft, & Computers, billions of chained 96$
55	MNIA2BM	Macroeconomic [1]	Imports, Computers & Peripherals, billions of nominal $
56	M92CNIA3	Macroeconomic [1]	Imports, Automotive Vehicles, Engines & Parts, billions of chained 96$
57	M92CNIA4	Macroeconomic [1]	Imports, Consumer Goods except Automotive, billions of chained 96$
58	MS92C	Macroeconomic [1]	Imports, Services, billions of chained 96$
59	PAYYF92C	Macroeconomic [1]	Payments of Factor Income, billions of chained 96$
60	INV92CCH	Macroeconomic [1]	Change in Business Inventories, billions of chained 96$

61	GDP92C	Macroeconomic[1]	Gross Domestic Product, billions of chained 96$
62	GDP	Macroeconomic[1]	Gross Domestic Product, billions of nominal $
63	C92C	Macroeconomic[1]	Personal Consumption Expenditures, Total, billions of chained 96$
64	C	Macroeconomic[1]	Personal Consumption Expenditures, Total, billions of nominal $
65	I92C	Macroeconomic[1]	Gross Private Domestic Investment, billions of chained 96$
66	I	Macroeconomic[1]	Gross Private Domestic Investment, billions of nominal $
67	IFIXNR92C	Macroeconomic[1]	Fixed Investment, Nonresidential, billions of chained 96$
68	IFIX92C	Macroeconomic[1]	Fixed Investment, Total, billions of chained 96$
69	G92C	Macroeconomic[1]	Government Consumption Expenditures & Gross Investment, billions of chained 96$
70	EX92C	Macroeconomic[1]	Exports of Goods & Services, billions of chained 96$
71	M92C	Macroeconomic[1]	Imports of Goods & Services, billions of chained 96$
72	GNP92C	Macroeconomic[1]	Gross National Product, billions of chained 96$
73	PCWGDP	Macroeconomic[1]	Chain-Type Price Index, GDP, 1996 = 1.0 (1987 = 1.0 in MACOUT)
74	GDP92CFE	Macroeconomic[1]	Full Employment Level of Real Gross Domestic Product, billions of chained 96$
75	PCWEX	Macroeconomic[1]	Chain-Type Price Index, Exports of Goods & Services, 1996 = 1.0
76	PCWM	Macroeconomic[1]	Chain-Type Price Index, Imports of Goods & Services, 1996 = 1.0
77	RMGBS3NS	Macroeconomic[1]	Discount Rate on 3-Month U.S. Treasury Bills
78	RMMTGCCNS	Macroeconomic[1]	Conventional 30-Year Mortgage Commitment Rate
79	RMPUAANS	Macroeconomic[1]	Yield on AA Utility Bonds
80	REALRMGBLUS	Macroeconomic[1]	Real Average Yield on 10-Year U.S. Government Bonds, Constant Maturity
81	ECIWSP	Macroeconomic[1]	Employment Cost Index, Wages & Salaries, Private Sector, June 1989 = 1.0
82	JULCNF	Macroeconomic[1]	Unit Labor Costs Index, Non-Farming Business Sector, 1992 = 1.0
83	SQTRCARSIMP	Macroeconomic[1]	Unit Sales of Automobiles, Foreign, millions of units

84	SQTRCARS	Macroeconomic [1]	Unit Sales of Automobiles, Total, millions of units
85	SQDTRUCKSL	Macroeconomic [1]	Truck Deliveries, Light Duty, millions of units
86	SQDTRUCKSH&M	Macroeconomic [1]	Truck Deliveries, Heavy and Medium Duty, millions of units
87	RUC	Macroeconomic [1]	Unemployment Rate, All Civilian Workers
88	WPI	Macroeconomic [1]	Producer Price Index, All Commodities, 1982 = 1.0
89	WPI14	Macroeconomic [1]	Producer Price Index, Transportation Equipment, 1982 = 1.0
90	WPI11	Macroeconomic [1]	Producer Price Index, Machinery & Equipment, 1982 = 1.0
91	LC	Macroeconomic [1]	Civilian Labor Force, millions of persons
92	RMFEDFUNDNS	Macroeconomic [1]	Effective Rate on Federal Funds
93	CPI	Macroeconomic [1]	Consumer Price Index (All Urban) - All Items, 1982-84 = 1.0
94	YD92C	Macroeconomic [1]	Disposable Personal Income, billions of chained 96$
95	WSD	Macroeconomic [1]	Wage & Salary Disbursements, billions of nominal $
96	YP92C	Macroeconomic [1]	Personal Income, billions of chained 96$
97	SHUMBL	Macroeconomic [1]	Mobile Homes Shipments, millions of units
98	HUSTS1	Macroeconomic [1]	Single-Family Housing Starts, Private including Farm, millions of units
99	HUSTS2&	Macroeconomic [1]	Multi-Family Housing Starts, Private including Farm, millions of units
100	KQMH	Macroeconomic [1]	Stock of Mobile Homes, millions of units
101	KQHUSTS1	Macroeconomic [1]	Stock of Single-Family Housing, millions of units
102	KQHUSTS2&	Macroeconomic [1]	Stock of Multi-Family Housing, millions of units
103	N	Macroeconomic [1]	Population Including Armed Forces Overseas, millions of persons
104	N16&	Macroeconomic [1]	Population Aged 16 and Over, millions of persons
105	RWM@SUM	Regional[4]	Average Annual Manufacturing Wages, nominal $
106	RWNM@SUM	Regional[4]	Average Annual Non-Manufacturing Wages, nominal $
107	KAMUSE@SUM	Regional[4]	Commercial Floor Space, Amusement, billion square feet

108	KAUTO@SUM	Regional[4]	Commercial Floor Space, Automobile Sales, billion square feet
109	KDORM@SUM	Regional[4]	Commercial Floor Space, Dormitories, billion square feet
110	KEDUC@SUM	Regional[4]	Commercial Floor Space, Education, billion square feet
111	KHEALTH@SUM	Regional[4]	Commercial Floor Space, Health, billion square feet
112	KHOTEL@SUM	Regional[4]	Commercial Floor Space, Hotel, billion square feet
113	KMFG@SUM	Regional[4]	Commercial Floor Space, Manufacturing, billion square feet
114	KMISCNR@SUM	Regional[4]	Commercial Floor Space, Miscellaneous Non-Residential, billion square feet
115	KOFFICE@SUM	Regional[4]	Commercial Floor Space, Office, billion square feet
116	KPUB@SUM	Regional[4]	Commercial Floor Space, Public, billion square feet
117	KREL@SUM	Regional[4]	Commercial Floor Space, Religion, billion square feet
118	KSTORES@SUM	Regional[4]	Commercial Floor Space, Stores, billion square feet
119	KWARE@SUM	Regional[4]	Commercial Floor Space, Warehouse, billion square feet
120	EEA	Employment[3]	Total Non-Agricultural, millions of employees
121	EC	Employment[3]	Construction (SIC 15-17), millions of employees
122	EGF	Employment[3]	Federal Government, millions of employees
123	EFIR	Employment[3]	Finance, Insurance, and Real Estate (SIC 60-67), millions of employees
124	EMI	Employment[3]	Mining (SIC 10-14), millions of employees
125	ESV	Employment[3]	Services (SIC 70-89), millions of employees
126	EGSL	Employment[3]	State & Local Government, millions of employees
127	ER	Employment[3]	Transportation, Communications, Public Utilities (SIC 40-49), millions of employees
128	ETR	Employment[3]	Retail Trade (SIC 52-59), millions of employees
129	ETW	Employment[3]	Wholesale Trade (SIC 50-51), millions of employees
130	E24	Employment[3]	Lumber & Wood Products (SIC 24), millions of employees
131	E25	Employment[3]	Furniture & Fixtures (SIC 25), millions of employees
132	E32	Employment[3]	Stone, Clay, & Glass (SIC 32), millions of employees
133	E33	Employment[3]	Primary Metals (SIC 33), millions of employees
134	E34	Employment[3]	Fabricated Metal Products (SIC 34), millions of employees
135	E35	Employment[3]	Industrial Machinery and Equipment (SIC 35), millions of employees
136	E36	Employment[3]	Electronic and other Electrical Equipment (SIC 36), millions of employees
137	E37	Employment[3]	Transportation Equipment (SIC 37), millions of employees
138	E38	Employment[3]	Instruments (SIC 38), millions of employees
139	E39	Employment[3]	Miscellaneous Manufacturing (SIC 39), millions of employees
140	E20	Employment[3]	Food & Kindred Products (SIC 20), millions of employees
141	E21	Employment[3]	Tobacco Products (SIC 21), millions of employees
142	E22	Employment[3]	Textile Mill Products (SIC 22), millions of employees
143	E23	Employment[3]	Apparel & Other Textile Products (SIC 23), millions of employees

144	E26	Employment[3]	Paper & Allied Products (SIC 26), millions of employees
145	E27	Employment[3]	Printing & Publishing (SIC 27), millions of employees
146	E28	Employment[3]	Chemicals & Allied Products (SIC 28), millions of employees
147	E29	Employment[3]	Petroleum & CoalProducts (SIC 29), millions of employees
148	E30	Employment[3]	Rubber & Miscellaneous Plastics Products (SIC 30), millions of employees
149	E31	Employment[3]	Leather & Leather Products (SIC 31), millions of employees
150	Blank row		
151	Gross Output	PCIO[2]	Food & Kindred Products (SIC 20), millions of fixed 92$
152	Gross Output	PCIO[2]	Tobacco Products (SIC 21), millions of fixed 92$
153	Gross Output	PCIO[2]	Textile Mill Products (SIC 22), millions of fixed 92$
154	Gross Output	PCIO[2]	Apparel & Other Textiles (SIC 23), millions of fixed 92$
155	Gross Output	PCIO[2]	Lumber & Wood Products (SIC 24), millions of fixed 92$
156	Gross Output	PCIO[2]	Furniture & Fixtures (SIC 25), millions of fixed 92$
157	Gross Output	PCIO[2]	Paper & Allied Industries (SIC 26), millions of fixed 92$
158	Gross Output	PCIO[2]	Printing & Publishing (SIC 27), millions of fixed 92$
159	Gross Output	PCIO[2]	Inorganic Chemicals (SIC 281), millions of fixed 92$
160	Gross Output	PCIO[2]	Organic Chemicals (SIC 286), millions of fixed 92$
161	Gross Output	PCIO[2]	Plastic Materials & Synthetics (SIC 282), millions of fixed 92$
162	Gross Output	PCIO[2]	Agricultural Chemicals (SIC 287), millions of fixed 92$
163	Gross Output	PCIO[2]	Other Chemicals & Allied (SIC 28, nec), millions of fixed 92$
164	Gross Output	PCIO[2]	Petroleum Refining (SIC 291), millions of fixed 92$
165	Gross Output	PCIO[2]	Asphalt, Coal, & Miscellaneous Products (SIC 295, 299), millions of fixed 92$
166	Gross Output	PCIO[2]	Rubber & Miscellaneous Plastic Products (SIC 30), millions of fixed 92$
167	Gross Output	PCIO[2]	Leather & Leather Products (SIC 31), millions of fixed 92$
168	Gross Output	PCIO[2]	Glass & Glass Products (SIC 321, 322, 323), millions of fixed 92$
169	Gross Output	PCIO[2]	Cement, Hydraulic (SIC 324), millions of fixed 92$
170	Gross Output	PCIO[2]	Other Stone, Clay, & Glass Products (SIC 32, nec), millions of fixed 92$
171	Gross Output	PCIO[2]	Blast Furnace & Basic Steel (SIC 331), millions of fixed 92$
172	Gross Output	PCIO[2]	Aluminum (SIC 3334, pt 3341, 3353-5, 3363, 3365), millions of fixed 92$
173	Gross Output	PCIO[2]	Other Primary Metals (SIC 33, nec), millions of fixed 92$
174	Gross Output	PCIO[2]	Fabricated Metal Products (SIC 34), millions of fixed 92$
175	Gross Output	PCIO[2]	Industrial Machinery & Equipment (SIC 35), millions of fixed 92$
176	Gross Output	PCIO[2]	Electronic & Other Electric Equipment (SIC 36), millions of fixed 92$
177	Gross Output	PCIO[2]	Transportation Equipment (SIC 37), millions of fixed 92$
178	Gross Output	PCIO[2]	Instruments & Related Products (SIC 38), millions of fixed 92$
179	Gross Output	PCIO[2]	Miscellaneous Manufacturing Industries (SIC 39), millions of fixed 92$
180	Gross Output	PCIO[2]	Agricultural Production, Crops (SIC 01), millions of fixed 92$

181	Gross Output	PCIO[2]	Other Agricultural Production Including Livestock (SIC 02, 07, 08, 09), millions of fixed 92$
182	Gross Output	PCIO[2]	Coal Mining (SIC 12), millions of fixed 92$
183	Gross Output	PCIO[2]	Oil & Gas Extraction (SIC 13), millions of fixed 92$
184	Gross Output	PCIO[2]	Metal & Other Mining (SIC 10, 14), millions of fixed 92$
185	Gross Output	PCIO[2]	Construction (SIC 15, 16, 17), millions of fixed 92$
186	Gross Output	PCIO[2]	Transportation Services (SIC 40, 41, 42, 43, 44, 45, 46, 47), millions of fixed 92$
187	Gross Output	PCIO[2]	Communications (SIC 48), millions of fixed 92$
188	Gross Output	PCIO[2]	Electric Utilities (SIC 491, part of 493), millions of fixed 92$
189	Gross Output	PCIO[2]	Gas Utilities (SIC 492, part of 493), millions of fixed 92$
190	Gross Output	PCIO[2]	Water & Sewer Services (SIC 494, 495, 496, 497, part of 493), millions of fixed 92$
191	Gross Output	PCIO[2]	Wholesale Trade (SIC 50,51), millions of fixed 92$
192	Gross Output	PCIO[2]	Retail Trade (SIC 52, 53, 54, 55, 56, 57, 59, 739), millions of fixed 92$
193	Gross Output	PCIO[2]	Finance, Insurance, Real Estate (SIC 60, 61, 62, 63, 65, 66, 153), millions of fixed 92$
194	Gross Output	PCIO[2]	Services (SIC 58, 70, 73, 75, 76, 78, 79, 80, 82, 83, 84, 86, 89), millions of fixed 92$
195	Gross Output	PCIO[2]	Government Enterprises (SIC part of 41, 431), millions of fixed 92$
196	Blank row		
197	Employment	Employment[3]	Food & Kindred Products (SIC 20), millions of employees
198	Employment	Employment[3]	Tobacco Products (SIC 21), millions of employees
199	Employment	Employment[3]	Textile Mill Products (SIC 22), millions of employees
200	Employment	Employment[3]	Apparel & Other Textiles (SIC 23), millions of employees
201	Employment	Employment[3]	Lumber & Wood Products (SIC 24), millions of employees
202	Employment	Employment[3]	Furniture & Fixtures (SIC 25), millions of employees
203	Employment	Employment[3]	Paper & Allied Industries (SIC 26), millions of employees
204	Employment	Employment[3]	Printing & Publishing (SIC 27), millions of employees
205	Employment	Employment[3]	Inorganic Chemicals (SIC 281), millions of employees
206	Employment	Employment[3]	Organic Chemicals (SIC 286), millions of employees
207	Employment	Employment[3]	Plastic Materials & Synthetics (SIC 282), millions of employees
208	Employment	Employment[3]	Agricultural Chemicals (SIC 287), millions of employees
209	Employment	Employment[3]	Other Chemicals & Allied (SIC 28, nec), millions of employees
210	Employment	Employment[3]	Petroleum Refining (SIC 291), millions of employees
211	Employment	Employment[3]	Asphalt, Coal, & Miscellaneous Products (SIC 295, 299), millions of employees
212	Employment	Employment[3]	Rubber & Miscellaneous Plastic Products (SIC 30), millions of employees

213	Employment	Employment[3]	Leather & Leather Products (SIC 31), millions of employees
214	Employment	Employment[3]	Glass & Glass Products (SIC 321, 322, 323), millions of employees
215	Employment	Employment[3]	Cement, Hydraulic (SIC 324), millions of employees
216	Employment	Employment[3]	Other Stone, Clay, & Glass Products (SIC 32, nec), millions of employees
217	Employment	Employment[3]	Blast Furnace & Basic Steel (SIC 331), millions of employees
218	Employment	Employment[3]	Aluminum (SIC 3334, pt 3341, 3353-5, 3363, 3365), millions of employees
219	Employment	Employment[3]	Other Primary Metals (SIC 33, nec), millions of employees
220	Employment	Employment[3]	Fabricated Metal Products (SIC 34), millions of employees
221	Employment	Employment[3]	Industrial Machinery & Equipment (SIC 35), millions of employees
222	Employment	Employment[3]	Electronic & Other Electric Equipment (SIC 36), millions of employees
223	Employment	Employment[3]	Transportation Equipment (SIC 37), millions of employees
224	Employment	Employment[3]	Instruments & Related Products (SIC 38), millions of employees
225	Employment	Employment[3]	Miscellaneous Manufacturing Industries (SIC 39), millions of employees
226	Employment	Employment[3]	Agricultural Production, Crops (SIC 01), millions of employees
227	Employment	Employment[3]	Other Agricultural Production Including Livestock (SIC 02, 07, 08, 09), millions of employees
228	Employment	Employment[3]	Coal Mining (SIC 12), millions of employees
229	Employment	Employment[3]	Oil & Gas Extraction (SIC 13), millions of employees
230	Employment	Employment[3]	Metal & Other Mining (SIC 10, 14), millions of employees
231	Employment	Employment[3]	Construction (SIC 15, 16, 17), millions of employees
232	Employment	Employment[3]	Transportation Services (SIC 40, 41, 42, 43, 44, 45, 46, 47), millions of employees
233	Employment	Employment[3]	Communications (SIC 48), millions of employees
234	Employment	Employment[3]	Electric Utilities (SIC 491, part of 493), millions of employees
235	Employment	Employment[3]	Gas Utilities (SIC 492, part of 493), millions of employees
236	Employment	Employment[3]	Water & Sewer Services (SIC 494, 495, 496, 497, part of 493), millions of employees
237	Employment	Employment[3]	Wholesale Trade (SIC 50,51), millions of employees
238	Employment	Employment[3]	Retail Trade (SIC 52, 53, 54, 55, 56, 57, 59, 739), millions of employees
239	Employment	Employment[3]	Finance, Insurance, Real Estate (SIC 60, 61, 62, 63, 65, 66, 153), millions of employees
240	Employment	Employment[3]	Services (SIC 58, 70, 73, 75, 76, 78, 79, 80, 82, 83, 84, 86, 89), millions of employees
241	Employment	Employment[3]	Federal Government, millions of employees
242	Employment	Employment[3]	State & Local Government, millions of employees

[1] Macroeconomic: DRI U.S. Quarterly Macroeconomic Model

[2] PCIO: DRI Input-Output Model for the Personal Computer

[3] Employment: DRI Econometric Model of Employment by Industry

[4] Regional: DRI Regional Model for the Personal Computer

Table A-10. MAM Variables Used by Other NEMS Modules

MCBASS Row Number	DRI Name	MACOUT Common Block Name	Macroeconomic Variable Description	Referencing NEMS Module
28	GFML92C	MC_GFML92C	Federal Government Purchases, Defense, billions of chained 96$	TRAN
48	EXD&N92C	MC_EXDnN92C	Exports, Goods, billions of chained 96$	TRAN
61	GDP92C	MC_GDP92C	Gross Domestic Product, billions of chained 96$	RENEW TRAN
70	EX92C	MC_EX92C	Exports of Goods & Services, billions of chained 96$	TRAN
71	M92C	MC_M92C	Imports of Goods & Services, billions of chained 96$	TRAN
72	GNP92C	MC_GNP92C	Gross National Product, billions of chained 96$	TRAN
73	PCWGDP	MC_PCWGDP	Chain-Type Price Index, GDP, 1996 = 1.0 (1987 = 1.0 in MACOUT)	COMM EPM IND NGHIST NGPTM NGTDM REFETH REFINE RESD TRAN UEFP ULDSM WELLAK WELLEOR WELLOFF
77	RMGBS3NS	MC_RMGBS3NS	Discount Rate on 3-Month U.S. Treasury Bills	UEFP
79	RMPUAANS	MC_RMPUAANS	Yield on AA Utility Bonds	NGPTM NGTDM UEFP
		MC_RLRMPUAANS	Real Yield on AA Utility Bonds	COALCPS WELLOGS
80	REALRMGBLUS	MC_REALRMGBLUS	Real Average Yield on 10-Year U.S. Government Bonds, Constant Maturity	COMM NGTDM
81	ECIWSP	MC_ECIWSP	Employment Cost Index, Wages & Salaries, Private Sector, June 1989 = 1.0	NGTDM UEFP
84	SQTRCARS	MC_SQTRCARS	Unit Sales of Automobiles, Total, millions of units	TRAN
85	SQDTRUCKSL	MC_SQDTRUCKSL	Truck Deliveries, Light Duty, millions of units	TRAN
88	WPI	MC_WPI	Producer Price Index, All Commodities, 1982 = 1.0	UEFP

90	WPI11	MC_WPI11	Producer Price Index, Machinery & Equipment, 1982 = 1.0	UEFP
93	CPI	MC_CPI	Consumer Price Index (All Urban) - All Items, 1982-84 = 1.0	NGTDM TRAN
94	YD92C	MC_YD92C	Disposable Personal Income, billions of chained 96$	COMM HEM TRAN
97	SHUMBL	MC_SHUMBL	Mobile Homes Shipments, millions of units	RESD
98	HUSTS1	MC_HUSTS1	Single-Family Housing Starts, Private including Farm, millions of units	RESD
99	HUSTS2&	MC_HUSTS2n	Multi-Family Housing Starts, Private including Farm, millions of units	RESD
103	N	MC_N	Population Including Armed Forces Overseas, millions of persons	COALCPS COMM RESD TRAN TRANFRT
104	N16&	MC_N16n	Population Aged 16 and Over, millions of persons	RESD TRAN
106	RWNM@SUM	MC_NMFGWGRT	Average Annual Non-Manufacturing Wages, nominal $	COALCPS
107-119	Commercial Floorspace	MC_COMMFLSP	Commercial Floor Space by Type of Building, billion square feet	COMM
151-179	Gross Output	MC_MFGO	Gross Output by Manufacturing (SIC 20-39) Sector, millions of fixed 92$	IND TRAN TRANFRT
180-185	Gross Output	MC_NMFGO	Gross Output by Non-Manufacturing (Agriculture, Mining, Construction) Sector, millions of fixed 92$	TRAN TRANFRT
197-231	Employment	MC_EMPNA	Employment by Industrial (SIC 20-39, Agriculture, Mining, Construction) Sector, millions of employees	IND

NEMS Module Descriptions:

COALCPS	Coal Production Module
COMM	Commercial Sector Demand Module
EPM	Future Emission Policy Module
HEM	Household Expenditure Model
IND	Industrial Sector Demand Module
NGHIST	Natural Gas Interstate Transmission Module Historical Processing Code
NGPTM	Natural Gas Transmission & Distribution Tariff Module
NGTDM	Natural Gas Transmission & Distribution Module

REFETH	Ethanol Code - Separating for Petroleum Marketing Module
REFINE	Refinery (Petroleum Marketing) Module
RENEW	Renewables Module
RESD	Residential Sector Demand Module
TRAN	Transportation Sector Demand Module
TRANFRT	Freight Portion of Transportation Module
UEFP	Electricity Market Module Financial Planning Routines
ULDSM	Electricity Market Module Demand Side Management Routines
WELLAK	Oil & Gas Production, Alaskas
WELLEOR	Oil & Gas Production, Enhanced Oil Recovery
WELLOFF	Oil & Gas Production, Offshore
WELLOGS	Oil & Gas Production, Main Module

Appendix B. Mathematical Description

Introduction

Appendix B provides a mathematical description of equations, transformations, and other computations for the National, Interindustry (including the Growth Industry Component of the Interindustry Submodule), Employment, and Regional Submodules of the MAM used to generate the AEO2001 production runs of the NEMS system.

The National Submodule

The National Submodule of the MAM is a kernel regression representation of the DRI U.S. Quarterly Macroeconomic Model and is used in the AEO2001 production runs of NEMS to provide each of the energy supply, demand, and conversion submodules with key macroeconomic variable forecasts.

Before the 1999 Annual Energy Outlook, the response surface model representation of Standard and Poor's DRI US model was replaced in the Macroeconomic Activity Module with a nonparametric estimation technique known as kernel regression. Kernel estimators are commonly used for nonparametric estimation of regression functions. Consider the following model

$$Y_i = m(x_i) + e_i \qquad \textbf{(B-1)}$$

The Y_i's are observed random variables, the x_i's are known constants and the e_i's are independent random variables with mean zero and constant variance. In the

Macroeconomic Activity Module, the Y_i's are the one hundred and nineteen national and regional macroeconomic concepts that the module forecasts. The x_i's are fourteen inputs from the National Energy Modeling System. These inputs are tax collections and energy prices and quantities.

Kernel regression estimates the unknown function *m* without assuming more about the function than certain smoothness conditions. Using a kernel estimator requires the selection of a kernel function and a bandwidth. The kernel function determines the shape of a sequence of weights applied to data within a neighborhood whose size is determined by the bandwidth. The Nadaraya-Watson estimator is used as the kernel estimator in the Macroeconomic Activity Module

$$m(x) = \frac{\sum K(u_i)Y_i}{\sum K(u_i)} \qquad \textbf{(B-2)}$$

The kernel function is Epanechnikov

$$K(u) = (1 - u^2) \qquad \textbf{(B-3)}$$

The bandwidth in the Macroeconomic Activity Module is not fixed but is a function of the number of observations and variance. If the resulting neighborhood contains no elements, a fixed factor is applied. This adjustment is repeated until at least one element appears in the neighborhood or until a predetermined threshold is exceeded. If the threshold is exceeded, the kernel regression writes an error and terminates.

Before calling the National Submodule, MAM calculates the kernel regression input variables, MCKCOMM, from the NEMS variables described in Table A-6 of Appendix A of this report. To estimate the unknown function *m* for the AEO 2000, the kernel regression relies upon databases containing twenty-two simulations of the DRI U.S. Quarterly Macroeconomic Model. The simulations represent different assumptions about the path of the real average refiners' acquisition price of crude oil. The databases are linked so that the input variables (i.e., tax collections and energy prices and quantities) from each simulation are associated with the respective output variables (i.e., macroeconomic concepts.).

The Interindustry Submodule

The Interindustry Submodule of MAM is a response surface representation of the DRI-PCIO model which responds to changes from baseline levels in macroeconomic final demand components from the National Submodule and calculates consistent changes in industrial gross output. If the current solution year, CURIYR, is greater than the last historical year, MCLHISYR, the Interindustry Submodule calculates the change in industrial gross output, EDIND, based on the changes in the macroeconomic final demands, ESMAC - EBMAC, from the National Submodule:

$$EDIND_{i,\,CURIYR} = \sum_{j=1}^{MCNMFDVARS} \begin{aligned}&((ECIND_{i,\,j} + ECNDCH_{i,\,j} \\ &*(CURIYR - 7)) \\ &*(ESMAC_{j,\,CURIYR} - EBMAC_{j,\,CURIYR})\end{aligned} \qquad \textbf{(B-4)}$$

The solution levels of industrial gross output, ESIND, are then calculated by adding the computed changes, EDIND, to the baseline levels, EBIND:

$$ESIND_{MNUMCR,\,i,\,CURIYR} = EBIND_{i,\,CURIYR} + EDIND_{i,\,CURIYR} \qquad \textbf{(B-5)}$$

The Growth Industry Submodule

The description in the preceding section applies to all the industrial gross output sectors except the energy supply sectors. Industrial Gross Output for the Petroleum Refining, Coal Mining, Oil and Gas Extraction, Electric Utilities, and Gas Utilities sectors are all benchmarked in DRI historical years, but change at rates determined by selected NEMS energy supply and conversion modules. Figure 4 in Chapter 3 of the main text of this report illustrates the flow of the Growth Industry Submodule. Table A-7 also describes the NEMS variables used to calculate MCINDGROW, the growth rate for each energy supply sector. The solution output, ESIND, for these sectors is calculated as:

$$ESIND_{i,\,CURIYR} = (MACINDGROW_{j,\,CURIYR} + 1.0) * ESIND_{i,\,(CURIYR\,-\,1)} \quad \textbf{(B-6)}$$

The Employment Submodule

The Employment Submodule is a response surface version of the DRI Econometric Model of Employment by Industry. The Employment Submodule calculates the employment impacts of altered energy market conditions based on the following causal relationships. When energy prices change, the level and composition of macroeconomic final demands are affected. In turn, the level and composition of interindustry gross outputs required to satisfy the new final demands are changed. Finally, faced with new demands for their products, industries will adjust the number of workers employed. The response surface Employment Submodule represents this last link in the chain.

The Employment Submodule is constructed similarly to the Interindustry Submodule of MAM. Within MAM <u>changes</u> in employment are determined by <u>changes</u> in gross output. The response surface Employment Submodule is specified as a partial adjustment model. Increasing and decreasing employment is costly for businesses. Firms will not adjust employment to the ultimately desired level immediately when output demand changes, but will wait to see whether the demand change persists. For each sector, the equation for change in employment is:

$$EDEMP_{EMPIND,\,CURIYR} = ((ECEMP_{EMPIND,1}) + (ECEMP_{EMPIND,2}) \\ *(CURIYR - 7) * EDIND_{GOIND,\,CURIYR} \\ +ECEMP_{EMPIND,3} * EDEMP_{EMPIND,\,CURIYR-1} \quad \text{(B-7)}$$

The solution levels of employment, ESEMP, are then calculated by adding the computed changes, EDEMP, to the baseline levels, EBEMP:

$$ESEMP_{11,\,GOIND,\,CURIYR} = EDEMP_{EMPIND,\,CURIYR} \\ +EBEMP_{GOIND,\,CURIYR} \quad \text{(B-8)}$$

The Regional Submodule

The Regional Submodule of the MAM apportions the national totals computed in the National, Interindustry, and Employment Submodules between the nine Census Divisions. The first step is to calculate the national aggregates by looping through the EBREG regional levels contained in MCRGBAS:

$$EBREGSUM_{i,\,CURIYR} = EBREGSUM_{i,\,CURIYR} \\ +EBREG_{i,\,r,\,CURIYR} \quad \text{(B-9)}$$

Next, regional shares are calculated:

$$REGSHRS_{r,\,i,\,CURIYR} = EBREG_{i,\,r,\,CURIYR} \\ /EBREGSUM_{i,\,CURIYR} \quad \text{(B-10)}$$

The resulting shares are applied to the National Submodule (including Employment) values to arrive at the regional levels:

$$ESMACREG_{r,\,i,\,CURIYR} = ESMACREG_{11,\,i,\,CURIYR} \\ *REGSHRS_{r,\,i,\,CURIYR} \quad \text{(B-11)}$$

and to the Interindustry Submodule values to arrive at the regional levels:

$$ESIND_{r,\ j,\ CURIYR} = ESIND_{11,\ j,\ CURIYR} \\ REGSHRS_{r,\ i,\ CURIYR} \qquad \textbf{(B-12)}$$

Appendix C. Bibliography

Introduction

This Appendix provides a bibliography of sources from the literature used in the theoretical and analytical design, development, implementation, and evaluation of MAM. The references supplied here are supplemented by additional detail including page citations, in the body of this report.

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Appendix D. Model Abstract

Model Name:

Macroeconomic Activity Module of the National Energy Modeling System

Model Acronym:

MAM

Description:

MAM is comprised of four Submodules: National, Interindustry, Employment, and Regional. The National Submodule is a kernel regression approximation of the proprietary U.S. Quarterly Macroeconomic Model developed by Data Resources/McGraw-Hill, Inc. (DRI). The U.S. Quarterly Model is a 1,200 equation econometric specification that forecasts macroeconomic driver variables at the national level of detail.

The Interindustry Submodule is a response surface approximation of the DRI Personal Computer Input-Output (PCIO) Model. The DRI PCIO Model is a detailed input-output representation of interindustry linkages that works in tandem with the full DRI U.S. Quarterly Model.

The Employment Submodule is a response surface approximation of the DRI Econometric Model of Employment by Industry. The DRI Econometric Model of Employment by Industry, on which the response surface Employment Submodule is based, uses interindustry gross output from DRI's Personal Computer Input-Output (PCIO) Model as its major input when determining employment.

The Regional Submodule consists of a set of shares at the nine Census Division level of detail developed from simulations of DRI's U.S. Quarterly Macroeconomic Model, PCIO

Model, Employment Model, and Regional Model. The regional shares included as the Regional Submodule of MAM are used to disaggregate the national results generated by the National, Interindustry, and Employment Submodules of MAM to the nine Census Division level of detail.

Purpose of the Model:

MAM links the National Energy Modeling System (NEMS) to the rest of the economy by providing industrial sector activity and macroeconomic inputs to the energy modules of NEMS. Macroeconomic variables such as GDP, disposable income, aggregate prices, interest rates, and employment drive energy demands and are important determinants of energy prices and quantities. Conversely, changes in energy supplies and prices impact GDP, prices, interest rates, and other macroeconomic variables. MAM responds to changes in energy supplies and prices to generate forecasts of approximately 200 macroeconomic variables for use in various energy modules within NEMS.

Most Recent Model Update:

September 2000

Part of Another Model?

National Energy Modeling System (NEMS).

Model Interfaces:

MAM provides sectoral macroeconomic driver variables including housing starts, commercial floorspace, industrial gross output, light duty vehicle sales, and disposable income projections to the NEMS Residential Sector, Commercial Sector, Industrial Sector, and Transportation Sector Demand Modules. MAM provides financial indicators such as aggregate prices and interest rates to both the demand and supply modules of NEMS.

Official Model Representative:

Ron Earley, Economist
Office of Integrated Analysis and Forecasting
International Economic and Greenhouse Gases Division
(202) 586-1398

Documentation:

Model Documentation Report: Macroeconomic Activity Module (MAM) of the National Energy Modeling System, December 2000.

Energy System Described:

Domestic macroeconomic sector.

Coverage:

- Geographic: Nine Census Divisions.
- Time Unit/Frequency: Annual, 1990 through 2020
- Products: Forecasts of domestic macroeconomic driver variables, at the national, interindustry, and nine Census Division levels of detail.
- Economic Sectors: National macroeconomic activity.

Modeling Features:

- Model Structure: MAM is composed of four Submodules: National, Interindustry, Employment, and Regional. The four Submodules are executed sequentially in the order presented, and subsequent Submodules build upon the results of previously-executed Submodules.

- Modeling Techniques: The National Submodule is a kernel regression representation and the Interindustry and Employment Submodules of MAM are econometric response surface representations of large proprietary econometric models. The Regional Submodule of MAM is composed of shares developed from simulations of large econometric macroeconomic, interindustry, employment, and regional models.

- Special Features: None.

Non-DOE Input Sources:

DRI Input data from the DRI U. S. Quarterly Macroeconomic Model, the DRI PCIO Model, the DRI Employment Model, and the DRI Regional Model.

DOE Input Sources:

MAM relies upon the DRI Input data to generate the baseline growth path. Alternative growth paths are developed based on alternative economic driver variable growth path assumptions. DOE data is not used to develop the MAM.

Independent Expert Reviews Conducted:

None.

Status of Evaluation Efforts by Sponsor:

None.

Appendix E. Kernel Regression Database and Pseudo Data Development

Introduction

Appendix E describes the development of the database used by the Kernel Regression National Submodule of MAM and the pseudo data used to estimate the coefficients of the Interindustry and Employment Submodules of MAM.

Kernel Regression Database

The success of the kernel regression approach to approximating a larger model is directly related to the content of the database. The simulations which make up the database must be similar along the important dimensions of input variation for the algorithm to calculate outputs which mimic the larger model's results. The AEO world oil price portion of the kernel regression database contains simulation results for twenty-two alternative world oil price paths, ranging from a 50% reduction to a 100% increase relative to the baseline path. The price paths begin to diverge in 1999. This database easily covers the range of oil prices for the Low, Reference, and High world oil price scenarios of AEO2001.

Although the DRI model includes an equation for exchange rates, the simulations which make up the database held the exchange rate at baseline levels. This setting forces a one-for-one pass through of changes in domestic interest rates on foreign interest rates. This procedure was adopted because the MAM is primarily a national model.

Interindustry Submodule Pseudo Data

In order to estimate the coefficient matrices α and β, the first final demand component in the macroeconomic model was increased 1 billion dollars (1992$) throughout the forecast period of PCIO while holding all other final demands constant. The resulting change from baseline levels of gross output for each of the 110 industries was then calculated, and the changes aggregated to the level of industrial detail required for the Interindustry Submodule (45 sectors). The mapping of PCIO sectors to Interindustry Submodule sectors is shown in Table 3 in the main text of this report. This process was repeated for each of the macroeconomic final demand categories of the National Submodule. The result of these controlled simulations of PCIO was 2610 time series of interindustry impacts, each relating change in gross output of a specific industrial sector to change in a particular final demand component.

Each of the 2610 gross output time series was divided by 1000 because the National Submodule final demands are in billions of dollars, while the Interindustry Submodule gross outputs are in millions of dollars. A linear regression was then performed on each of the resulting multiplier time series, with time as the independent variable. The α_{ij} coefficients represent the amount that sector i's output would change for a unit change in final demand j, for the base year of the simulation (1996). Because the PCIO model is not static, time is included in the regressions. The β_{ij} coefficients are designed to capture the effects of both the changing row scalars and the changing bridge matrices within PCIO.

Employment Submodule Pseudo Data

In order to estimate the coefficient matrices, each of the output aggregates contained in the Interindustry Submodule was increased within PCIO by 1 million dollars (1992$) throughout the forecast period of the employment model while holding all other gross outputs constant. The resulting change from baseline levels of employment as projected by the structural employment model were regressed against the change in gross output and the lagged change in employment.

Although only 30 disaggregated employment sectors are reported, the response surface model operates at the Interindustry Submodule level of disaggregation (45 sectors). Except for two employment sectors, each sector's change in employment is related to that sector's change in gross output only. Because of differences between the response surface and structural modeling systems, two of the 45 employment sectors (Agricultural Production – Crops, and Retail Trade) are each related to two gross output categories. Employment in the Agricultural Production – Crops sector is based on gross output in both the Agricultural Production – Crops sector and the Other Agriculture including Livestock sector. Employment in the Retail Trade sector is based on gross output in both the Retail Trade sector and the Services sector.

The β_1 coefficient, which can be viewed as the base year (or constant) coefficient relating employment change to a 1 million dollar (1992$) gross output change, is positive for all industries, as would be expected. The purpose for the time counter is to capture the productivity trends contained in the structural employment model. The β_2 coefficient is generally negative, indicating that productivity increases over time for most industries. The β_3 coefficient is generally positive, indicating that most industries do not immediately adjust employment fully to the desired level when output demand changes.

Regional Share Estimates

As discussed previously, regional share estimates were developed by simulating the full scale DRI models. The shares are used in the NEMS MAM to disaggregate the results of the National, Interindustry, and Employment Submodules to the Census Division level of detail for those variables provided on a regional basis.

Supporting Data Availability

The kernel regression database of the National Submodule, the regression coefficients and related statistics for the Interindustry and Employment Submodules, and the regional share estimates used by the Regional Submodule are all available in electronic form from the Model Contact identified in Chapter 1 of the main text of this report.