America's New Energy Future:

The Unconventional Oil and Gas Revolution and the US Economy

Volume 3: A Manufacturing Renaissance

Appendix C. Economic Contribution Assessment – Methodology and Model Documentation

Prepared by:

IHS Inc.
1150 Connecticut Avenue NW, Suite 401
Washington, D.C. 20036

September 2013

About IHS (www.ihs.com)

IHS (NYSE: IHS) is the leading source of information, insight and analytics in critical areas that shape today's business landscape. Businesses and governments in more than 165 countries around the globe rely on the comprehensive content, expert independent analysis and flexible delivery methods of IHS to make high-impact decisions and develop strategies with speed and confidence. IHS has been in business since 1959 and became a publicly traded company on the New York Stock Exchange in 2005. Headquartered in Englewood, Colorado, USA, IHS is committed to sustainable, profitable growth and employs approximately 8,000 people in 31 countries around the world.

For more information, contact:

Richard F. Fullenbaum
Vice President, Public Sector Consulting, IHS
richard.fullenbaum@ihs.com

John W. Larson
Vice President, Public Sector Consulting, IHS
john.larson@ihs.com

For press information, contact:

Jim Dorsey
Senior Manager Media Relations, IHS
jim.dorsey@ihs.com

Jeff Marn
Senior Manager Public Relations, IHS
jeff.marn@ihs.com

Project Directors

- John W. Larson, Vice President, Economics and Public Sector Consulting
- Richard Fullenbaum, Vice President, Economics and Public Sector Consulting

Project Team

- Tabitha M. Bailey, Director, Economics and Public Sector Consulting
- Mohsen Bonakdarpour, Managing Director, Economics and Public Sector Consulting
- James Fallon, Director, Downstream Consulting
- Russell Heinen, Senior Director, Chemical Research
- Bob Ineson, Senior Director, Energy Research
- Andrew Slaughter, Vice President, Energy Insight
- Mark Wegenka, Managing Director, Chemical Consulting

Key Contributors

- Patty DiOrio, Senior Research Manager; Coal, Gas, Power & Renewables Research
- Bob Flanagan, Director, Economics and Public Sector Consulting
- Mark Griffith, Research Director; Coal, Gas, Power & Renewables Research
- Patrick Thomson, Senior Consultant, Economics and Public Sector Consulting

Acknowledgments

We extend our appreciation to our internal Advisory Board, which consists of IHS Vice Chairman Daniel Yergin, IHS Senior Vice President James Rosenfield, and IHS Chief Economist Nariman Behravesh. They offered critical insight, guidance and support in reviewing the methodologies and findings from this study.

We would also like to thank the subject matter experts, technical experts, industry experts and analysts who also contributed to this study: Sam Andrus, John Anton, Miguel Goncalves, Daniel Lichtenstein, Kenneth Kremar, Charlie McCarren, Mike Montgomery, John Mothersole, Rajeevee Panditharatna, Stewart Ramsey, Paul Robinson, Mihaela Solcan, and Tom Runiewicz.

This report offers an independent assessment of the importance of unconventional oil and gas to the US economy. This research was supported by the American Chemistry Council, America's Natural Gas Alliance, the American Petroleum Institute, the Fertilizer Institute, the US Chamber of Commerce – Institute for 21st Century Energy, the National Association of Manufacturers, the Natural Gas Supply Association, Rio Tinto, and the Society of the Plastics Industry. IHS is exclusively responsible for this report and all of the analysis and content contained herein. The analysis and metrics developed during the course of this research represent the independent views of IHS and are intended to contribute to the dialogue on the role of the unconventional oil and gas production in promoting employment, economic growth, and energy security.

Table of Contents

Appendix C: Economic Contribution Assessment Methodology and Model Documentation

Data Requirements and Assumptions

IHS Economics, with support from IHS Energy and IHS Chemical, compiled the data required to undertake the economic contribution assessment of unconventional oil and natural gas revolution in the United States, including upstream production activity, and midstream and downstream energy activity and energy-related chemicals activity. The midstream and downstream energy and energy-related chemicals value chains were segmented to distinguish the various forms of economic activity taking place. The direct contributions from this activity, in terms of production and capital expenditures, were used as inputs to the IMPLAN model as well as the IHS US Macroeconomic Model (US Macro Model). The models require average annual estimates for capital investment and related output activity metrics. The following sector activities were determined to be the major, direct economic contributors in this analysis:

- unconventional oil and natural gas extraction,
- unconventional oil and natural gas drilling,
- support activities for unconventional oil and natural gas,
- construction of facilities, related materials and machinery for hydraulic fracturing and completions, and construction of oil and natural gas pipelines,
- construction of processing, storage, and distribution networks, and
- expansion of infrastructure and capacity in energy-related chemicals.

The IMPLAN model required oil and natural gas production to be valued in dollar terms, while the US Macro Model's inputs were transformed into quadrillions of British thermal units (Btus). Capital expenditure inputs for the IMPLAN model were in nominal dollars, and the US Macro Model inputs were in real 2005 dollars. Production levels were transformed into value of production using corresponding price series from IHS Energy and a conversion factor.

For the IMPLAN model, forecasts of oil and natural gas production were transformed into values of output, using corresponding price series and a conversion factor. Drilling capital expenditures and support services for oil and natural gas operations directly correspond to sectors within the model. The breakdown of activities – completion, facilities, gathering and processing, and pipeline construction, midstream and downstream energy, and energy-related chemicals – were mapped to the detailed categories used in the IMPLAN model.

For the US Macro Model, oil and natural gas production forecasts were transformed into quadrillion Btus by using corresponding conversion ratios. Upstream capital expenditures were summed to represent total investment and all dollar estimates were converted to 2005-based estimates and were input into the US Macro Model. The model then estimated investment changes in midstream and downstream oil and natural gas activity, along with energy-related chemicals activity.

Methodology

The economic contribution of unconventional oil and natural gas activity can be traced through all of the industries that make up the US economy. In this section, we define the key terms and the conceptual framework underlying the analysis of this sector's economic contribution. IHS

Economics has utilized a comprehensive approach that integrates an industry model (IMPLAN) and a US Macro Model to arrive at the total contribution. Documentation for these models is provided in a later section.

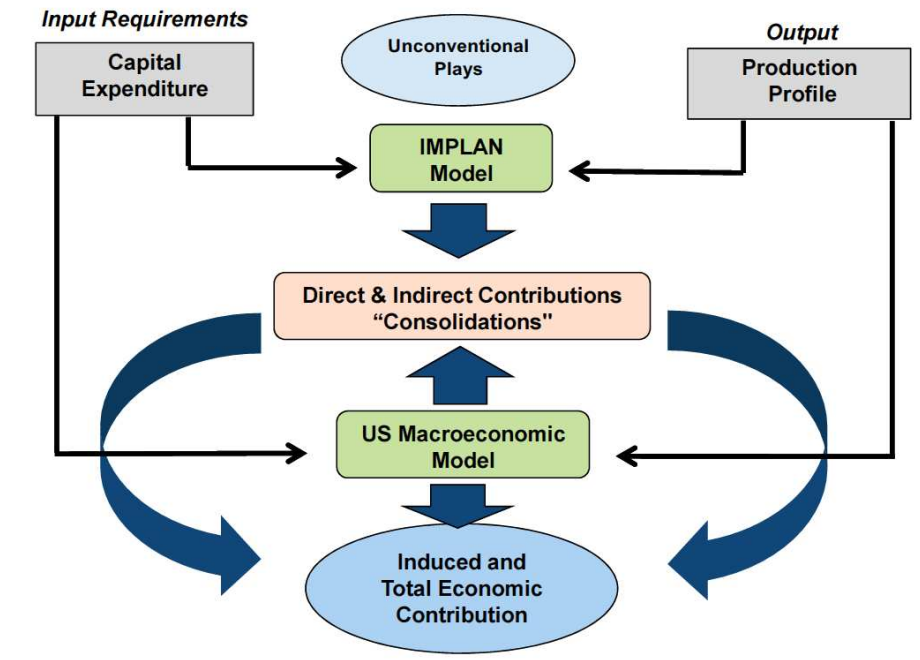
Integrated Approach

To capitalize on the strengths and avoid the weaknesses of various economic modeling methods, IHS Economics has taken the initiative to build an integrated methodology that uses two sets of modeling systems. This methodology is better equipped to capture the following important aspects of economic modeling:

- **Direct and indirect contributions of the value chain.** The IMPLAN model has a detailed and up-to-date input-output system to trace various economic contributions via the complete supplier chain throughout the US economy and its industrial sectors.
- **Dynamic econometric equilibrium.** IHS' US Macroeconomic Model strives to incorporate the best insights of many theoretical approaches. This structure guarantees that short-run cyclical developments will converge to a robust long-run equilibrium. The Macro Model is the preferred modeling approach when evaluating long-term income contributions from the unconventional oil and natural gas sector. The US Macro Model was used to assess the induced contribution of the value chain. It was also used in a more dynamic framework to assess unconventional oil and natural gas activity changes in the price of natural gas and shifts in global trade patterns.

The methodology used has employed outlooks for production and capital expenditures taken from IHS Energy and IHS Chemicals. In the first step, the analysis evaluated the direct, indirect, and induced contributions of the complete unconventional oil and natural gas value chain and energy-related chemicals via the IMPLAN and US Macro models. Second, the US Macro Model was used to measure the broader contributions throughout the economy, especially in the manufacturing sector.

Enhanced Economic Contribution Assessment Methodology Schematic



Modeling Objectives

The primary objective of this type of study is to present a complete account of how the impact of a policy or an industrial sector — in this case, the unconventional oil and natural gas sector — flows through the national industrial economy. IHS Economics used an internally consistent set of modeling and database capabilities to measure the contributions to the US economy.

To summarize, each additional dollar of industrial revenue results in both direct and indirect repercussions on final demand. In theory, a reduction of unconventional oil and natural gas production, with everything else constant, would lead to less revenue and output for industries such as chemicals and professional services that supply the industry. This decline would also reduce US demand for manufactured products such as pumps and compressors, which would in turn require fewer fabricated metal products. These are only a few of the repercussions in the complex chain that would results from an isolated initial change in an industry.

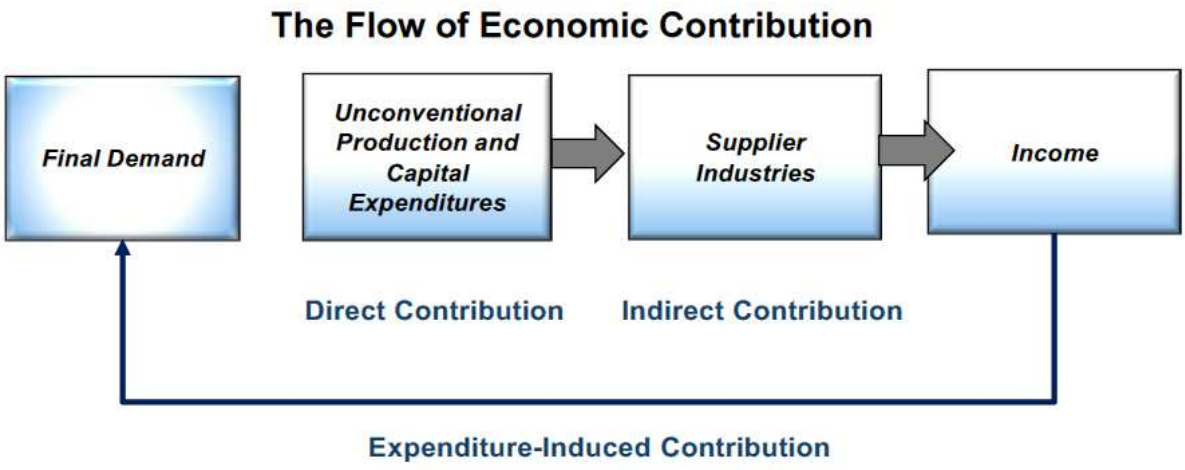
Because unconventional oil and natural gas drilling and production, along with midstream, downstream and energy-related chemicals activities, use many different products and services, many mining, manufacturing, and service industries would be directly affected by a change in this activity. The impact on these industries would have repercussions on all other producing industries, magnifying the indirect contribution through the supply-chain process.

The net effects of these changes on the US industrial sectors due to the *direct* contribution from, in this case, increased production of unconventional oil and natural gas, are divided into two stages that are described below: the *indirect* contribution and *expenditure-induced* contribution.

The direct contribution is the effect of an industrial sector on the core industry's output, employment, and income. The detailed industry IMPLAN model can evaluate these changes in the context of a linked, comprehensive industrial structure for the US economy. For instance, the change in the value of unconventional oil and natural gas production and the differential requirements, capital expenditures, for drilling and facilities construction is the direct contribution; this was calculated for 2012 and for each five-year interval from 2015 through 2025. The production and capital expenditure requirements were provided for the upstream, midstream and downstream value chains by segment, and for energy-related chemicals; these expenditures were translated into the IMPLAN requirements. In input-output modeling, the mechanism through which these direct values are analyzed is as an inputted "change."

The change in purchasing activities of an industry and its immediate impact on the mining, manufacturing, transportation, and other sectors leads to indirect effects on output, employment, and income that are attributable to those sectors, their suppliers, and suppliers' inter-industry linkages. Supplier activities will include the majority of industries in the US economy

The induced contributions occur as workers and their families in both the direct and indirect industries spend their incomes on food, housing, autos, household appliances, medical care, clothing, and other consumer items. The additional output, employment, and income effects are part of the expenditure-induced contribution.

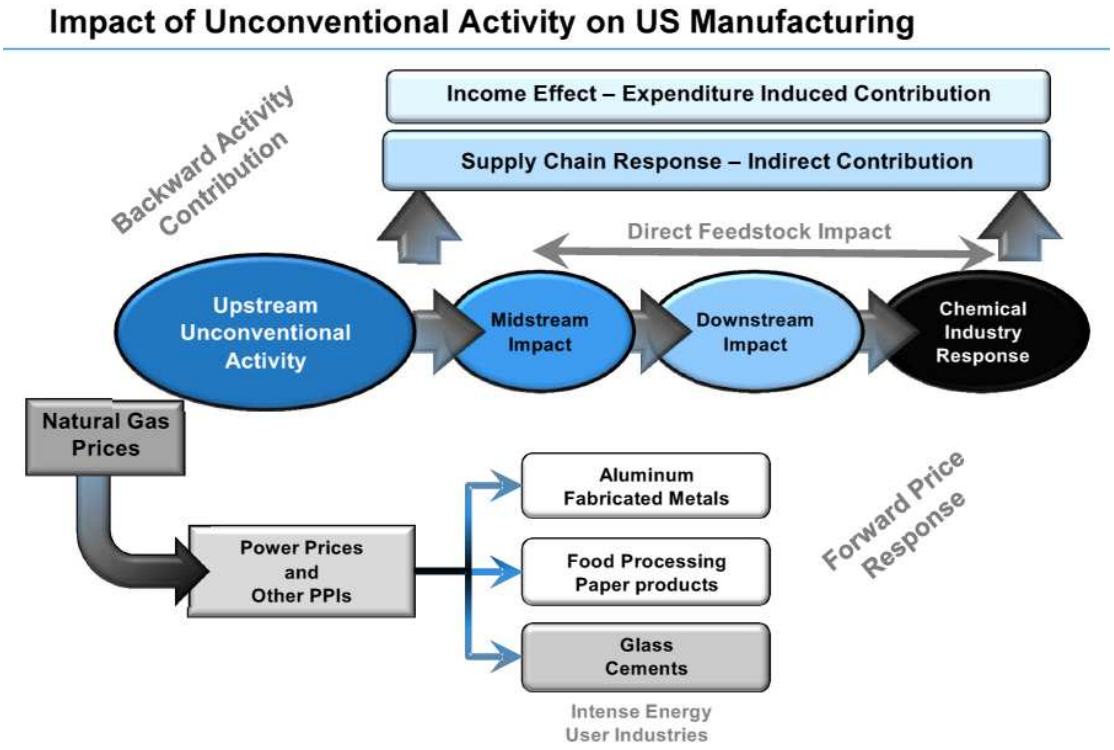


The direct and indirect contributions represent all of the production, marketing, and sales activities required to bring primary products to the marketplace in a consumable form. The use of an input-output model allows an analysis and quantification of these direct and indirect contributions. The sum of all contributions, relative to the economy's total size, provides an initial benchmark with which to evaluate the impact and importance to the economy of a given industry or sector. The expenditure-induced contribution represents the changes consumers make when their incomes are altered. Finally, additional dynamic price and industry reallocation contributions can be captured beyond what can be captured by a static input-output model. The use of a dynamic equilibrium model to measure this contribution creates a very solid modeling and measurement system.

Methodology Implementation

To forecast the direct, indirect and induced contributions by the unconventional value chain and energy-related chemicals, IHS Economics used the IMPLAN model to quantify the contribution of the unconventional oil and natural gas value chain and energy-related chemicals on the US national and industrial economies. The IMPLAN model closely aligns with accounting conventions used in the US Bureau of Economic Analysis's study, *Input-Output Study of the U.S. Economy,* and is flexible enough to evaluate changes via the value of output or employment from the source industry. When possible, IHS Economics customized the inputs to the IMPLAN model to correspond with the capital expenditure requirements of the unconventional oil and natural gas and energy-related chemicals industries. This process allowed us to examine the contributions of selected, large elements of the energy and chemicals industries and their interactions with other sectors.

In preparing this study, IHS Economics enhanced the standard methodology of measuring the expenditure-induced contribution and used the US Macro Model to capture additional contributions outside the unconventional value chain and energy-related chemicals. The primary reason for this was to depart from the static determination of income effects and rely on a more comprehensive dynamic equilibrium modeling methodology to capture changes throughout the manufacturing sector. Production and capital expenditure assumptions were inserted into the US Macro Model, which was then run to provide a more robust estimate of the complete induced contribution.



Model Documentation

IMPLAN Model

The indirect and induced job estimates in this report were quantified through input-output modeling using the IMPLAN model. This modeling effort also produced estimates of value added and labor income related to direct, indirect, and induced jobs. This appendix provides additional information about the IMPLAN model. The discussion is based in part on descriptions by Minnesota IMPLAN Group, Inc. (MIG), the model's sponsor.[1]

IMPLAN, short for "Impact Analysis for Planning," is a widely used commercially available model for input-output analysis. MIG is responsible for the production of the IMPLAN data, model, and software. Using classic input-output analysis in combination with regionally specific social accounting matrices and multiplier models, IMPLAN provides a highly accurate and adaptable model for its users. The IMPLAN system was designed to serve three functions:

- data retrieval
- data reduction and model development
- impact analysis

Comprehensive and detailed data coverage for the US economy and the ability to incorporate user-supplied data at each stage of the model-building process provide a high degree of flexibility in terms of both geographic coverage and model formulation. The IMPLAN system has two components: the databases and the software. The databases provide information needed to

[1] www.IMPLAN.com.

create IMPLAN models. The software performs the calculations and provides an interface for the user to make final demand changes.

The IMPLAN system includes:

- a national-level technology matrix
- estimates of sectoral activity for final demand, final payments, industry output, and employment for the United States

Input-output accounting describes commodity flows from producers to intermediates and final consumers. The total industry purchases of commodities, services, employment compensation, value added, and imports are equal to the value of the commodities produced.

Purchases for final use (final demand) drive the model. Industries produce goods and services for final demand and purchase goods and services from other producers. These other producers, in turn, purchase goods and services. This buying of goods and services (indirect purchases) continues until leakages from the region (imports and value added) stop the cycle.

These indirect and induced effects (the effects of household spending) can be mathematically derived. The derivation is called the Leontief inverse. The resulting sets of multipliers describe the change of output for every regional industry caused by a one dollar change in final demand for any given industry.

Creating regional input-output models requires a tremendous amount of data. The costs of surveying industries within each region to derive a list of commodity purchases production functions are prohibitive. IMPLAN was developed as a cost-effective means to develop regional input-output models.

IMPLAN easily allows the user to do the following:

- develop a complete Social Accounting Matrix (SAM) for a regional economy
- develop Multiplier models for predicting economic impacts
- modify components of the SAM including
    - industry-specific information such as employment and income values
    - production functions
    - by-products
    - trade flows
- create custom impact analyses based on the nature of an event
- generate a wide variety of reports describing the social accounts, the multiplier model, and the direct, indirect, and induced effects of an economic event
- examine how the effects of economic impact in a single region ripple into surrounding regions
- view tax impacts of economic changes

IMPLAN Software

The IMPLAN Group developed the current version of IMPLAN Version 3.0 in 2009. It is a Windows-based software package that performs the calculations necessary to create the predictive model. The software reads the database and creates the complete set of SAMs and the input-output accounts. Next the IMPLAN software derives the predictive multipliers. The software enables the user to make changes to the data, the trade flows, or technology. It also enables the user to make final demand changes that result in the impact assessment.

Features of the IMPLAN Version 3.0 include:

- direct export to Excel for ease of report manipulation or printing
- advanced data editing functions with balancing features

- complete SAM
- a choice of trade-flow assumptions
    - IMPLAN National Trade Flows model
    - econometric regional purchase coefficients
    - supply/demand pooling
- libraries for storing custom activities and the ability to import already created IMPLAN libraries
- flexible model aggregation tools—allowing for aggregation of the model or the results
- single reports location—all results can be viewed, exported and printed from a single screen
- Study Area, Social Accounts, Industry Accounts, and Multiplier Reports demonstrating all stages of model building and analysis
- activity menu structure for easy intuitive impact analysis
- event-based impact databases
- built-in and editable margins and deflators
- model data in MS Access Database format

Database

For this project IHS Economics used the 2008 IMPLAN databases. Each database contains information on the following components for each industrial sector in the IMPLAN model.

- **Employment** is total wages for salary jobs as well as self-employment jobs in the US economy.
- **Value added** is an industry's or an establishment's total output less the cost of intermediate inputs. Value added is further divided into three subcomponents:
    - **Labor income** captures all forms of employment income, including employee compensation (wages and benefits, employer-paid payroll taxes, unemployment taxes, etc.) and proprietor income (payments received by self-employed individuals and unincorporated business owners).
    - **Other property type income** consists of payments from rents, royalties, and dividends. This includes payments to individuals in the form of rents received on property, royalties from contracts, and dividends paid by corporations. This also includes corporate profits earned by corporations.
    - **Indirect business taxes** consist primarily of excise and sales taxes paid by individuals to businesses. These taxes are collected during the normal operation of these businesses but do not include taxes on profit or income.
- **Final demand** includes goods and services purchased for their ultimate use by an end user. For a region this would include exports as that is a final use for that product. In an input-output framework final demands are allocated to producing industries, with margins allocated to the service sectors (transportation, wholesale and retail trade, insurance) associated with providing that good to the final user. Thus final demands are in producer prices, and the model provides them by components of gross domestic product (GDP).
- **Personal consumption expenditures (PCE)** consist of payments by individuals/households to industries for goods and services used for personal consumption. Individuals tend to buy little directly from industries other than retail trade. However, in an input-output table, purchases made by individuals for final consumption are shown as payments made directly to the industry producing the good. PCE is the largest component of final demand.

- **Federal government purchases** are divided among military purchases, nonmilitary uses, and capital formation. Federal military purchases are those made to support the national defense. Goods range from food for troops to missile launchers. Nonmilitary purchases are made to supply all other government functions. Payments made to other governmental units are transfers and are not included in federal government purchases.
- **State (provincial) and local government purchases** are divided among public education, non-education, and capital formation. Public education purchases are for elementary, high school, and higher education. Non-education purchases are for all other government activities. These include state (provincial) government operations, including police protection and sanitation. Private sector education purchases are not counted here. Private education purchases show up in IMPLAN sectors 495 and 496.
- **Inventory purchases** are made when industries do not sell all output created in one year, which is generally the case. Each year a portion of output goes to inventory. Inventory sales occur when industries sell more than they produce and need to deplete inventory. Inventory purchases and sales generally involve goods-producing industries (e.g., agriculture, mining, and manufacturing).
- **Capital formation** is private expenditures made to obtain capital equipment. The dollar values in the IMPLAN database are expenditures made to an industrial sector producing the capital equipment. The values are not expenditures by the industrial sector.
- **Foreign exports** are demands made to industries for goods for export beyond national borders. These represent goods and services demanded by foreign parties. Domestic exports are calculated during the IMPLAN model creation and are not part of the database.

IMPLAN Multipliers

The notion of a multiplier rests upon the difference between the initial effect of a change in final demand and the total effects of that change. Total effects can be calculated either as direct and indirect effects or as direct, indirect, and induced effects. Direct effects are production changes associated with the immediate effects or final demand changes. Indirect effects are production changes in backward-linked industries cause by the changing input needs of directly affected industries (for example, additional purchases to produce additional output). Induced effects are the changes in regional household spending patterns caused by changes in household income generated from the direct and indirect effects.

For the US model used in this study, the IMPLAN model estimated Type I and SAM multipliers for direct, indirect, and induced impacts.

Type I Multipliers

A Type I multiplier is the direct effect produced by a change in final demand plus the indirect effect, divided by the direct effect. Increased demands are assumed to lead to increased employment and population, with the average income level remaining constant. The Leontief inverse (Type I multipliers matrix) is derived by inverting the direct coefficients matrix. The result is a matrix of total requirement coefficients, the amount each industry must produce in order for the purchasing industry to deliver one dollar's worth of output to final demand.

Type SAM Multipliers

Type SAM multipliers incorporate "induced" effects resulting from the household expenditures from new labor income. The linear relationship between labor income and household expenditure can be customized in the IMPLAN software. The default relationship is PCE and

total household expenditures. Each dollar of workplace-based income is spent based on the SAM relationship generated by IMPLAN.

IHS US Macroeconomic Model

The Model's Theoretical Position

As an econometric dynamic equilibrium growth model the IHS US Macroeconomic Model strives to incorporate the best insights of many theoretical approaches to the business cycle: Keynesian, New Keynesian, neoclassical, monetarist, and supply-side. In addition the IHS US Macroeconomic Model embodies the major properties of the neoclassical growth models developed by Robert Solow. This structure guarantees that short-run cyclical developments will converge to robust long-run equilibrium.

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

A modern model of output, prices, and financial conditions is melded with the growth model to present the detailed, short-run dynamics of the economy. In specific goods markets the interactions of a set of supply and demand relations jointly determine spending, production, and price levels. Typically the level of inflation-adjusted demand is driven by prices, income, wealth, expectations, and financial conditions. The capacity to supply goods and services is keyed to a production function combining the basic inputs of labor hours, energy usage, and the capital stocks of business equipment and structures, and government infrastructure. The "total factor productivity" of this composite of tangible inputs is driven by expenditures on research and development (R&D) that produce technological progress.

Prices adjust in response to gaps between current production and supply potential and to changes in the cost of inputs. Wages adjust to labor supply-demand gaps (indicated by a demographically adjusted unemployment rate), current and expected inflation (with a unit long-run elasticity), productivity, tax rates, and minimum wage legislation. The supply of labor positively responds to the perceived availability of jobs, to the after-tax wage level, and to the growth and age-sex mix of the population. Demand for labor is keyed to the level of output in the economy and the productivity of labor, capital, and energy. Because the capital stock is largely fixed in the short run, a higher level of output requires more employment and energy inputs. Such increases are not necessarily equal to the percentage increase in output because of the improved efficiencies typically achieved during an upturn. Tempering the whole process of wage and price determination is the exchange rate; a rise signals prospective losses of jobs and markets unless costs and prices are reduced.

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

transactions, the federal funds rate. Other interest rates are keyed to this rate, plus expected inflation, US Treasury borrowing requirements, and sectoral credit demand intensities.

The old tradition in macroeconomic model simulations of exogenous fiscal or environmental policy changes was to hold the Federal Reserve's supply of reserves constant at baseline levels. While this approach makes static analysis easier in the classroom, it sometimes creates unrealistic policy analyses when a dynamic model is appropriate. In the IHS US Macroeconomic Model, "monetary policy" is defined by a set of targets, instruments, and regular behavioral linkages between targets and instruments. The model user can choose to define unchanged monetary policy as unchanged reserves or as an unchanged reaction function in which interest rates or reserves are changed in response to changes in such policy concerns as the price level and the unemployment rate.

Monetarist Aspects

The model pays due attention to valid lessons of monetarism by carefully representing the diverse portfolio aspects of money demand and by capturing the central bank's role in long-term inflation phenomena.

The private sector may demand money balances as one portfolio choice among transactions media (currency, checkable deposits), investment media (bonds, stocks, short-term securities), and durable assets (homes, cars, equipment, structures). Given this range of choice, each medium's implicit and explicit yield must therefore match expected inflation, offset perceived risk, and respond to the scarcity of real savings. Money balances provide benefits by facilitating spending transactions and can be expected to rise nearly proportionately with transactions requirements unless the yield of an alternative asset changes.

Now that even demand deposit yields can float to a limited extent in response to changes in Treasury bill rates, money demand no longer shifts quite as sharply when market rates change. Nevertheless the velocity of circulation (the ratio of nominal spending to money demand) is still far from stable during a cycle of monetary expansion or contraction. The simple monetarist link from money growth to price inflation or nominal spending is therefore considered invalid as a rigid short-run proposition.

Equally important, as long-run growth models demonstrate, induced changes in capital formation can also invalidate a naive long-run identity between monetary growth and price increases. Greater demand for physical capital investment can enhance the economy's supply potential in the event of more rapid money creation or new fiscal policies. If simultaneous, countervailing influences deny an expansion of the economy's real potential, the model will translate all money growth into a proportionate increase in prices rather than in physical output.

"Supply-side" Economics

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

Rational Expectations

As the rational expectations school has pointed out, much of economic decision-making is forward looking. For example the decision to buy a car or a home is not only a question of current affordability but also one of timing. The delay of a purchase until interest rates or prices decline has become particularly common since the mid-1970s when both inflation and interest

rates were very high and volatile. Consumer sentiment surveys, such as those conducted by the University of Michigan Survey Research Center, clearly confirm this speculative element in spending behavior.

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

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

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

The IHS US Macroeconomic Model allows a choice in this matter. On the one hand, the user can simply accept IHS Economics' judgments and let the model translate policy initiatives into initial changes in the economy, simultaneous or delayed changes in expectations, and subsequent changes in the economy. On the other hand, the user can manipulate the clearly identified expectations variables in the model, i.e., consumer sentiment, and inflation expectations. For example if the user believes that fear of higher taxes would subdue spending, the consumer sentiment index could be reduced accordingly. Such experiments can be made "rational" through model iterations that bring the current change in expectations in line with future endogenous changes in employment, prices, or financial conditions.

Theory as a Constraint

The conceptual basis of each equation in the IHS US Macroeconomic Model was thoroughly worked out before the regression analysis was initiated. The list of explanatory variables includes a carefully selected set of demographic and financial inputs. Each estimated coefficient was then thoroughly tested to be certain that it meets the tests of modern theory and business practice. This attention to equation specification and coefficient results has eliminated the "short circuits" that can occur in evaluating a derivative risk or an alternative policy scenario. Because each equation will stand up to a thorough inspection, the IHS US Macroeconomic Model is a reliable analytical tool and can be used without excessive iterations. The model is not a black box: it functions like a personal computer spreadsheet in which each interactive cell has a carefully computed, theoretically consistent entry and thus performs logical computations simultaneously.

Major Sectors

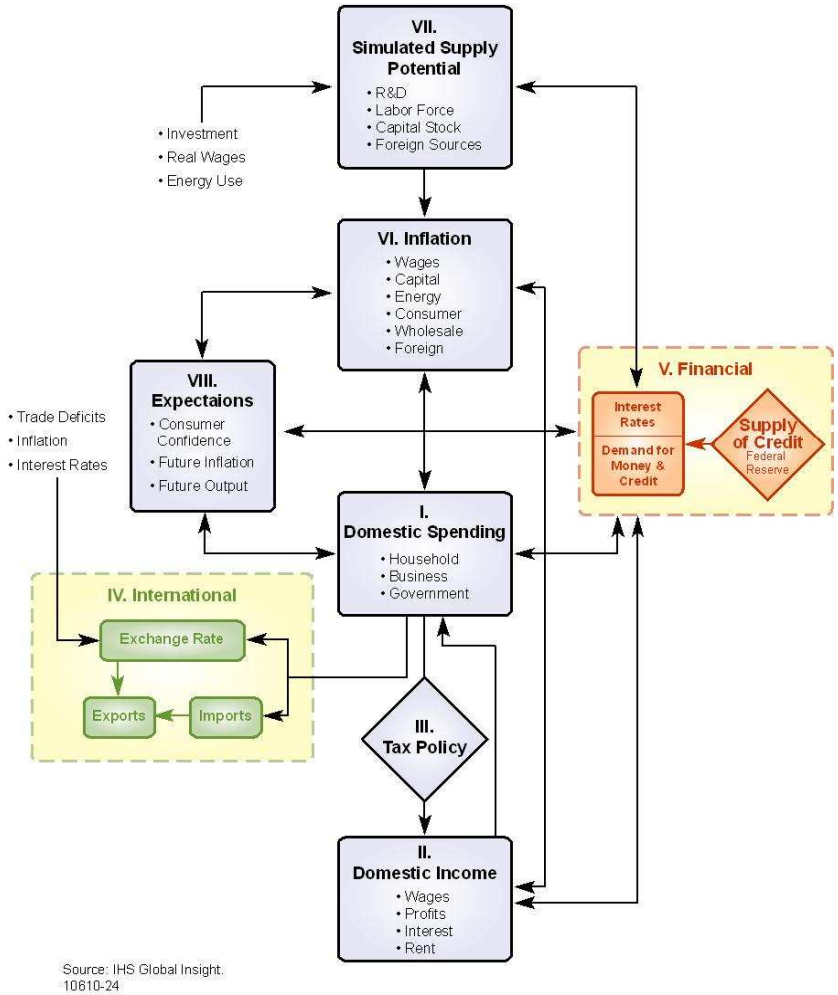
The IHS US Macroeconomic Model captures the full simultaneity of the US economy, forecasting over 1,400 concepts spanning final demands, aggregate supply, prices, incomes, international trade, industrial detail, interest rates, and financial flows. Figure C-5 summarizes the structure of the eight interactive sectors (noted in Roman numerals). The following discussion presents the logic of each sector and the significant interactions with other sectors.

Spending—Consumer

The domestic spending (I), income (II), and tax policy (III) sectors model the central circular flow of behavior as measured by the national income and product accounts. If the rest of the model were "frozen," these blocks would produce a Keynesian system similar to the models pioneered by Tinbergen and Klein, except that neoclassical price factors have been imbedded in the investment and other primary demand equations.

Figure C-5

The IHS Global Insight Macroeconomic Model of the US Economy



Source: IHS Global Insight.
10610-24

Consumer spending on durable goods is divided into 12 categories: two new vehicles categories; two net purchases of used cars categories; motor-vehicle parts and accessories; furnishings and durable household equipment; computers; software; calculators, typewriters and other; other recreational goods and services; therapeutic appliances and equipment; and "other." Spending on nondurable goods is divided into seven categories: food; clothing and shoes; motor vehicle fuels, lubricants, and fluids; fuel oil and other fuels; tobacco; pharmaceutical and other medical products; and "other." Spending on services is divided into 17 categories: housing, three utilities categories, four transportation categories, health care, recreation, food, accommodation, two financial categories, insurance, telecommunication, and "other." In addition, there is an additional services category for final consumption of nonprofit institutions serving households. In nearly all cases, real consumption expenditures are motivated by real income and the user price of a particular category relative to the prices of other consumer goods. Durable and semi-durable goods are also especially sensitive to current financing costs, and consumer speculation on whether it is a "good time to buy." The University of Michigan Survey of Consumer Sentiment monitors this last influence, with the index itself modeled as a function of current and lagged values of inflation, unemployment, and the prime rate.

Spending—Business Investment

Business spending includes nine fixed investment categories within equipment and software: four information processing equipment categories, industrial equipment, three transportation equipment categories, and other producers' durable equipment. Within structures there are three building categories; mining and petroleum structures, power and communication structures, land and all others. Equipment and (non-utility, non-mining) structures spending components are determined by their specific effective post-tax capital costs, capacity utilization, and replacement needs. The cost terms are sophisticated blends of post-tax debt and equity financing costs (offset by expected capital gains) and the purchase price of the investment good (offset by possible tax credits and depreciation-related tax benefits). This updates the well-known work of Dale Jorgenson, Robert Hall, and Charles Bischoff.

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

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

Spending—Residential Investment

The residential investment sector of the model includes two housing starts categories (single and multifamily starts) and three housing sales categories (new and existing single family sales, and new single family units for sale). Housing starts and sales, in turn, drive investment demand in five GDP account categories: single family housing, multifamily housing, improvements, miscellaneous, and residential equipment.

Residential construction is typically the first sector to turn down in a recession and the first to rebound in a recovery. Moreover, the magnitude of the building cycle is often the key to that of the subsequent macroeconomic cycle. The housing sector of the IHS US Macroeconomic Model explains new construction as a decision primarily based on the after-tax cost of home ownership relative to disposable income. This cost is estimated as the product of the average new home price adjusted for changes in quality, and the mortgage rate, plus operating costs, property taxes, and an amortized down payment. "Lever variables" allow the model user to specify the extent to which mortgage interest payments, property taxes, and depreciation allowances (for rental properties) produce tax deductions that reduce the effective cost.

The equations also include a careful specification of demographic forces. After estimating the changes in the propensity for specific age-sex groups to form independent households, the resulting "headship rates" were multiplied by corresponding population statistics to estimate the trend expansion of single- and multifamily households. The housing equations were then specified to explain current starts relative to the increase in trend households over the past year, plus pent-up demand and replacement needs. The basic phenomenon being scrutinized is therefore the proportion of the trend expansion in households whose housing needs are met by current construction. The primary determinants of this proportion are housing affordability, consumer confidence, and the weather. Actual construction spending in the GDP accounts is the value of construction "put-in-place" in each period after the start of construction (with a lag of up to six quarters in the case of multifamily units) plus residential improvements and brokerage fees.

Spending—Government

The last sector of domestic demand for goods and services, the government, is largely exogenous (user-determined) at the federal level and endogenous (equation-determined) at the state and local level. The user sets the real level of federal nondefense and defense purchases (for compensation, consumption of fixed capital, commodity credit corporation, inventory change, other consumption, and gross investment), medical and nonmedical transfer payments, and medical and nonmedical grants to state and local governments. The model calculates the nominal values through multiplication by the relevant estimated prices. Transfers to foreigners, wage accruals, and subsidies (agricultural, housing, and other) are also specified by the user but in nominal dollars. One category of federal government spending—interest payments—is determined within the model because of its dependence on the model's financial and tax sectors. Federal interest payments are determined by the level of privately held federal debt, short and long-term interest rates, and the maturity of the debt.

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

Income

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

Pretax income categories include private and government wages, corporate profits, interest, rent, and entrepreneurial returns. Each pretax income category except corporate profits is determined by some combination of wages, prices, interest rates, debt levels, and capacity utilization or unemployment rates. In some cases, such as wage income, these are identities based on previously calculated wage rates, employment, and hours per week.

Profits are logically the most volatile component of GNP on the income side. When national spending changes rapidly, the contractual arrangements for labor, borrowed funds, and energy imply that the return to equity holders is a residual that will soar in a boom and collapse in a recession. The model reflects this by calculating wage, interest, and rental income as thoroughly reliable near-identities (e.g., wages equal average earnings multiplied by hours worked) and then subtracting each nonprofit item from national income to solve for profits.

Taxes

Since post-tax rather than pretax incomes drive expenditures, each income category must be taxed at an appropriate rate; the model therefore tracks personal, corporate, payroll, and excise taxes separately. Users may set federal tax rates; tax revenues are then simultaneously projected as the product of the rate and the associated pretax income components. However, the model automatically adjusts the effective average personal tax rate for variations in inflation and income per household, and the effective average corporate rate for credits earned on equipment, utility structures, and R&D. Substitutions or additions of "flat" taxes and value-added taxes for existing taxes are accomplished with specific tax rates and new definitions of tax bases. As appropriate, these are aggregated into personal, corporate, or excise tax totals.

State and local corporate profits and social insurance (payroll) tax rates are exogenous in the model, while personal income and excise taxes are fully endogenous: the model makes reasonable adjustments automatically to press the sector toward the legally required approximate budget balance. The average personal tax rate rises with income and falls with the government operating surplus. Property and sales taxes provide the bulk of state excise revenue and reflect changes in oil and natural gas production, gasoline purchases, and retail sales, as well as revenue requirements. The feedback from expenditures to taxes and taxes to expenditures works quite well in reproducing both the secular growth of the state and local sector and its cyclical volatility.

International

The international sector (IV) is a critical block that can either add or divert strength from the central circular flow of domestic income and spending. Depending on the prices of foreign output, the US exchange rate, and competing domestic prices, imports capture varying shares of domestic demand.

Depending on similar variables and the level of world GDP, exports can add to domestic spending on US production. The exchange rate itself responds to international differences in inflation, interest rates, trade deficits, and capital flows between the United States and its competitors. In preparing forecasts, IHS' US Macroeconomic and World Economic Services collaborate in determining internally consistent trade prices and volumes, interest rates, and financial flows.

Eight categories of goods and two service categories are separately modeled for both imports and exports, with one additional goods category for oil imports. For example export and import detail for computers is included as a natural counterpart to the inclusion of the computer component of producers' durable equipment spending. The computers detail allows more accurate analysis because computers are rapidly declining in effective quality-adjusted prices relative to all other goods, and because such equipment is rising so rapidly in prominence as businesses push ahead with new production and information processing technologies.

Investment income flows are also explicitly modeled. The stream of huge current account deficits incurred by the United States has important implications for the investment income balance. As current account deficits accumulate, the US net international investment position and the US investment income balance deteriorate. US foreign assets and liabilities are therefore included in the model, with the current account deficit determining the path of the net investment position.

Financial

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

Interest rates, the key output of this sector, are modeled as a term structure, pivoting off the federal funds rate. As noted earlier, the model gives the user the flexibility of using the supply of reserves as the key monetary policy instrument, reflecting the Federal Reserve's open market purchases or sales of Treasury securities, or using a reaction function as the policy instruction. If the supply of reserves is chosen as the policy instrument, the federal funds rate depends upon the balance between the demand and supply of reserves to the banking system. Banks and other thrift institutions demand reserves to meet the reserve requirements on their deposits and the associated (exogenous) fractional reserve requirements. The private sector in turn demands deposits of various types, depending on current yields, income, and expected inflation.

If the reaction function is chosen as the monetary policy instrument, the federal funds rate is determined in response to changes in such policy concerns as inflation and unemployment. The reaction function recognizes that monetary policy seeks to stabilize prices (or to sustain a low inflation rate) and to keep the unemployment rate as close to the natural rate as is consistent with the price objective. A scenario designed to display the impact of a fiscal or environmental policy change in the context of "unchanged" monetary policy is arguably more realistic when "unchanged" or traditional reactions to economic cycles are recognized than when the supply of reserves is left unchanged.

Longer-term interest rates are driven by shorter-term rates as well as factors affecting the slope of the yield curve. In the IHS US Macroeconomic Model such factors include inflation expectations, government borrowing requirements, and corporate financing needs. The expected real rate of return varies over time and across the spectrum of maturities. An important goal of the financial sector is to capture both the persistent elements of the term structure and to interpret changes in this structure. Twenty interest rates are covered in order to meet client needs regarding investment and financial allocation strategies.

Inflation

Inflation (VI) is modeled as a carefully controlled, interactive process involving wages, prices, and market conditions. Equations embodying a near accelerationist point of view produce substantial secondary inflation effects from any initial impetus such as a change in wage demands or a rise in foreign oil prices. Unless the Federal Reserve expands the supply of credit, real liquidity is reduced by any such shock; given the real-financial interactions described

above, this can significantly reduce growth. The process also works in reverse: a spending shock can significantly change wage-price prospects and then have important secondary impacts on financial conditions. Inspection of the simulation properties of the IHS US Macroeconomic Model, including full interaction among real demands, inflation, and financial conditions, confirms that the model has moved toward central positions in the controversy between fiscalists and monetarists, and in the debates among neoclassicists, institutionalists, and "rational expectationists."

The principal domestic cost influences are labor compensation, nonfarm productivity (output per hour), and foreign input costs; the latter are driven by the exchange rate, the price of oil, and foreign wholesale price inflation. Excise taxes paid by the producer are an additional cost fully fed into the pricing decision. This set of cost influences drives each of the 19 industry-specific producer price indexes, in combination with a demand pressure indicator and appropriately weighted composites of the other 18 producer price indexes. In other words the inflation rate of each industry price index is the reliably weighted sum of the inflation rates of labor, energy, imported goods, and domestic intermediate goods, plus a variable markup reflecting the intensity of capacity utilization or the presence of bottlenecks. If the economy is in balance — with an unemployment rate near 5 percent, manufacturing capacity utilization steady near 80–85% and foreign influences neutral — then prices will rise in line with costs, and neither will show signs of acceleration or deceleration.

Supply

The first principle of the market economy is that prices and output are determined simultaneously by the factors underlying both demand and supply. As noted above, the "supply-siders" have not been neglected in the IHS US Macroeconomic Model; indeed substantial emphasis on this side of the economy (VII) was incorporated as early as 1976. In the IHS US Macroeconomic Model aggregate supply is estimated by a Cobb-Douglas production function that combines factor input growth and improvements in total factor productivity. The output measure in the production function is a gross output concept that equals private GDP, excluding housing services, plus net energy imports.

Factor input equals a weighted average of labor, business fixed capital, public infrastructure, and energy. Based on each factor's historical share of total input costs, the elasticity of potential output with respect to labor is 0.65 (i.e., a 1 percent increase in the labor supply increases potential GDP 0.65 percent); the business capital elasticity is 0.26; the infrastructure elasticity is 0.025; and the energy elasticity is 0.07. Factor supplies are defined by estimates of the full employment labor force, the full employment capital stock, end-use energy demand, and the stock of infrastructure. To avoid double-counting energy input, the labor and capital inputs are both adjusted to deduct estimates of the labor and capital that produce energy. Total factor productivity depends upon the stock of R&D capital and trend technological change.

Potential GDP is the sum of the aggregate supply concept derived from the production function, less net energy imports, plus housing services and the compensation of government employees.

Taxation and other government policies influence labor supply and all investment decisions, thereby linking tax changes to changes in potential GDP. An expansion of potential reduces first prices and then credit costs, and thus spurs demand. Demand rises until it equilibrates with the potential output. Thus the growth of aggregate supply is the fundamental constraint on the long-term growth of demand.

Inflation created by demand that exceeds potential GDP or by a supply-side shock or excise tax increase raises credit costs and weakens consumer sentiment, thus putting the brakes on aggregate demand.

Expectations

The contributions to the model and its simulation properties of the rational expectations school are as rich as the data will support. Expectations (Sector VIII) impact several expenditure categories in the IHS US Macroeconomic Model, but the principal nuance relates to the entire spectrum of interest rates. Shifts in price expectations or the expected capital needs of the government are captured through price expectations and budget deficit terms, with the former affecting the level of rates throughout the maturity spectrum and the latter affecting intermediate and long-term rates, and hence the shape of the yield curve. On the expenditure side, inflationary expectations have an impact on consumption via consumer sentiment, while growth expectations affect business investment.