# Estimating the Economic Impact of Proposed GHG Mitigation Policies Using the DRI·WEFA Energy/Economic Modeling System

## Overview

In December 1997, the Kyoto Protocol was agreed to by the Conference of the Parties to the Framework Convention on Climate Change. Under this Protocol, the 38 Annex B countries agreed to reduce their greenhouse gas emissions in aggregate to about 5% below 1990 levels for the period 2008–2012. Specific targets were set for individual countries. While the target reductions were defined in the Protocol, the specific measures to achieve these targets were not. As countries assess the reasonableness of the targets, timetable and potential mitigation measures, they are interested in the impact these potential measures may have on their country's economic performance.

DRI•WEFA uses its Energy Modeling System to analyze the impacts of major energy issues on industrialized countries' energy sectors and the feedback effects from energy markets on its economies. The system is composed of the

- DRI•WEFA Macroeconomic Models
- DRI•WEFA Energy Models

The Energy Modeling System ensures that forecasts of energy demand and economic activity are mutually consistent.

The Macroeconomic Model defines the economic environment in which the energy markets are operating. Projections of real GDP growth, inflation, industrial production, employment, income, housing, vehicle sales, etc., are provided to the Energy Model from the Macro Model. Also feeding into the Energy Model is a complete array of present and expected future energy and environmental regulations which impact the pricing and/or availability of domestic energy supplies, assumptions regarding the technical or efficiency characteristics of the energy-using capital stocks, and world oil prices. Renewable energy sources that are in-place, under-construction or planned are included. With these inputs, the Energy Model determines the prices, demands, and supplies of the major energy sources in each country.

Forecasts of a country's fuel consumption are also mutually consistent. Coal, oil, gas, renewables and electricity compete for demand on the basis of efficiency adjusted prices. As demand for a fuel increases, however, the *supply* price of that fuel also increases, which dampens further demand growth.

Descriptions of the DRI•WEFA Energy and Economic Models are described below.

# DRI·WEFA's Energy Models

DRI•WEFA's Energy Models have been designed to analyze the factors that determine the outlook for energy markets. The modeling system is constructed as a system of sub-models that can be used to independently assess intra-market issues.

Each country Energy Model is an integrated system of fuel and electric power models and the End-use Demand Model. Final solution is achieved through an iterative procedure. The major models of the Energy Model and their inter-relationships are described below.

## End-use Demand Model

Demand for final energy is modeled by sector by fuel by census region, based on the competitive position of each fuel in its end-market. The total demand for energy is estimated as a function of the stock of energy equipment, technology change, prices of competing final energy sources and economic performance. The initial demand profile for each fuel is then integrated with the Petroleum, Natural Gas, Coal and Electric Power Models, which each consist of three major sub-modules -- a supply and transformation module, a transportation/transmission/distribution module, and a wholesale/retail price module.

## Petroleum Model

The Petroleum Model uses the world oil price projection from DRI•WEFA's Global Petroleum Model. The model then determines refined petroleum product prices to end-users by adding refining markups, inventory, and transportation costs. For selected products, national, state and local taxes are also accounted for in the model. The Petroleum Model also provides a baseline projection of domestic crude and NGL production that is based on an annual review of data/literature on reserves, production, and technological progress. A simulation block for investigating the supply response under alternative assumptions is part of this module. Imported supplies of crude and petroleum products are developed by difference between domestic production and the sum of the direct consumption of petroleum by consumers and the transformation demand for petroleum by the power sector.

## Natural Gas Model

The Natural Gas Model consists of three major submodules: a wholesale pricing model, a supply module, and a transmission/distribution module. The supply module projects production based on analysis of reserve data, exploratory and development drilling and technological progress. A simulation block for investigating supply responses under alternative assumptions is part of this module. The transmission/distribution module projects cost by customer class. The wholesale pricing model integrates the results of the End-use Demand Model, the natural gas demand by the power sector from the Electric Power Model, and the embedded supply and

transmission/distribution modules to determine producer prices by basin. A final solution is developed through an interactive process.

## Coal Model

The Coal Model consists of three major submodules: a wholesale pricing model, a supply module, and a transportation module. The supply module projects production based on analysis of reserve data, productivity and technological progress. A simulation block for investigating supply responses under alternative assumptions is part of this module. The transportation module projects rail/barge costs. The wholesale pricing model integrates the results of the End-use Demand Model, the Coal demand by the power sector from the Electric Power Model, and the embedded supply and transportation modules to determine producer prices by basin. A final solution is developed through an interactive process.

## Electric Power Model

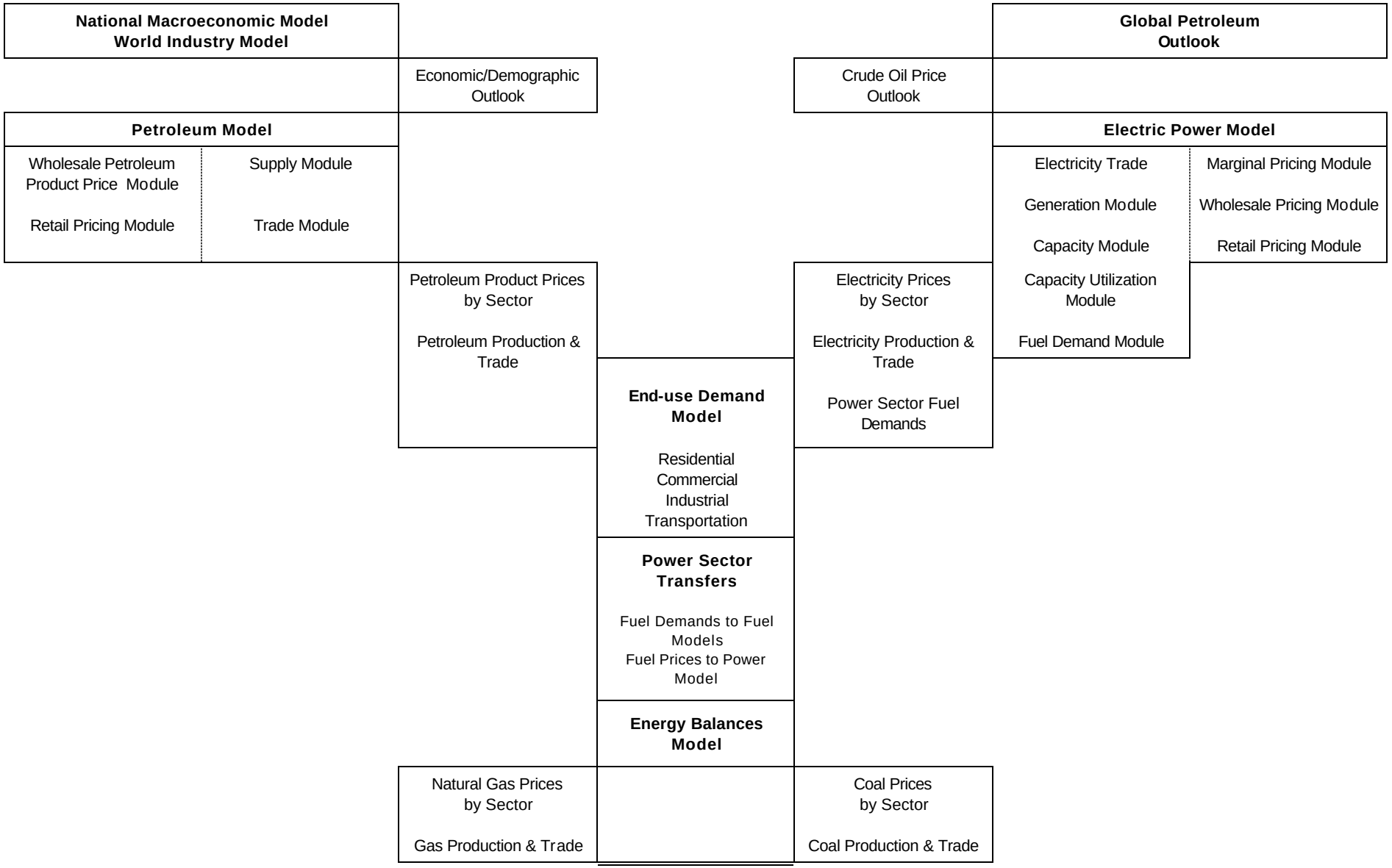
The Electric Power Model is a detailed model of the power generation sector combined with a more aggregate model of the regional transmission and distribution sector. The preliminary demand for regional generation is determined as a function of the demand for electricity determined in the End-use Demand Model, transmission losses and trade. Generation requirements are met through the capacity module, which projects capacity decisions based on fuel prices, O&M costs, and technological progress. Utilization is projected as a function of load and marginal production cost. Average wholesale prices are calculated, and successive iterations allow for an assessment of the price of electricity that clears markets. Through this analysis, a preliminary demand for a fuel by the power sector is developed that is finalized in the iterative process.

## Energy Balances Model

The Energy Balances Model completes the process. This model provides summations of energy use across fuel and customer class.

A schematic of the Energy Modeling System is shown below.

# DRI·WEFA ENERGY MODELS



| Natural Gas Model | | Coal Model | |
|---|---|---|---|
| Wellhead Price Module | Supply Module | Basin Supply Module | Minemouth Price Module |
| Transmission & Distribution Cost Module | Flow Module | Flow Module | Rail Cost Module |
| | Trade Module | Trade Module | |

# Macroeconomic Models

DRI•WEFA's Macroeconomic Models combine the latest econometric and economic research with traditional Keynesian macroeconomics. The model is best described as a complete detailed version of the model found in intermediate-level macroeconomics textbooks. It is as close to a consensus as is currently possible. The model has Keynesian properties in the short run. Over the medium term, however, policy shifts or economic shocks will affect prices, while output and employment return to the long-run growth path. This long-run growth path is determined by a neo-classical growth model based on a Cobb-Douglas production function. Most final demand equations, and many other key equations, are specified as error correction models, and estimated using cointegration techniques.

This overview of the model starts by describing the technical details of the model. The economic structure of the model is then discussed. The equation listing shows the exact specifications and structure of each equation.

## Model Structure

The "core" model describes how aggregate demand, aggregate supply, financial markets, and labor markets interact. This block determines the major economic aggregates including inflation, unemployment and production. It can be solved independently. For selected countries, a second block uses an input-output framework to forecast industrial production, wages, and employment for individual industries at the two and three digit SIC code level. Given a solution or simulation using the core model, the industry block can show the impact on specific industries of a macroeconomic shock.

## Overview and Specification: The Core Model

### Economic Characteristics

Despite its size and complexity, the core model's basic structure is similar to those usually described in intermediate level macroeconomics textbooks. Aggregate demand is determined by a real sector and a financial sector (IS and LM curves). Prices adjust slowly, so shocks to demand affect production and Gross Domestic Product (GDP) in the short run. The economy adjusts to medium-run full employment through a Phillips curve that consists of two parts: an expectations-augmented equation for labor costs and a price-capacity equation. In the price-capacity equation, firms set a mark-up over labor and import costs depending on capacity utilization.

Long run growth is determined through a Cobb-Douglas production function that calculates an estimate of potential GDP. Capital investment and labor force growth raise potential GDP and capacity and (through the mark-up equation) reduce prices. A lower overall price level increases real incomes, creating, in the long run, sufficient aggregate demand to absorb the additional capacity and raise production. Note that the impact of investment on the economy in the short run will mainly be through the traditional Keynesian channels because the capital stock

is very large relative to new investment. Higher rates of capital growth or technical change may take a decade or more to affect economic performance.

## Aggregate Demand

Aggregate demand is determined largely according to Keynesian economic theory, although other approaches are used selectively. Much of the model's size arises from the large number of categories of aggregate demand in the model.

### *Consumption*

The standard consumption equation is driven by income, relative prices, and demographic characteristics. The equations are estimated in an error-correction framework, in some cases assuming that the long-run marginal propensity to consume is equal to one. The error correction framework is particularly useful for consumption because it imposes a version of the permanent income hypothesis on the model. Specifically, shocks to income will typically result in relatively small consumption increases in the short run. Only if income remains higher will consumption spending gradually rise toward the new income level.

#### The Auto Sector

The auto sector is the most cyclical area of consumption. Consumer spending on autos and related products is determined by a set of equations that estimates the demand and production for motor vehicles. The key variable is unit light vehicle sales (ULTVEH). This stochastic equation assumes that there is a long-run demand for cars and light trucks which depends on the driving age population, real income, and the existing stock of light vehicles. When the desired stock of light vehicles is below the actual stock (KULTVEH), light vehicle sales will rise, all other things being equal. In the short-run, car sales are also determined by consumer confidence (JCS) and the real interest rate, measured by the prime rate expected consumer price index (CPI) inflation (RCPIHAT). Light vehicle stocks are determined by adding stocks of trucks and cars, and subtracting scrappage determined by the exogenous scrappage rates (RSCRAPCAR and RSCRAPTRKLE3).

The proportion of trucks in light vehicle sales depends positively on the proportion of households with heads aged 35 to 44 and negatively on the relative price of gasoline. Car sales (USCAR) are the difference between light vehicle sales and truck sales. The model uses BEA numbers for the key variables, but also provides Auto News numbers. The discrepancy between Auto News and BEA car sales and light truck sales is exogenous. Consumer spending for passenger cars (CEDMNC92) follows BEA auto sales (USCAR), and spending for other motor vehicles (CEDMTR92) follows BEA light truck sales (UTRKLE3).

### *Investment*

Non-residential investment is divided into three broad categories: inventories, structures, and equipment. Structures and equipment depend on a user cost of capital term and aggregate demand, and thus respond both according to the Q-theory of investment and according to the accelerator principle.

## User Cost of Capital

The user cost of capital is defined as the cost of financing an investment, including both the cost of the equipment (or structure) and the required after-tax return on capital (RATRR#). The after tax rate of return is a weighted average of the expected cost of debt and equity financing, where the expected cost of debt is a long-term bond rate, and the expected cost of equity adds a constant to the cost of debt. We use the bond rate plus a fixed risk premium of 3%. The model assumes that 35% of equipment investment is financed by debt (65% by equity) and 50% of structures investment is financed by debt (50% by equity). The depreciation method, tax life, and after-tax required return on investment determine the present value of tax depreciation.

## Inventories

Inventory investment is disaggregated into farm inventories (IIFRM), auto inventories (IICAR), non-auto manufacturing inventories (IIMFG), and non-manufacturing inventories (IINFMOTH).

Farm inventories are determined exogenously. Since the National Income and Product accounts do not count Federal Commodity Credit Corporation (CCC) purchases as inventory investment, but as government expenditures, the model includes a variable to measure total farm inventories including CCC stocks (IIFRM92). IIFRMACCC are determined exogenously, as are CCC purchases (GPFNONCCC). Farm inventories are simply calculated as the difference between these two.

Nonfarm inventories are divided into manufacturing, nonmanufacturing, and inventories at auto dealers. Desired non-farm non-auto inventory levels are estimated using error correction models. There is an estimated long-run desired level of inventories based on sales; when the level of inventories goes below this level, inventory accumulation occurs. Inventories at auto dealers depend directly on the difference between car sales (USCAR) and car production (UPCAR) as well as the difference between imports and exports of motor vehicles (IMMVP92-EXMVP92). Note that inventories are generally determined as levels, with the inventory change being a series of identities calculated from the levels.

## Housing

Existing home sales (UHESLD) is the key variable that drives the housing sector. Existing home sales relative to the number of households depends on permanent and transitory income (similar to the consumption equations), mortgage interest rates, housing prices, consumer sentiment, and the proportion of the total population in the 25 to 44 age category. Housing is an easily postponable purchase and is perhaps the most cyclical sector of the economy. Housing is highly sensitive to fluctuations in interest rates. The proportion of the population in the 25 to 44 age category is important because this in the primary home purchase age. Existing home sales feed into the equation for single family housing starts (UHSONE) that ultimately determine residential investment.

Housing starts are affected by many of the same variables as existing home sales. One important difference is the inclusion of a stock adjustment variable. There is a desired stock of housing in relation to the number of households. Disequilibrium can be calculated by the relationship

between the existing stock and the desired stock. The desired stock is calculated from the growth rate of the number of households, the 25-44 age share of households, and real permanent income. Economic conditions determine the rate at which the gap between the desired and the actual stock is closed. This stock adjustment concept is introduced in the equation for single family housing starts by including the real value of the stock of housing relative to the number of households lagged one period. This term is an effective means of introducing the stock-flow adjustment created by past variations of housing stock accumulation. The higher the value of the stock of housing last quarter relative to the number of households, the lower the demand for new single family construction this quarter.

## *Foreign Trade*

Exports depend on relative prices and foreign GDP growth; imports depend on relative prices and home demand. Exports, in particular, respond with long and variable lags to changes in prices and foreign demand, and this is reflected in the estimated short- and long-run coefficients in the export equations.

### Exchange Rate

The exchange rate is vital for determining demand for exports and imports. The real exchange rate that appears in the export and import equations (REXMOR18R) is the Morgan Guaranty 18 country trade-weighted index. The real exchange rate is driven by an equation for the nominal exchange rate (REXMOR18), which takes into account U.S. prices compared to foreign prices and relative short-term interest rates. Any action which affects interest rates may have a potentially significant affect on the foreign sector through this channel. The real exchange rate is an identity given home and foreign prices and the nominal exchange rate.

### Exports

Real export demand generally depends on foreign GDP growth (GDP18W92) and relative prices. Both foreign GDP and foreign prices are constructed by weighting individual country values using the Morgan Guaranty trade-weighted exchange rate weights. Relative prices generally include the export deflator, the nominal exchange rate, and a general measure of foreign prices (PPIROW18).

### Imports

Real imports are estimated on a per capita basis. Imports are assumed to depend on appropriate categories of domestic demand and the relative prices (expressed by the implicit deflators) of similar home and imported goods. Since import deflators depend on the exchange rate, it indirectly affects import volumes, as well.

## *Government Sector*

The government sector is divided into two parts: Federal, indicated in mnemonics by "F" and state and local, indicated in mnemonics by "N".[1] Each is further subdivided into an expenditure side and a revenues side. Revenues are further divided into personal taxes (TXP-), indirect business taxes (TXI-), corporate taxes (TXC-), and social security taxes (TXS-). All but the

last exist for both levels of government. Tax collections are determined by applying an effective tax rate to the correct tax base, but can be altered directly (see the Levers Chapter for more detail). Expenditures are broken out into purchases (GP), transfers (TRPG), net subsidies to government enterprises (GSLS), grants-in-aid to state and local governments (GIA), which are an expenditure for the Federal government and a revenue for state and local governments, and, for the Federal government only, net interest payment on the Federal debt (YINGF). (State and local governments earn net interest (YINGN), so this appears as a reduction in spending for this sector.) Note that only purchases matter directly for aggregate demand, although some categories, such as transfers and Medicaid spending, indirectly affect income and consumer spending.

**Table 1 Federal Purchases NIPA**

<table>
<tr><td colspan="3">Defense<br>(GPFD)</td><td colspan="3">Nondefense<br>(GPFN)</td></tr>
<tr><td colspan="2">Consumption<br>(GCEFD)</td><td>Investment<br>(IGGFD)*</td><td colspan="2">Consumption<br>(GCEFN)</td><td>Investment<br>(IGGFN)*</td></tr>
<tr><td colspan="2">Pay<br>(GCEFDPAY)</td><td rowspan="2"></td><td>Nonpay<br>(GCEFD-XPAY)</td><td>Pay<br>(GCEFN-PAY)</td><td rowspan="2"></td></tr>
<tr><td>Military Pay<br>(GCEFDPAYMIL)</td><td>Civilian Pay<br>(GCEFDPAYCIV)</td></tr>
</table>

* Investment spending is not included in the NIPA expenditure definition (GEF).

[1] For example, GPN is total purchases by state and local governments, and GP*F* is total purchases by the Federal government.

**Table 1** shows how Federal purchases are broken down into subcategories. All purchases are divided into defense and non defense, and further divided in each case into investment and noninvestment and pay and non pay consumption expenditures. Note that the NIPA definition of investment includes a small amount of Federal Pay ("Force Account Construction") but we estimate the consumption pay variables using total Federal workers, as no breakdown of the Federal workforce is available, and the amount of spending for Force Account Construction is small. The compensation levels are therefore stochastic, depending on the number of workers in each category and the pay levels, which in turn depend on private-sector labor costs. Noncompensation spending, both consumption and investment, is exogenous.

Transfers are divided into a number of categories (see the section on personal income for a more complete description). Medical transfer payments, including Medicare (TRPGFHI), health subsidies (TRPGFHEA), and veteran's payments (TRPGFVETMED), directly affect consumption of medical services (CESMED92).

Grants-in-aid are divided into two categories: Medicaid (GIAMEDCAI) and other (GIAMEDOTH). Note that total Medicare payments include a state and local component which is added to the Federal component to reach total Medicaid spending

(TRPGNMEDCAI). Like the other transfer payments for medical services, Medicaid directly affects total consumer spending for medical services (CESMED92).

Interest payments (YINGF) depend on interest rates and the amount of outstanding Federal debt (KDEDBTGFNET). The level of subsides to government-owned business (GSLSF) is exogenous.

The differences between the NIPA and unified spending and tax measures are calculated using two adjustment variables, TXFADJ and GEFADJ. The major differences between these variables include the treatment of government capital consumption (included in the NIPA, not included in the unified budget measure) and investment spending (included in the unified, not included in the NIPA measure). Most observers now use the unified budget and deficit measures and indicators of fiscal policy.

## *Income*

National income in Mark 10 is divided into corporate profits and personal income. Personal income is estimated in a series of stochastic equations, while profits are the residual. Note that some care must be taken to monitor corporate profits (Z) when shocking the model since this variable will be sensitive to changes in personal income.

### Personal Income

A large part of personal income is directly related to employment. Employment is divided into seven stochastic categories, corresponding to one-digit industries. (Wholesale and retail trade are added together into one category). Each category depends on a distributed lag of demand for that industry and real unit labor costs (JULCNFMPRIAVG*100/PDCGDP). Unit labor costs depend on compensation per hour, which is in turn determined by the unemployment rate and expected inflation, thus creating feedback in the labor market between wages and employment.

### Labor Income

Labor income is divided into two categories: wage and salary income (WD) and other labor income (YOL). Wage and salary income is estimated from the wage compensation per hour (JECWAP) times total hours in the non-farm business sector, plus the wage bill for the public sector (WDGOV). Other labor income includes bonuses and the value of fringe benefits. It depends largely on profits and productivity.

### Other Income

Personal income from other sources is estimated from a top-line perspective. Other income (YOTH) depends on a variety of variables that affect the underlying variables: dividend income (YDVPER), interest income (YIRPER) and non-farm proprietors' income (YPR). Dividend and interest income are forecast separately, and proprietors' income is forecast as the residual of other income (YOTH).

### Transfer Payments

Transfer payments are divided into Federal (F) and state and local (N) payments. State and local payments include Medicaid (TRPGNMEDCAI), the Federal portion of which is measured as part of Grants-in-aid to state and local governments. Federal payments include Medicaid (TRPGFHI), Social Security (TRPGFOASDI), retirement (TRPGFRET), veterans' benefits (TRPGFVET), unemployment insurance (TRPGFUIB) and other transfers (TRPGFOTH). We have also included a category for health-care subsidies (TRPGFHEA) which can be used in simulations of health care reform. Medical payments, including Medicaid, Medicare, Veterans' medical payments (TRPGFVETMED), and health-care subsidies are included directly in consumer spending for medical services (CESMED92). These transfers do not generally provide cash payments to recipients, and it is unclear how much spending behavior for other categories is affected by transfers in kind. A jump in the medical services deflator which pushes up nominal transfers and income does not really represent additional income from a behavioral point of view. We have therefore included a variable, YDPXMED92, real income less medical transfers, which measures real cash income. This variable is used in many of the consumption equations in place of actual real disposable income.

## *Profits*

The Quarterly Model calculates profits as a residual, because national income is divided into personal income and profits. National income is calculated from GNP, tax payments, and other adjustments (including capital consumption allowances). **Table 2** shows the relationship between GNP, national income, profits, and personal income.

Note that production can differ from income for a variety of reasons, including capital consumption allowances, business transfers, government subsidies, indirect taxes and the statistical discrepancy.

### The Financial Sector (LM Curve)

Mark 11 uses two key interest rates to forecast financial conditions. The Fed funds rate is the main proxy for short-term interest rates, and mainly reflects Federal Reserve monetary policy. Long-term interest rates follow the 30-year bond rate, which is determined by economic conditions, the size of the Federal debt, and short-term rates.

## *Short Term Interest Rates and Monetary Policy*

Monetary policy and short-term interest rates are determined together. The key equations are the reserves equation (MRES), which summarizes Federal reserve behavior, and the Fed funds rate (RFF), which is an inverted money demand function. The Fed sets reserve growth depending on present and past inflation and capacity utilization. Higher inflation or capacity utilization will reduce reserve growth; lower inflation or capacity utilization will raise reserve growth. The level of demand deposits (MDD) follows the level of reserves closely, and is the main determinant of the crucial monetary aggregate in the model, M1. The Fed Funds rate is equation is an inverted money demand function of the standard form:

$$m - p = fy - lr$$

where m is the nominal stock of money, p is the price level, y is the level of real output, and r is an inflation-adjusted interest rate. All variables are in logs, so $\phi$ is the income elasticity of money, and $\lambda$ is the interest elasticity of money. The income elasticity of money in the model equals 0.57, with an income elasticity close to one.

### *Long-term Interest Rates*

The key long-term interest rate in the model is the 30-year Treasury bond rate (RTBOND30Y). The 30 year bond rate equation includes a long-run relationship between the bond rate, expected inflation, and the 3-month T-bill rate. In the short run, the level of the Federal deficit relative to GDP can move the long-term interest rate off of the long-run level.

### *Other Interest Rates*

Short-term interest rates depend on the Fed funds rate (RFF), often through the impact on the 3 month T-bill (RTBILL3M). Long-term interest rates depend on the 30-year Treasury bond yield (RTBOND30Y). Intermediate maturities, like the 5-year Treasury note, depend on a weighted average of the two rates. Private/public spreads and other spreads are estimated based on business cycle variables and other relevant information. Spreads will therefore move appropriately: for example, in a recession simulation, the private/public spreads will widen, reflecting the greater risk in private sector securities.

### *Expectations*

Inflationary expectations play an important role in a number of important equations, including long-term interest rates, the user cost of capital, and the key wage equation. In the model, inflationary expectations are defined as the expected inflation rate over the next four quarters, and measured by the Survey of Professional Forecasters of the Philadelphia Fed. Expected inflation (RCPIHAT) is forecast though a stochastic equation which depends on past CPI inflation, M1 growth, and oil prices. Because this equation is stochastic, the modeler can test the sensitivity of simulations to different assumptions about expectations.

### *Medium Term Price Response*

Prices adjust in the medium term when aggregate demand is not equal to aggregate supply. The price adjustment serves to force aggregate demand toward aggregate supply over the five- to ten-year horizon. Two equations determine the Phillips curve for the model.

#### Phillips Curve Equations

The model's price response works through two equations which allow for cost-push wage inflation as well as the effect of capacity constraints and bottlenecks. The result is an expectations adjusted Phillips curve in which workers attempt to maintain real wages, but which allows for traditional Keynesian demand-pull inflation as well. Inflationary shocks can become embedded in the model through the wage process, unless aggregate demand falls sufficiently to create slack labor markets.

Wage inflation enters the model in the equation for compensation per hour index (JQWRHNFM). Workers are assumed to attempt to at least maintain the *ex ante* real

compensation, where compensation is deflated by expected inflation (RCPIHAT). Labor market conditions, as measured by the relationship between the actual unemployment rate and full-employment unemployment rate also affect wage growth. When unemployment is below the full-employment level, wage inflation will accelerate above the rate of expected inflation. When unemployment is below the full-employment level, wage inflation will decelerate below the rate of expected inflation. The unit labor cost equation helps to maintain model stability in the medium turn, as labor market conditions create self-correcting price movements.

Labor market conditions then determine final demand deflators through the non-farm business GDP deflator (PDCGDPBUS), the second key equation of the aggregate price group. Energy prices also enter here, as does capacity utilization (RKUMFGFRB), which signals the ability of firms to raise prices above labor costs.

**Table 2: GNP, National Income, Profits, and Personal Income**

**GNP**

- Corporate capital consumption allowance (CFXCOR)
- Non-corporate capital consumption allowance (CFXNON)
- Government Capital Consumption (CFXG)

**= Net National Product (NNP)**

- Federal indirect business taxes (TXIF)
- State and local indirect business taxes (TXIN)
- Business transfer payments (TRPB)
- Statistical Discrepancy (GNPSDX)

**= National Income (NI)**

- Personal income (YP)
- Employer contributions for social insurance (TXSE)
- Wage Accruals less disbursements

**= Corporate Profits (Z)**

- Capital consumption allowance
- Inventory valuation allowance

**= Corporate Profits before taxes (ZB)**

- Corporate Federal Income Tax Payments (TXCF)
- Corporate State and Local Income Tax Payments (TXCN)

**= Corporate Profits after taxes (ZA)**

## Aggregate Supply

### *Potential GDP*

Potential GDP is determined through a Cobb-Douglas production function. The unemployment rate is assumed to reach the natural rate of unemployment (RUNCN) when the economy is performing at potential.

### *Population and Labor Force*

Population and labor force are exogenous. This greatly simplifies the model, but shocks to the model that might affect labor supply should be carried out with some caution, especially for very long-run simulations (more than ten years).

The population is divided into five-year age categories by gender, each determined exogenously. A population lever (NPTPCNT) allows all categories to be changed simultaneously in equal proportion. The labor force is divided into ten-year categories by gender. Each category is an identity determined by multiplying the labor force participation rate for that category by population. Labor force participation rates are exogenous, and may be altered together using a lever (NLFPCNT) similar to the population lever. Note that the labor force cannot be changed directly – it is necessary to change participation rates, or the aggregate participation lever, instead.

The number of households is determined in a manner similar to the labor force. Household headship rates for 10 year age categories are multiplied by the population numbers to obtain the number of households by age of head.

### *Capital Stock*

The second factor of production, the capital stock, is determined through identities that relate real investment to the stock of capital by final demand type. There are equipment and structures capital stocks (KPENET92 AND KPSNET92) as well as a stock of residential housing (KPRNET92). Depreciation rates are exogenous (RDEP---). Depreciation rates are typically below 10% for structures, and between 10% and 20% for equipment.

### *Technical Change*

The rate of technical change (RTECHCHG) is estimated as part of the procedure for estimating the production function. It is forecast as an exogenous variable. The capital stock, labor force, and technical change determine the long-run potential growth rate of the economy.