

The Applied Dynamic Analysis of the Global Economy (RTI ADAGE™) Model (2013): U.S. Regional Module Final Release



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1. OVERVIEW

The *Applied Dynamic Analysis of the Global Economy* (RTI ADAGE™): *U.S. Regional Module* is a dynamic computable general equilibrium (CGE) model capable of examining a wide range of economic policies and estimating how all parts of an economy will respond over time to policy announcements. Among the feasible set of policies are many types of economic, energy, and environmental policies. Of particular note is the ability of the ADAGE model to investigate climate-change mitigation policy issues affecting six types of greenhouse gases (GHG).

The latest iteration of the U.S. Regional Module includes nine household types, delineated by income, and nine regions for a total of 81 representative households. The income grouping provides a finer level of granularity among lower-income households and extends up to a \$150K+ household group at the high end. The groups are based on the IMPLAN economic data that form the model's benchmark dataset.¹ The nine model regions are defined by the U.S. Census bureau's Census Divisions.² The production structure architecture also has an abridged representation of several sectors including electricity generation.

The *U.S. Regional Module* uses a classical Arrow-Debreu general equilibrium framework to describe economies. Households are assumed to have perfect foresight and maximize their welfare (received from consumption of goods and leisure time) subject to budget constraints across all years in the model horizon, while firms maximize profits subject to technology constraints. Economic data come from IMPLAN databases and energy data, and various growth forecasts come from the U.S. Energy Information Administration (EIA) of the U.S. Department of Energy³ (see Table 1).

Table 1. RTI ADAGE™ Model Data Sources

Module	Version	Energy Data	Economic Data	Model Update
<i>U.S. Regional Module</i>	2013	AEO 2013	IMPLAN 2013	June 2015

A baseline growth forecast is established using EIA forecasts for economic growth, industrial output, energy consumption and prices, and GHG emissions. Starting from the year 2010,

¹ See www.implan.com for additional information.

² See http://www2.census.gov/geo/docs/maps-data/maps/reg_div.txt for additional information.

³ The current year of IMPLAN economic data is 2015 (see <http://www.implan.com> for information on the IMPLAN Group LLC). ADAGE uses the AEO 2013 forecast (see <http://www.eia.gov/forecasts/archive/aeo13/index.cfm>).

RTI ADAGE™ solves in 5-year time intervals along forecast paths for each policy analysis.⁴ The *U.S. Regional Module* includes four sources of economic growth: (1) growth in the available effective labor supply from population growth and changes in labor productivity, (2) capital accumulation through savings and investment, (3) increases in stocks of natural resources, and (4) technological change from improvements in manufacturing and energy efficiency.

For baseline and policy simulations, the module estimates the following economic variables:

- gross domestic product (GDP), consumption, industry output, and changes in prices;
- employment impacts and changes in wage rates;
- capital earnings and real interest rates;
- investment decisions;
- input purchases and changes in production technologies of firms;
- flows of traded goods among regions;
- energy production and consumption by businesses and households;
- fuel and GHG permit prices; and
- Hicksian equivalent variation (a metric used in benefit-cost analysis to describe the overall monetary value of economic welfare changes after considering all economy-wide adjustments, for example, changes in prices, income).

The *U.S. Regional Module* uses MPSGE (Mathematical Programming Subsystem for General Equilibrium; Rutherford [1999]) general purpose software.⁵ ADAGE is solved as a mixed complementarity problem (MCP) within the Generalized Algebraic Modeling System (GAMS) language (Brooke et al. [1998]).⁶ The GAMS/PATH solver is used to solve the MCP equations generated by the MPSGE software.

2. HISTORY, ACKNOWLEDGMENTS, AND GLOBAL MODULE

The original forward-looking ADAGE model was developed by Dr. Martin Ross and went through a peer review process in 2010. The Environmental Protection Agency (EPA) used variants of ADAGE when conducting climate economic analyses between 2007 and 2010.⁷ ADAGE was also used to support working group studies such as the Energy Modeling Forum (EMF 24) Study on "U.S. Technology and Climate Policy Strategies." This study included a pairing with the Electricity Market Analysis model a dynamic linear programming model of

⁴ Beyond the termination of policy investigations (generally around 2050), additional time periods are run to ensure that the model converges to a new steady-state equilibrium after a policy is implemented.

⁵ See also Horridge et al.'s Chapter 20, "Solution Software for Computable General Equilibrium Modeling," in the *Handbook of Computable General Equilibrium Modeling* (Dixon and Jorgenson, 2012) and <http://www.gams.com/solvers/solvers.htm#MPSGE> for more information.

⁶ See <http://www.gams.com> for more information.

⁷ <http://www.epa.gov/climatechange/EPAactivities/economics/legislativeanalyses.html>

U.S. wholesale electricity markets (Ross, 2008). The latest variation of the ADAGE international module is now a recursive dynamic, multiregion and multisector CGE model projecting the global/regional economy from 2010 to 2050 at 5-year time steps. The model uses the MPSGE framework and includes fossil fuel energy (coal, gas, oil, electricity), renewable energy (hydro, nuclear, wind, solar, bioenergy), highly detailed sectors on agriculture, bioenergy, land cover, and land use change. With the capacity to model all greenhouse gas emission (GHG) (including emission from land use change), marginal abatement cost of GHG emissions, and mitigation options (carbon tax and cap and trade), the model is capable of examining the interactions among agriculture, energy, and climate mitigation and performing public analysis for food, energy, and environmental issues at both regional and global scopes.

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