Concepts, Data Sources, and Techniques

Handbook of Energy Modeling Methods

World Energy Projection System (WEPS): Global Activity Model

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1.1. GLAM Components

The WEPS Global Activity Module (GLAM) projects economic driver variables for the supply, demand, and conversion modules of WEPS. GLAM's baseline economic projection contains the economic assumptions used in WEPS to help determine energy demand and supply. GLAM can also provide WEPS with alternative economic assumptions representing a range of uncertainty about economic growth. The economic impacts of these assumptions become inputs for the remaining supply and demand modules of WEPS.

The GLAM comprises two models:

- Oxford Economics Global Economic Model (GEM)
- Oxford Economics Global Industrial Model (GIM)

GEM is the same model that Oxford Economics uses to produce its economic forecasts for the company's monthly assessment of the global economy. GIM provides the industrial output detail that WEPS requires. The GEM and GIM releases used for a particular IEO varies by IEO. GEM and GIM are linked to provide a fully integrated approach to estimating economic activity at the country/regional and industrial levels.

GEM projects each national economy's growth path and the final demand mix. The global industrial model ensures that supply by industry is consistent with the final demands (consumption, investment, government spending, exports and imports) calculated in GEM. Together, GEM and GIM constitute the Global Activity Module (GLAM) of the World Energy Projection System (WEPS).

To execute its suite of models, GLAM uses energy prices and quantities as inputs. In the current version, GLAM extracts oil and natural gas prices and demands, natural gas supply, electricity prices, and coal demand from the output of the demand and supply modules of WEPS. This data from WEPS is transformed into more aggregated data for GLAM. GEM and GIM execute in sequence to produce consistent estimates of macroeconomic and industrial activity. GLAM passes the economic driver variables for this output to the supply, demand and conversion modules of WEPS, and the system reacts to the new economic activity assumptions.

1.2. Oxford Economics Global Economic Model (GEM)

Key inputs: National population by age cohort, total factor productivity, tax rates and nominal expenditures, money supply, and energy prices and quantities

Key outputs: Final demands (consumption, investment, government purchases, exports, imports), inflation, foreign exchange and interest rates, incomes, employment, and balance of payments

1.2.1. Overview

The Oxford Economics Global Economic Model (GEM) is an international macroeconomic model that covers 80 countries and six additional regions with projections through 2050. Countries are modelled similarly, but larger economies have greater disaggregation and more financial sector detail. All of the

countries have forecasts for gross domestic product (GDP), consumer prices, exchange rates, and the current account. Each of the countries and regions is fully linked through trade, prices, exchange rates, and interest rates.

The structure of each country and regional model in GEM is based on standard economic theory. In the long-run, population growth and productivity drive economic activity, but the business cycles have fluctuations in the short-run. These business cycles arise from a number of factors, including wages and prices that do not adjust over short periods, non-competitive behavior by firms, and regulations, to name a few.

The long-run price level depends on monetary policy, which has no impact on economic activity over this time period. Monetary policy does, however, have a short-run impact on output, which also affects the price level.

Consumption in each country or region depends on income, wealth, interest rates, and inflation. Investment varies based on its risk-adjusted after-tax return, and exports are a function of world demand and the real exchange rate. Imports are determined by domestic demand and competitiveness.

1.2.2. Coverage of GEM

GEM covers 81 countries in depth and provides high-level details in another six regional groupings, including OPEC (Organization of the Petroleum Exporting Countries). Countries covered in detail include the following:

Europe	Americas	Asia	Middle East & Africa
Austria	Argentina	Australia	Algeria
Belgium	Brazil	China	Angola
Bulgaria	Canada	Hong Kong	Bahrain
Croatia	Chile	India	Egypt
Cyprus	Colombia	Indonesia	Ghana
Czech Republic	Ecuador	Japan	Iran
Denmark	Mexico	Malaysia	Iraq
Estonia	Peru	New Zealand	Israel
Finland	United States	Philippines	Kenya
France	Uruguay	Singapore	Kuwait
Germany	Venezuela	South Korea	Mauritius
Greece		Taiwan	Morocco
Hungary		Thailand	Namibia
Ireland		Vietnam	Nigeria
Italy			Oman
Latvia			Pakistan
Lithuania			Qatar
Luxembourg			Saudi Arabia
Malta			South Africa
Netherlands			Tunisia
Norway			Uganda

Poland	UAE
Portugal	Zambia
Romania	Zimbabwe
Russia	
Slovak Republic	
Slovenia	
Spain	
Sweden	
Switzerland	
Turkey	
United Kingdom	

The model also includes global and multi-region variables such as oil and commodity prices, world GDP and industrial production, OECD (Organisation for Economic Cooperation and Development) average inflation, and others.

Most of the countries map directly into one of the WEPS regions listed below:

- OECD: United States, Canada, Other OECD Americas, OECD Europe, Japan, Australia/New Zealand, South Korea.
- Non-OECD: Russia, Other non-OECD Europe and Eurasia, China, India, Other non-OECD Asia, Middle East, Africa, Brazil, Other non-OECD Americas.

For example, Argentina falls in *Other non-OECD Americas,* and Germany is in *OECD Europe*. The Oxford regions are broken up where appropriate (according to their shares of economic activity within the region) and assigned to the WEPS regions. For example, Syria is in Oxford's *rest of the world* region; it is separated from that region and assigned to the WEPS *Middle East* region.

We followed the same procedure for all of the countries that compose the remaining regional groups in GEM. The *rest of the world* and *rest of OECD* aggregations consist of all countries within those two groupings that are not already in the model.

1.2.3. Detailed Model Structure

1.2.3.1. Model Variables

Model variables are divided into demand and supply, core and non-core. Coverage of core variables is standard across all country models; non-core coverage is determined by data availability and country-specific requirements.

Core demand variables include all the aggregate expenditure components—consumption, investment, government spending, and net exports—at constant and current prices, monetary policy variables, and financial variables. The demand non-core variables include disaggregated consumption and investment, as well as important indicator variables such as retail sales and car sales.

Core supply variables include variables that determine output, unemployment, and real wages. Prices are also disaggregated within core supply. Non-core supply variables include disaggregated employment and nominal earnings. Other variables related to government and personal and corporate sector flow accounts are based on relationships outside of demand and core supply.

The model variables are expressed either in units of the local currency that most of the country or region use or in rates or ratios that have no units. Lowercase letters denote natural logarithms in the equations below. The data sets we used to estimate the model parameters also vary by country.

1.2.3.2. Projecting Consumption

For each region and projection year, the model estimates the natural logarithm of energy consumption by a 2-stage least squares (2SLS, described in Section B1) time series regression.

In the first stage, the model estimates a function of the following instrumental variables:

- Natural logarithm of energy consumption in the previous year
- A weighted average of the following:
    - Natural logarithm of real income during the previous year
    - Ratio of financial wealth to income during the previous year
- Real interest rate in the previous year

In the second stage, the model estimates the natural logarithm of year-to-year change in energy consumption as a function of the following variables:

- Year-to-year change in the natural logarithm of real income
- Year-to-year change in the natural logarithm of the unemployment rate
- The function of instrumental variables calculated in the first stage

1.2.3.3. Projecting Investment

Three aspects of gross fixed investment are identified in the model: private business, private housing, and government, which is input into the model.

The model projects private business investment based on standard theories of investment, which includes real oil price. Oxford assumed that the capital stock reaches its equilibrated level in the long run and fluctuates in the short run. These fluctuations occur because capital installation is costly and time-consuming, which means there is a difference between the benefit of an installed unit of capital and its cost. Firms invest when this benefit exceeds the cost, but they reduce or scrap capital in the reverse case.

This business behavior can also amplify changes in the economy, because firms may reduce or increase investment in response to changes in the value of the relative rate of return on investment, which is defined as the ratio of the market value of a company's assets to the replacement cost of the company's assets.

For each region and projection year, a regression model estimates year-to-year change in private sector business fixed investment (in local currency) as a function of the following independent variables:

- Relative rate of return on investment during the current year (percentage)
- The difference between the previous year's private sector business fixed investment and the previous year's value of capital stock
- Year-to-year change in real GDP (current year's GDP minus previous year's GDP)

The model estimates personal sector housing investment analogously to consumption, using real income, wealth, and interest rates, because they are part of a portfolio of spending decisions households make.

1.2.3.4. Projecting International trade

The model disaggregates trade flows into fuel, non-fuel goods, and services. The non-fuel goods components make up the majority of exports and imports for most countries. The model uses 2-stage least squares time series regression models to project year-to-year change in non-fuel exports and imports by region.

For the year-to-year change in exports model, the first-stage independent variables are as follows:

- Exports of non-fuel goods during the previous year
- World trade during the previous year
- A time trend

The second-stage independent variables are as follows:

  - Year-to-year change in world trade during the current year
  - Capacity utilization rate for the current year
  - Year-to-year change in labor costs in the country or region under consideration, relative to those in its trading partners, during the current year
  - The function estimated in the first stage

For the year-to-year change in imports model, the first-stage independent variables are as follows:

- Imports of non-fuel goods during the previous year
- Total final expenditures during the previous year
- Labor costs in the country or region under consideration, relative to those in its trading partners, during the previous year
- Capacity utilization rate during the previous year

The second-stage independent variables are as follows:

  - Year-to-year change in total final expenditures

- Year-to-year change in labor costs in the country or region under consideration, relative to those in its trading partners
- Year-to-year change in total final expenditure
- The function estimated in the first stage

The data sources for each of the variables above vary by country and region. The model coefficients capture the effects of non-price factors on a country's world trade share, as well as the effects that a sustained increase in production specialization has on imports. In general, a sustained decline in relative labor costs—an improvement in competitiveness—leads to an improvement in the trade balance in the long run.

The regression models for trade in services and total trade are analogous to those for non-fuel goods. Fuel trade is calculated as the residual—total trade less the sum of trade in services and non-fuel goods.

1.2.3.5. Links between economies

Through the core regression models described above and other financial calculations, GLAM links the individual countries and regions in a number of ways:

- Trade
- Labor and energy costs in a country relative to trading partners—competitiveness
- Interest and exchange rates
- Oil and other commodity prices
- Prices of manufactured goods

1.3. Oxford Economics Global Industrial Model (GIM)

Key inputs: Final demand, prices, and productivity measures from Oxford Economics model of the global economy

Key outputs: Real gross output for industrial and service sectors

GIM has a top-down structure, and sector forecasts are driven by national trends and aggregate demand from three regional blocs: the Americas, Asia Pacific and Europe, and Middle East and Africa. Sector demands from the three blocks are allocated to individual industries using weights based on regional input-output relationships. These relationships—derived from national input-output tables—show the percentage of each industry's output driven by consumer expenditure, investment, exports, government spending, and intermediate demand.

The model also takes into account the impacts of changes in competitiveness on an industry's market share, both regionally and nationally. Industry classification follows the European standard classification structure NACE, specifically NACE 2. This structure has eight major manufacturing sectors that are further broken down into subsectors:

- Basic metals

- Iron and steel, non-ferrous metals, casting
- Basic chemicals
- Other chemicals
- Coke, petroleum and nuclear fuel products
- Glass, ceramics, bricks, cement, and plaster
- Food, beverages and tobacco
- Pulp and paper
- Engineering and metal goods, motors, electrical equipment, machinery, electronics and computers, and appliances
- Motor vehicles, transportation equipment, and parts
- Wood and wood products, furniture, textiles, garments, leather goods, printing and publishing, rubber and plastics, and all other manufacturing

Other production sectors outside manufacturing include agriculture, extraction, utilities, and construction. We do not include utilities in aggregates of the industrial sector, but instead group it with the service sector.

The service sector includes the following subsectors:

- Retail and wholesale distribution
- Accommodation and catering
- Transport and storage
- Information and communications
- Financial services
- Business services
- Public administration services
- Education services
- Health care and social work
- Other services

The industry model provides projections of other variables, such as

- Value-added output and gross output across all industries and countries
- Producer prices across all industries for the United Kingdom , Germany, France, Italy, Japan, the United States, and China
- Employment and real and nominal investment across all industries for the United Kingdom

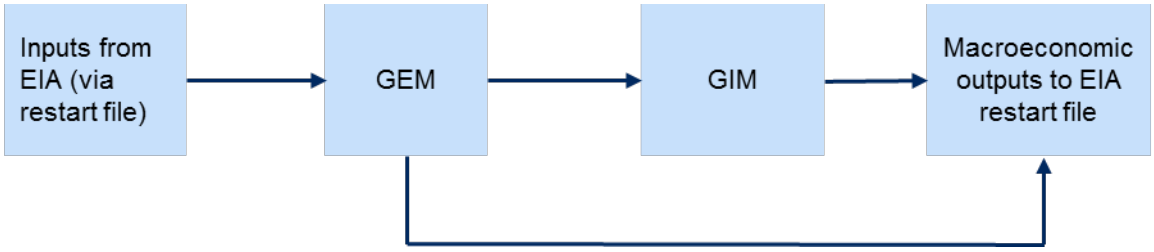
- Car and truck registrations and number of vehicles on the road for more than 44 countries
- Steel production for Belgium, China, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, the United Kingdom, and the United States
- Investment across all industries for all countries

2. The GLAM Interface with WEPS

2.1. Relationship to the WEPS System

The Global Activity Module (GLAM) provides economic projections for the other WEPS models to use, based on energy prices and quantities provided by other WEPS models. Because the time aggregation, country and region mapping, and variable definitions are different in GLAM than in other WEPS models, we use a transfer system to make them consistent.

Figure 1. Schematic of Global Activity Module (GLAM) transfer system

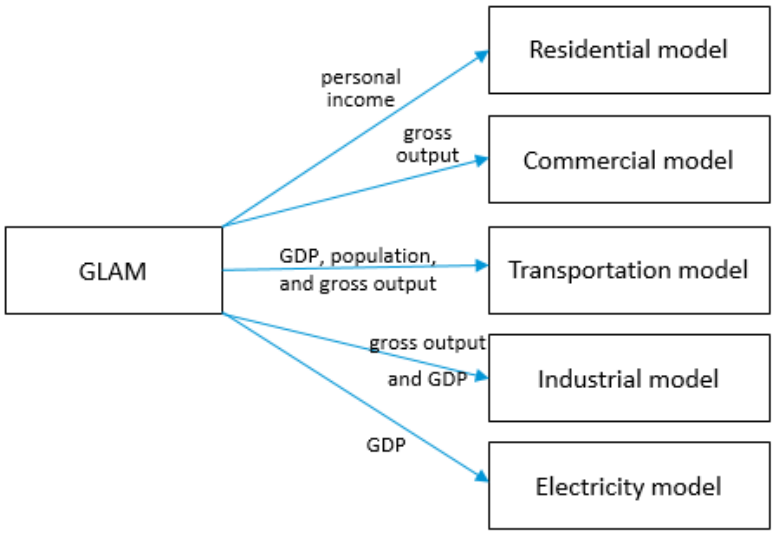


GLAM takes energy inputs from the WEPS common database and transfers them into GEM, aggregating and modifying as necessary. GEM converges to an equilibrium then passes relevant information to GIM, which then also converges to an equilibrium. Each model stores relevant outputs in the common database. In the final step, economic and population variables are passed from the GIM back to WEPS via a database.

2.2. Relationship to Other WEPS Models

Figure 2 shows the basic output structure of GLAM to the different end-use demand models in WEPS. GLAM also takes in energy prices and quantities from other WEPS modules.

Figure 2. The Global Activity Module (GLAM) relationship to other WEPS models



Note: gross domestic product (GDP)

GLAM projects many series and currently provides four main projected series to WEPS:

- Gross domestic product (GDP) by region, expressed in purchasing power parity (PPP)
- Population by region
- Personal income by region
- Gross output by region and economic sector

Before running GLAM, EIA modifies it to make it consistent with EIA energy prices. We export the GLAM results to the WEPS common database for use by the other WEPS models.