The Regulatory Assistance Project

The E3-India Model

Technical model manual, Volume 7:
Special modules

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clarity from complexity

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Contents

1 Introduction

1.1 Introduction

This volume provides additional technical detail about some of the features of E3-India. It is anticipated that this volume will be expanded as the model develops over time.

The following section describes different approaches to energy modelling, which are highly relevant to E3-India. Section 3 provides initial insights as to how the model could be linked to other specialised modelling platforms.

One example of model linking which has already been carried out is the integration of the FTT power sector model. A description of FTT is provided in Volume 5, Section 3.

2 Top-Down and Bottom-Up Modelling Approaches

1.1 Overview

The terms ‘top-down’ and ‘bottom-up’ are often used in economic and energy modelling. Unfortunately, they have more than one meaning which can lead to confusion. This appendix aims to clarify the position of E3-India with regards to top-down and bottom-up modelling, and discusses the issues in the context of energy modelling more generally.

1.2 Top-down and bottom-up in the economic context

For E3 modelling the terms top-down and bottom-up in general refer to the approach used for the energy sector, as discussed in the next section. However, the labels are still sometimes applied to economic sectoral models.

A top-down economic model is one where macro-level indicators are determined first and then the sectoral outputs are estimated by sharing out the macro results. In contrast, a bottom-up economic model is one where output is determined at the sectoral level, and then the macro impacts are derived as the sum of the sectoral results.

In economic terms, E3-India is a bottom-up model. It consists of 20 sectors in and outcomes of macro-level indicators, such as GDP, are determined by taking the sum of the sectors.

The one exception to this is the model’s consumption equations, where a top-down approach is applied for theoretical reasons. First, total household expenditure is estimated based on available incomes; this is then shared between different consumption categories. These equations are described in more detail in volume 4.**Error! Reference source not found.**

1.3 Top-down and bottom-up in the energy-environment context

E3ME, and the E3-India model, are both intended to be integrated top-down, bottom-up models of E3 interaction. The current model can be summarised as:

- including a bottom-up model of the electricity supply industry
- being otherwise top-down in approach

Future bottom-up submodels are being planned for the domestic and transport sectors but are not included in the current model version.
Top-down economic analyses and bottom-up engineering analyses of changes in the pattern of energy consumption possess distinct intellectual origins and distinct strengths and weaknesses (see Table A1).

Similarly the mechanisms which represent the driving forces in the respective analyses are very different. In economic models change is usually modelled using elasticities, such as substitution between factors, or price and income elasticities. In bottom-up modelling the determinant force is captured by the relationship between technological options and usually by some notion of the discount rate employed by economic agents (households, firms and the government). In some sense, the discount rate employed in bottom-up models is the mirror image of an elasticity employed in top-down models. Both factors will determine the extent to which agents react to changes in the conditions associated with the energy supply chain (see Barker, Ekins and Johnstone, 1995).

Perhaps the most significant difference is in the treatment of capital and technology. In top-down models capital is usually treated as a homogeneous input, which is related to energy only insofar as it is assumed to possess a degree of substitutability with energy inputs in production. Technological change (i.e. qualitative change in the characteristics of capital) is usually represented as an exogenous trend, sometimes explicitly related to energy consumption, affecting the productivity of the homogeneous capital input.

Conversely, in bottom-up models capital is given an explicit empirical content and is related to energy in a very specific way, either in terms of generating equipment, other energy-related capital, or public infrastructure. Technological change is represented as a menu of options presently available or soon-to-be available which enjoy increasing market penetration.

Table A1: Comparison of top-down and bottom-up modelling methodology

	Bottom-up	**Top-down**
Classifications employed	Engineering-based	Economics-based
Treatment of capital	Precise description of capital equipment	Homogenous and abstract concept
Motive force	Discount rate employed by agents	Income and price elasticities
Perception of market	Market imperfections and barriers	Perfect markets (usually)
Potential efficiency improvements	Usually high with options for costless improvements	Usually low due to economic assumptions

The two approaches also start from different conceptions of the nature of markets. Most top-down models, although not E3ME or E3-India, do not admit to the possibility of market imperfections (e.g. imperfect competition). Most importantly, the existence of costless (i.e. economically preferable) opportunities is often assumed away (except at the margin). Energy consumption (and thus carbon dioxide emissions) are a reflection of revealed preferences and thus any alternative technological scenarios which have not been taken up in the economy are left unexploited for sound economic reasons, such as agent uncertainty (with respect to supply and demand factors) or 'hidden' factors (such as disruption or management costs). Conversely, in bottom-up models the inability of the economy to reach a technologically efficient supply chain in terms of the provision of energy services is attributed to market imperfections (e.g. credit constraints, information asymmetries, transaction costs). The relationship between such imperfections and decision-making is, however, left unexplored.

As noted, both types of analysis possess important strengths, but both have weaknesses when used to address long-term issues. On the one hand in top-down models, the notion that an elasticity of substitution between capital and other factors (estimated on the basis of 30-40 years of data, or imposed on the basis of intuition or the requirements of functional form) can be used to make useful comments about the world over the next 50 or 100 years from now is suspect. Indeed, beyond a certain number of years it is the engineering characteristics of the 'back-stop' technology, and not the behavioural relations themselves, around which the carbon-energy-output relationship revolves.

On the other hand the depiction of the long-run in bottom-up models as a menu of technological options is clearly unsatisfactory as well. At best, the technological options can be presented in chronological form (commercially available, in development stages, technologically feasible), coming on line progressively. By defining capital precisely the models cannot be made dynamic in a satisfactory manner unless the path of technological change is known, and as such are restricted in their relevance to short and medium-term analysis.

In addition, the characteristics of the two approaches limit the relevance of the respective analyses. For instance, top-down models are not able to analyse the effects of non-price based policies which affect the nature of the market itself and not just prices within the market. Institutions and regulations are (implicitly) not subject to change. Given the prevalence of imperfections in the market for energy services, such an omission is significant.

Conversely, bottom-up models are not able to analyse the price effects of the introduction of the options enumerated, or associated feedback effects. For instance, an analysis which examines the technological options available to the electricity supply industry misses important feedback effects unless it examines the effects of such a programme on the construction industry which undertakes the conversion, on the energy sector which is faced with significant dislocation, and on those sectors which use electricity and other energy carriers intensively as inputs in production.

3 Linking E3-India to other models

3.1 Why link to other models?

E3-India provides an integrated representation of the economy and energy systems in India. The analysis in the model is carried out at a relatively high level of detail, with 20 sectors covered in the 32 states and territories. E3-India is already linked to the FTT power sector model (see Volume 5, Section 3), which provides a representation of the key technologies in the power sector at state level.

However, as with all modelling tools, E3-India has clear limitations and boundaries and there are some policy-related questions that the model is not suitable to address. But the other existing modelling tools that could address these questions may not be able to provide insights to e.g. jobs and GDP that E3-India is designed to assess. There may therefore be benefits to using a combined modelling approach.

Issues to be aware of

There are both theoretical and practical considerations to bear in mind when linking models. For example, as a simulation model, E3-India does not make any assumptions about optimisation and thus there could be difficulties in interpretation when linking to other optimisation tools. At a more practical level, other models may use different classifications, units or definitions of key indicators.

One-way model linkages, where the results from one model are fed into another are reasonably common. Two-way linkages, where the models interact with each other iteratively, are less common and much more complicated to build.

This section of the manual provides two examples of how E3-India could be linked to other tools. In both cases the linkages are one-way. The links can be described as 'soft' in that they are in the form of data transfers. 'Hard' links involve integrating software, which is a much more resource-intensive exercise.

3.2 Linking E3-India to an energy systems model

Energy systems models are commonly used in academia and in analysis for the IPCC (for example as part of Integrated Assessment Models). The TIMES model, maintained by IEA ETSAP, is a commonly used example.

Energy systems models are 'bottom-up' in design; they cover the energy system from an engineering perspective at a high level of detail. They do not usually include links to the rest of the economy, however.

There are therefore potential advantages in combining energy systems models with E3-India. Most energy systems models are optimisation tools and results must be interpreted carefully – essentially E3-India suggests what might happen to GDP and jobs if the energy path determined by the energy model was realised.

The procedure for linking is as follows:

- Run the scenario in the energy systems model.
- Convert the results from the model into categories consistent with E3-India, for example in terms of fuels and sectors, and on an annual basis.
- Set the fuel equations in E3-India to exogenous. The easiest way to do this is to insert the line 'CALIB FR0,FRET,FRGT,FROT,FRCT ON' into the instructions file beneath the other calibration (CALIB) statements.
- Set the values of FR0A (total fuel consumption), FR01 (coal), FR02 (oil), FR03 (gas), FR04 (electricity) to be consistent with the results from the energy model – either by entering in the instructions file or writing to the model databank.
- Check to see if there are any other scenario inputs (e.g. carbon prices) that should be entered to E3-India.
- Run the scenario in E3-India.

3.3 Linking E3-India to micro-simulation model

Micro-simulation models provide breakdowns of impact by detailed social group. They are based on very detailed survey results that give indications of the structure of the population in terms of incomes and social condidtions. They thus address one of the limitations of E3-India, which, due to data requirements, does not include such a detailed aggregation.

The procedure for linking E3-India to a micro-simulation model is quite different to the one described above for energy modelling. Usually it would be the outputs from E3-India that are used in the micro-simulation model, rather than the other way round.

The key steps are:

- Define the key inputs that the micro-simulation requires – e.g. household incomes, unemployment rates.
- Run the scenario in E3-India, in the usual way.
- Convert the results from E3-India into the dimensions required by the micro-simulation model.
- Provide the inputs required by the micro-simulation model.