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Integrated Modeling Frameworks

Randall Jackson
West Virginia University, randall.jackson@mail.wvu.edu

Regional Research Institute
West Virginia University

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INTEGRATED MODELING FRAMEWORKS
A guide for research projects

Randall Jackson

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Abstract

This document is intended to clarify the foundations of the IO and CGE analytical frameworks and procedures that underlie the NSF and USDA/NIFA funded research projects. It covers environmental data, life cycle assessment (LCA), input-output models (IO), structural decomposition analysis (SDA), social accounting matrix models (SAMs), and computable general equilibrium modeling (CGE).

Introduction

This document is intended to clarify the foundations of the IO and CGE analytical frameworks and procedures that underlie the NSF and USDA/NIFA funded research projects. It will be presented very concisely, and is not intended to be completely comprehensive. Some obvious kinds of descriptive comparison techniques will be used. It also focuses on modeling foundations leading up to the construction of the SAM/CGE frameworks to be used, and is not intended to address fully the kinds of CGE analyses that can be done.

Environmental Data

Environmental data are generally linked to production levels by their relation to output volumes. For each industry, we will generally have estimates of emissions/$. While this is imperfect, since prices change over time, it provides a point of reference, and can be useful for qualitative comparisons. The quantitative results will

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bear some inaccuracy, but rankings of policy alternatives are likely to be more reliable.

Results relative to the power generation sector should be especially informative, given that we have environmental data at the sub-sector level (e.g., natural gas, coal, hydro) that when weighted according to supply percentages will yield markedly different emissions/$ estimates.

Life Cycle Assessment

LCA is an intensive focus on the processes involved in a particular economic production activity. The result of LCA is called a process model. A process model details the economic and environmental inputs and outputs used and produced in the production process.

Input-Output Models

IO models have a variety of applications, founded on a database that identifies the buyers of each industry's outputs, the sources of each industry's inputs, the goods and services purchased by households, governments, investment activities (like the construction of new factories), and exports. The sources of goods and services include industries, households, governments, and imports. All of these sales and purchases are quantified in financial amounts (e.g., $US).

These data can be arranged in tabular (matrix) format such that the rows correspond to sellers (i.e., industries, households, government and other institutions, capital) and columns correspond to buyers. The industry accounts are "double-entry" in the sense that the sum of industry purchases (inputs) equals the sum of industry sales (outputs) for each industry. Industry purchases include all payments by industry, including payments to capital (profits), so receipts (sum of sales) always equal expenditures (sum of purchases).

The IO accounts become a behavioral modeling framework when some behavioral assumptions are made, the most important of which is that each industries purchases are fixed proportions of output, so that increases in output of n% will require increasing all purchases by n%. With this assumption, we can solve the input-output system for the total requirements of all inputs that are needed to produce a given amount of output, e.g., for export. Since each industry requires inputs from other industries to produce output, each supplying industry will need to purchase more inputs from other industries, and so on. This set of interindustry relationships gives rise to the well-known multiplier effects that are often used to characterize economic structure, economic impacts, etc.

It is apparent, then, that if one industry's purchasing pattern – its production function – changes, the other industries will also be either directly or indirectly effected. Likewise, the region's overall economic structure will change. This link between economic structure and industry production function provides the first direct link to the two projects.

The NSF project involves the comparison of two regions – first without any change, and then under policies or strategic programs that will alter the production functions of the energy sector. The energy sector production function will change as the two regions adopt new technologies (e.g., gas or renewables to replace coal). These changes will result in altered economic structures. The differences between new and old structures can be quantified and assessed for their implications on economy and environment. Note that the changes can be real and observed or hypothetical. Hypothetical scenarios allow the ex ante assessment of alternative energy policies and programs. Databases exist that can be used to parameterize the production functions and the environmental emissions of energy and other industry activity.

The NIFA project involves the introduction to an economy of new biomass energy production technologies and related industrial activity. The introduction of these activities will fundamentally change the economic structure of the region, which will again allow for the quantification and assessment of these economic and environmental changes. LCA data will be used to modify and augment publicly available production and environmental data.

Structural Decomposition Analysis

SDA is a mathematical approach to the comparison of two economic structures that uses IO accounts as input data. SDA can facilitate a temporal analysis by comparing the economic structure of one region but two different time periods, or cross-sectional by comparing two different in one time period.

Differing levels of economic output reveal economic structural changes or differences. These changes, for each industry, are decomposable into two parts: the change/difference that is attributed to changes/differences in final demand (i.e., increases or decreases in personal consumption, investment, government, exports), and the change/difference that is attributed to technology (i.e., production functions and interindustry relationships). Both types of changes will be expected for temporal analyses, and both can be relevant for cross-sectional comparisons depending on the nature of the policies and programs under study.

The Social Accounting Matrix

SAM models are often viewed as extended IO models. The extensions typically include the provision of additional detail on institutions – particularly households – and the relationship among value added (income, profits, government receipts) and final demand (investment, government expenditures, etc.). The SAM completes the representation of the circular flow of income in an economy. An expanded but still concise description of SAMs can be found here.

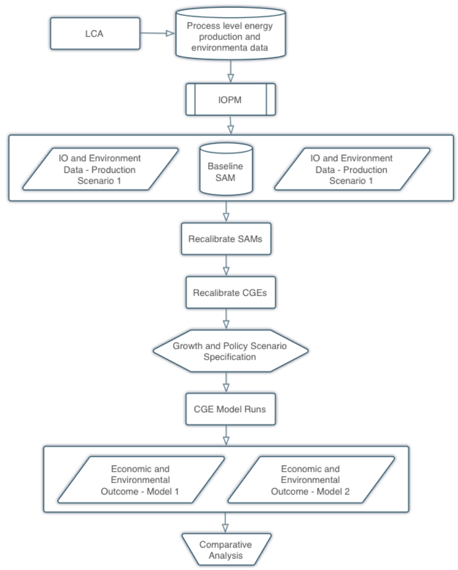
Since SAMs extend IO models, the information in IO models that differentiates economic structures will be embedded in SAMs that are derived from them.

Computable General Equilibrium

CGE models are used to simulate economic behavior that extends beyond the kinds of behaviors that can be modeled using IO or SAM models. Much of the data used to parameterize a CGE model come from SAMs. For this reason, a CGE built upon one SAM will exhibit different behavior and generate different solutions to a CGE built upon another. This provides the opportunity to develop separate models, e.g., for southern WV with and without biomass production, or to develop a single model that includes a biomass production sector, then run the model with economic activity in that sector and again without economic activity in that sector and compare the model outcomes. Likewise, for the NSF project, we can develop a CGE model with representations of all technologies but different levels of operation in each simulation scenario.

The generalized modeling process is shown in Figure 1, below.

Figure 1: Generalized Modeling Process



Note that the two projects currently underway will not be identical but will be instances of this generalized process. For example, the NIFA project will explicitly incorporate aspects of an LCA underway in the Forestry department as a part of the project, whereas in the NSF project we will make use of secondary data from LCA procedures implemented elsewhere and by others.

Also note that for the NSF project there will be two baseline SAMs, one for WV and one for Shanxi Province. Each will be modified according to the modeling scenarios to be evaluated. For the NIFA project, there will be one baseline IO and SAM that models the economy without having introduced woody biomass production, and that IO/SAM pair will be modified to generate the second IO/SAM/CGE model.

Both model databases will support SDA analyses. For NSF, the SDA will decompose the differences between the two regional economies (WV and Shanxi), while the NIFA SDA will be a before and after comparison of the same region.