EMPAX-CGE: Application Capabilities as an Economic Driver for Emissions Projections

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Abstract

EGAS 5.0 is EPA's tool for calculating emissions growth factors. It currently utilizes economic activity data from the Department of Energy and REMI 5.5 and 6.0 to drive emissions on a state level. Although REMI 6.0 provides the economic data used for the majority of EPA's non-EGU emissions projections, it lacks the specifications needed to consistently project economic growth in the energy-intensive sectors that generate the highest quantities of non-EGU emissions. REMI does not incorporate EPA's current and future rules, regulations, and standards as well as the control strategies required to comply with these regulations and standards. As a result, REMI's economic growth path driving EGAS 5.0 is not set up to adjust to output changes in the affected sectors caused by EPA regulation and tends to over estimate future emissions growth projections. EMPAX-CGE is a computable general equilibrium model of the US manufacturing sectors developed by EPA for the purpose capturing changes in the economy and its growth path resulting from compliance with EPA regulations. It interlinks the energy intensive sectors into regional economies that allow for cross regional trading and movement within sectors. EMPAX-CGE's dynamic component permits market clearing over multiple time horizons and generates an economic growth path in five year intervals (2005 to 2050). This paper details the merger of EMPAX-CGE with EGAS 5.0 which may create a system that more accurately and consistently projects emissions for the sectors considered significant to the emissions inventory. As EMPAX-CGE is further developed into a state level model, it can replace REMI as the main economic driver for the energy-intensive sectors in EGAS.

Introduction

The EPA conducts Regulatory Impact Analyses (RIAs) to assess the benefits and costs of air regulations. These RIAs require emissions forecasts for all relevant source categories. For most Regulatory Impact Analyses, EPA uses emissions from a historical year, or base year, (e.g., 2001) as the starting point for forecasting potential future-year emissions. In evaluating the potential impact of the subject regulation, EPA develops multiple future-year emission estimates based on a range of regulatory options. In general, EPA estimates the future-year emissions by forecasting changes in the various activities that generate emissions and using this forecasted activity to generate an emissions growth factor which increases (or decreases) emissions. In the case of stationary NonEGU point and area sources (For this document, stationary non-EGU or

non-utility sources include large industrial combustion and process point sources (e.g., industrial boilers, petroleum refineries, chemical manufactures, etc.), as well as, small stationary commercial, institutional, and residential non-point or area sources.), these activities are generally represented by economic variables.

Our economic growth factor for stationary non-EGU sources has been based upon the results of the Policy Insight® Model for Regional Economic Model, Inc (REMI) by state and Standard Industrial Classification (SIC) codes as well as North American Industry Classification System (NAICS) codes along with fuel consumption forecasts by fuel type and energy sector (e.g., industrial, commercial, residential) from the US Department of Energy. For mobile sources and Electrical Generating Units, EPA has developed improved models specific to mobile sources (MOBILE and NONROAD models) and EGUs (Integrated Planning Model). The Integrated Planning Model is a market model of the electric utility industry that captures the impact of capital turnover and economically-motivated fuel switching on emissions. In addition to EGUs and mobile sources, inventory projections for agricultural ammonia emissions are based on projected animal populations provided by US Department of Agriculture.

EPA has observed a potential disconnect between our emissions forecasts for certain stationary non-EGU source categories and the historical record that are not apparent with the mobile sector and electrical generating units (EGU). This discrepancy appears to have led to a significant over-prediction of NonEGU point and area source future year emissions in longer-forecast periods required for the National Ambient Air Quality Standard (NAAQS) and other programs. In the case of mobile sources, the sector model (MOBILE 6.0) addresses many of the deficiencies apparent in the current approach for stationary non-EGU sources. MOBILE 6.0 directly incorporates equipment turnover and the issue of fuel switching. For EGUs, the deficiencies apparent with NonEGU and area sources are addressed in the Integrated Planning Model (IPM). We also have better emissions source testing due to the installation of continuous emission monitoring for these electrical units. Therefore, the disconnect between economic activity forecasts and emissions projections is due in large part to energy-intensive sectors (point and area sources) that make up a large portion of the stationary NonEGU sources and their emissions.

Several factors are causing this disparity. One being investigated, recognizing that this alone will not resolve the issue completely but could represent a starting point, is the economic data driver for energy-intensive sectors. Currently, REMI Policy Insight data provides the economic activity required to generate emissions growth factors. However, REMI was not designed specifically for the EPA's Office of Air Quality Policy and Standards or the Agency's Emissions Inventory Group. As a result, although the model provides economic activity for 70 sectors for future years, its focus is not on the interconnections of the energy and energy intensive sectors. In addition, REMI does not incorporate compliance costs of future EPA regulations and standards which would likely temper the growth path of the aforementioned sectors. Consequently, REMI forecasts for these industries may be inflated.

This paper focuses on improving the economic data used to derive national and regional emissions projections by proposing to replace REMI based energy-intensive growth factors with EMPAX-CGE based growth factors. Therefore, we present the regional and sector detail of EMPAX-CGE as well as its structure and show how it could improve upon economic projections for the energy-intensive manufacturing sector by incorporating its future output estimates into EGAS 5.0.

EGAS: Economic Growth Analysis System

The Economic Growth Analysis System version 5.0 (EGAS 5.0) is an economic activity forecast tool designed by EPA to generate emissions growth factors which are used in the development of grown emissions inventories. EPA's analysts then use these emissions projections to estimate cost and benefits of its regulations. The tool is intended for use by States, Regional Planning Organizations, local governments, and the EPA so that these entities may project air pollution emissions and design appropriate policies to control them. EGAS 5.0 produces these emission growth factors by linking emissions output to economic activity through a series of economic activity tables which contain future year economic output by industry and state.

EMPAX-CGE

In order to improve upon the inflated emissions growth factors generated in EGAS 5.0 using REMI economic activity, EPA will apply its computable general equilibrium model EMPAX-CGE as the primary economic driver for energy-intensive manufacturing sectors. EMPAX-CGE is a regional CGE model developed for the Environmental Protection Agency's Office of Air Quality Planning and Standards (OAQPS). It is designed to estimate regional macroeconomic impacts of environmental regulations on the United States' economy. Many major regulations directly affect a large number of industries and/or substantially affect markets for key factors of production. In either case, substantial indirect impacts may result from changes in production, input use, income, and consumption patterns for directly affected markets.

EMPAX-CGE combines a variety of economic and energy data sources to characterize energy production and consumption decisions with sufficient regional and industry detail to allow investigation of policies that may alter these decisions. These data are contained in a social accounting matrix (SAM) that shows current production technologies and demands by agents in the economy. The economic data in the SAM come from state-level information provided by the Minnesota IMPLAN Group,[1] while the energy data are provided by the Energy Information Administration (EIA) at the US Department of Energy.

[1] See http://www.implan.com/index.html for a description of the IMPLAN Group and their data.

Regional Detail

EMPAX-CGE currently disaggregates the US into five regions. As Figure 1 demonstrates the models produces economic output results for the Northeast, Southeast, Midwest, Plains, and Western part of the US. EPA is currently working on developing a version of EMPAX-CGE that would generate outputs for each state thus matching the regional detail of REMI.

Sector Detail

EMPAX-CGE's sector detail is presented in Table 1. The model focuses on six energy sectors (with distinction between fossil and non-fossil fuel sectors) and seven energy-intensive sectors. The energy and energy-intensive sectors represent industries that make up a significant portion of the stationary NonEGU emissions inventory for pollutants such as NOx and SO_2. As part of EPA's augmentation plans for the model, it is anticipated that the number of total sectors will increase to 25 or more. This would further improve the model's ability to generate emissions growth factors for industries that have a considerable impact on the emissions inventory.

Future Year Output

EMPAX-CGE uses baseline data representing the economy in 2005 and solves in 5-year increments out to 2050. For years following 2005, the model incorporates energy consumption and production forecasts generated by EIA. Thus, the model maintains a consistency with the energy sector due to its links to IPM and the incorporations of EIA based forecasts.

Figure 1. Regional Detail

Table 1. Sector Detail

Energy Production	Energy-Intensive Sectors	Others
Coal	Food	Agriculture
Crude oil	Paper	Other Manufacturing
Electricity *(fossil and nonfossil)*	Chemicals	Services
Natural Gas	Glass	Transportation
Refined Petroleum	Cement	
	Iron and Steel	
	Aluminum	

Model Structure

EMPAX-CGE employs a nested Constant Elasticity of Substitution (CES) model structure. These types of nested equations are used by the model to portray the types of substitution possibilities available to producers and consumers. Figure 2 illustrates this general framework and gives a broad characterization of the model. The diagram begins at the top with household decisions on consumption, followed by the trade structures used to generate aggregate consumption goods from domestic and imported varieties, and

finally covers the production functions that provide the goods. These CES functions provide the inputs needed to produce each output with their elasticities defining the ease of substitution between each level of the 'nest' (Figure 2).

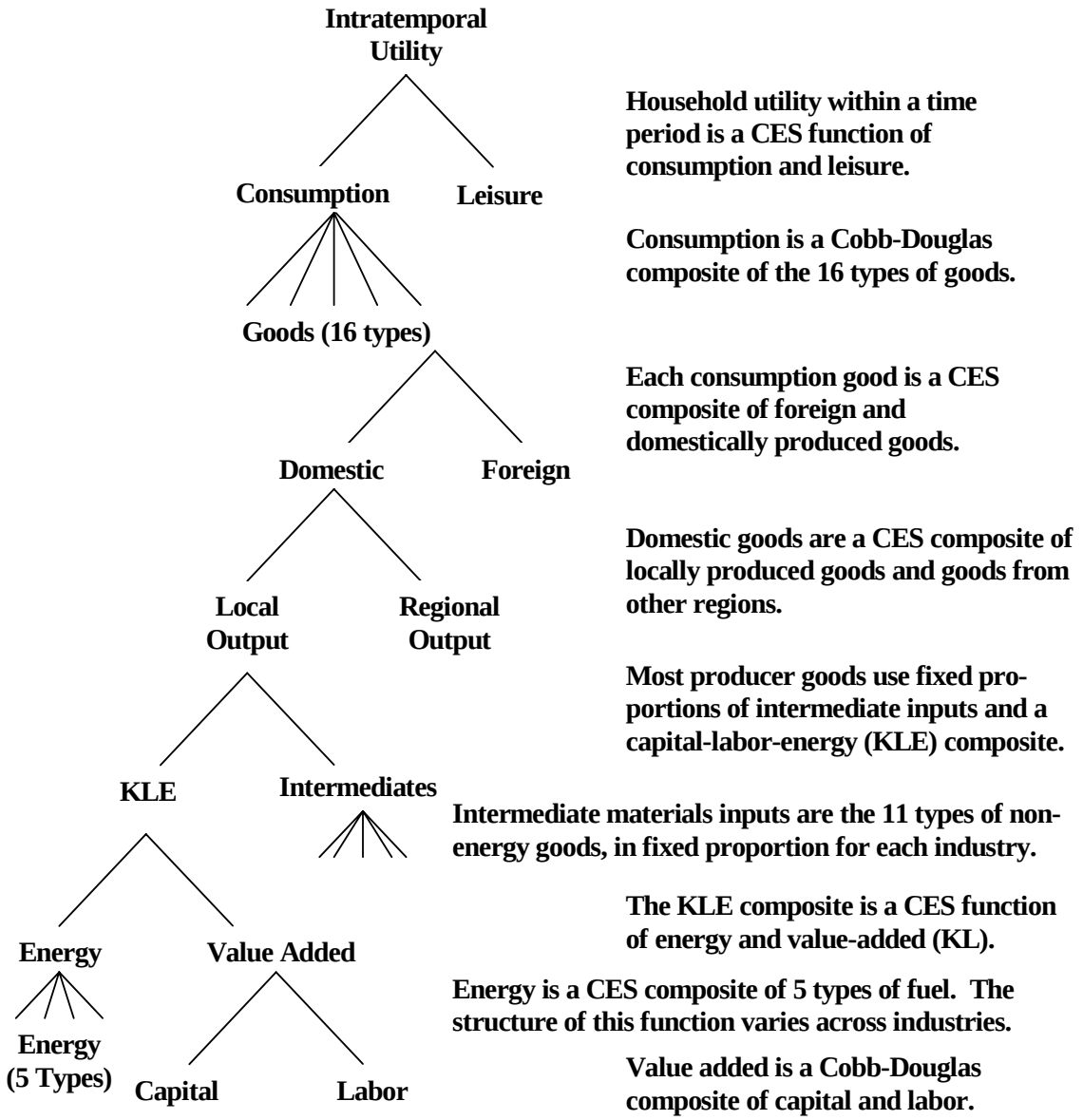
Households

As appropriate, each region within EMPAX-CGE contains one or more representative households. As shown at the top of Figure 2 (i.e., Level 1), the household(s) maximizes utility (welfare) received from consumption of goods and leisure time. Income used to purchase goods comes from sales of factors owned by the households, which include capital, labor and natural resources. As shown, in Level 2, households decide among the sixteen consumption goods in the model according to a Cobb-Douglas specification. This structure allows households to shift consumption of goods and services in response to policies. If a good's price increases, consumers can purchase less of that good and more of other types of goods. Effects of a policy on households' standard of living are determined by how willing and able they are to alter their consumption patterns.

Production Activities

The production activities used by most industries are illustrated in Levels 5, 6, and 7. Each industry maximizes profits, equal to the difference between revenues from sales and payments for factors and intermediate inputs, subject to technology constraints. The structure allows producers to change the

Figure 2. Structure



technology they use to manufacture goods. If, for example, electricity prices rise, an industry can shift away from electricity and into other types of energy. It can also elect to employ more capital or labor in place of electricity, which allows EMPAX-CGE to model improvements in energy efficiency. This ability to shift resource use and technology will then be incorporated into the emission growth factors generated in EGAS 5.0 and represent technology change and fuel switching capabilities among the energy-intensive sectors that are not available.

Levels four and five then describe the regional and international trade flows in the model that drive trade decisions.

Baseline Data

Economic data necessary to develop a SAM for EMPAX-CGE are provided by the Minnesota IMPLAN Group (see Table 2). State-level information from IMPLAN shows how goods are manufactured using various intermediate inputs and factors of production. It also shows demands for goods and services by agents such as households and government. In addition, IMPLAN contains information on how these expenditures are financed by households' sales of factors to businesses and by government tax collections.

Table 2. EMPAX-CGE Economic Data Sources

Data Source	Data Table	Data Elements
IMPLAN	State-level Economic data for 2000	Output by industry Inputs to industries Consumer purchases and income Exports and imports
Commodity Flow Survey (BEA)	Trade Flows in 1997	Interstate Trade Data by Commodity

IMPLAN contains data on production and consumption of 528 different types of commodities for the year 2000. These data have been developed from a variety of federal Government sources, including:

• U.S. Bureau of Economic Analysis Benchmark I/O Accounts of the United States,

• U.S. Bureau of Economic Analysis Output Estimates,

• U.S. Bureau of Economic Analysis REIS Program,

• U.S. Bureau of Labor Statistics Covered Employment and Wages (ES202) Program,

• U.S. Bureau of Labor Statistics Consumer Expenditure Survey,

• U.S. Census Bureau County Business Patterns,

• U.S. Census Bureau Decennial Census and Population Surveys,

• U.S. Census Bureau Economic Censuses and Surveys,

• U.S. Department of Agriculture Crop and Livestock Statistics, and

• U.S. Geological Survey.

The 528 sectors in IMPLAN have been aggregated into the 17 industries in EMPAX-CGE. These industries have been selected based on their relevance to the types of energy/environmental policies that EMPAX-CGE has been designed to investigate, in conjunction with the availability of complete energy and economic data. Thus, the model focuses on the energy-intensive sectors.

Energy Data Sources

The IMPLAN economic data are supplemented by additional data sources on energy production and consumption for two reasons: (1) because the policies being investigated by EMPAX-CGE focus on energy markets, it is essential to have the best possible characterization of these markets in the model, and (2) EMPAX-CGE uses a baseline starting year that is different from the year-2000 data provided by IMPLAN.

IMPLAN relies on government information when creating their datasets. Therefore, the focus of IMPLAN is not energy/environmental policies. This leads, in some instances, to differences between the IMPLAN economic data and the energy data collected by the Energy Information Administration at the Department of Energy. Where these differences occur, EMPAX-CGE is based on EIA data.

Information on energy production at the state level comes from EIA's annual industry profiles that collect data on coal, electricity, natural gas, and petroleum production. Energy consumption data in EMPAX-CGE are based on the Manufacturing Energy Consumption Survey (MECS) produced by EIA and historical data from EIA's Annual Energy Outlook (AEO), which shows industry-level consumption of different types of energy. The Commercial Buildings Energy Consumption Survey by EIA is also used to supplement energy consumption information from the MECS.

In addition, because EMPAX-CGE is used to investigate the effects of policies in the future, it requires a dataset that reflects changes that are expected to occur in energy markets in the absence of the policies under investigation. For this reason, EMPAX-CGE incorporates the forecasts from the AEO into its baseline dataset.

Sources of Growth

There are four sources of economic growth in the dynamic version of EMPAX-CGE: technological change from improvements in energy efficiency, growth in the available supply of labor from population growth and changes in labor productivity, increases in stocks of natural resources, and capital accumulation. Changes in energy use per unit of output are modeled through exogenous variables called autonomous energy efficiency improvements (AEEI), which are used to specify energy consumptions by fuel type and industry to replicate energy forecasts from EIA. Labor force growth, industrial output trends, changes in available natural resources, and resource prices are also based on the AEO forecasts. Therefore, to the extent that EIA can capture production efficiencies and output trends in the energy and energy-intensive sectors, these will then be incorporated

into EMPAX-CGE and potentially reflected in emissions growth estimates. Decisions regarding capital formation also control many of the dynamic aspects of the model.

Advantages of EMPAX-CGE over REMI for EPA's Use as an Economic Driver to EGAS 5.0

Advantages of EMPAX-CGE compared to REMI stem from its design and economic impact applications on EPA's Regulatory Impact Analyses. First, as previously described, EMPAX-CGE is designed to capture the economic impacts from environmental policy on the US economy focusing on the energy-intensive sectors while taking into account the industries' interconnections. As a result, the model output focuses on the regional economic and industry level impacts of these energy-intensive sectors and the response from interconnected industries and households to changes in quantity produced. REMI may lack the energy-intensive sector inter-relations needed for modeling these sectors. The augmentation of EMPAX-CGE to a state level model with perhaps 25 or more sectors will further improve its ability to generate credible regional and industry level output for EGAS 5.0. Second, due to its applications as the economic impact model for CAIR, CAVR, PM NAAQS, and eventually Ozone NAAQS, its growth path has incorporated compliance costs for these regulations that impact energy intensive sectors' output and likely result in lower emissions projections for these sectors. Finally, REMI is a proprietary model which is essentially a 'black box' to EPA while EMPAX-CGE is the Agency's dynamic computable general equilibrium model. This means that any detailed analysis or refinements of industry growth which may be required can be completed by EPA in a timely manner.

Other Factors Which Impact Emission Growth

EPA recognizes that a change in economic driver data will not alone resolve the potential disconnect between industry output and emissions growth. However, this represents a starting point and a constraint for economic variables that are likely to be linked to emissions growth. Other factors which influence the relation between economic activity and emissions growth are the following.

- Changes in the mix of production activities both within and between economic sectors,
- Changes in vintages of capital equipment,
- Changes in population, energy use, land use, or motor vehicle miles traveled,
- Technological innovation or changes altering:
    - Production processes for emission sources,
    - Control technologies available,
    - Substitution of inputs to production (e.g., fuel switching), and
- Emission controls implemented to satisfy CAA regulations, voluntary programs and other initiatives expected to reduce air emissions.

Although EMPAX incorporates energy use and is capable of capturing changes in production resulting from a change in the input use combination, as well as some technology changes resulting from changes in these input combinations, these policy evaluations are performed at the industry level. In many instances, a complete analysis of the relation between economic activity and emissions output will require facility level analysis of vintage of capital, production process trends, along with emission control technology changes. In addition, in some cases, variables such as land use, population growth, and/or migration may end up being more influential than industry output in determining the level of future year emissions. These factors should be analyzed in addition to industry activity in attempting to improve upon emissions growth forecasts.

Concluding Remarks

An incorporation of EMPAX into EGAS 5.0, as the primary driver for the energy intensive sectors may provide a starting point for improving the economic data used to drive emission projections. The economic activity would be based on a model designed to estimate economic impacts for an important portion of all stationary NonEGU sources in the emissions inventory. Economic growth paths would include compliance costs for current and future EPA standards and regulations and therefore result in reductions in emission projections. Research into other factors that influence future year emissions such as population growth, land use, motor vehicle miles traveled, voluntary emission controls, and facility level industry analysis of capital vintages and technology changes is still needed to more accurately specify emission projections.

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