

The Regulatory Assistance Project

# The E3-India Model

## Technical model manual, Volume 3: Data and Model Validation



This volume (3) is part of an 9-volume series covering the E3-India model

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## Authorisation and Version History

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# 1 Model Inputs and Outputs

## 1.1 Introduction

This volume describes E3-India's main model inputs and outputs. The following sections describe the main inputs that the model relies on, including data and econometric parameters. The final part of Chapter 1 describes the format of the main model outputs.

Chapter 2 in this volume describes the intensive model validation exercise that has been undertaken. The appendices provide a list of model inputs, outputs and classifications.

## 1.2 Data inputs

### Introduction to the model databanks

The data are the most important single input to E3-India. A lot of effort is put into ensuring that the model data are accurate and consistent to the maximum degree possible.

The following databanks are used to store the data:

- T – historical time-series data
- F – processed baseline forecast (see Section 4)
- X – cross-section data, including input-output tables and equation parameters
- E – energy balances, prices and emissions
- U – classification titles

One other databank is used for model operation:

- S – holds the calibration factors to match the baseline forecast (see section 4)

E3-India's data requirements are extensive and specific. All data must be processed so that they are in the correct classifications and units. Gaps in the data must be filled (see below). All data processing is carried out using the [Oxmetrics software package](#).

### Time-series economic data

It is a substantial exercise to create and maintain the time series of economic data. The main dimensions involved are:

- indicator
- states
- sector
- time period (annually from 1993)

In addition, indicators that are expressed in monetary units have constant and current price versions. Cambridge Econometrics therefore puts a large amount of resources into processing the time-series data.

The raw data are gathered from the sources described below and stored on the T databank. The model uses official sources as much as possible. It is often necessary to combine data sets to fill out gaps in the data and to estimate remaining missing values (see below).

*The main indicators*

A 'V' at the start of the name indicates a current price value; otherwise the indicator is expressed in constant prices (2010 rupees). The main indicators with full sectoral disaggregation are:

- QR/VQR – output (constant and current price bases)
- YVM/VYVM, YVF/VYVF – GVA at market prices and factor cost
- KR/VKR – investment
- CR/VCR – household expenditure (by product)
- GR/VGR – government final consumption (by category)
- QRX/VQRX – exports
- QRM/VQRM – imports
- YRE – employment
- YRLC – labour costs (current prices)

There are also time series for population (DPOP) and labour force (LGR), disaggregated by age and gender.

In addition, there are several macro-level time series that are used in the modelling. These include GDP, household incomes, tax and interest rates and the unemployment rate. They are also collected on an annual basis, starting from 1993.

*Data sources for E3-India's economic data*

Table 1-1 gives a summary of the data sources for economic variables used in the E3-India model.

The data must be consistent across states and in the same units. For monetary data, the rupee is used.

**Table 1-1: E3-India data sources for economic variables**

Variable	Source
Population	Census of India MOSPI Net State domestic product series
Unemployment and labour participation rates	NSSO Employment and Unemployment in India Surveys NSSO Employment and Unemployment Situation in India Surveys NSSO Household expenditure and Employment Situation in India Surveys
Employment	NSSO Employment and Unemployment in India Surveys NSSO Employment and Unemployment Situation in India Surveys

	NSSO Household expenditure and Employment Situation in India Surveys
Gross output and value added	MOSPI Gross State domestic product 1993-2006, 1999-2010, 2004-14 MOSPI Gross State value added 2011-2015 MOSPI Mining production by state and product 2009-13 Own estimation using information from national total
Consumer expenditure	NSSO Household Consumer Expenditure in India NSSO Household Consumer Expenditure and Employment situation NSSO Key Indicators of Household Consumer Expenditure in India NSSO Level and Pattern of Consumer Expenditure E3 India state rural and urban population
Government spending	Reserve Bank of India State Finances: A Study of Budgets India Ministry of Finance Union Budgets E3 India Population Own estimation using information from national total
Investment	Own estimation using information from national total (share of investment in national accounts)
External trade	Own estimation using information from national total (share of trade in national accounts)
Total gross disposable income	Own estimation using information from national total (ratio of gross disposable income and total wages and salaries in national accounts)
MOSPI – Indian Ministry of Statistics and Programme Implementation NSSO – Indian National Sample survey reports	

### *Values and price indices in E3-India*

The general principle adopted in E3-India is that variables are defined in the currency unit appropriate for the use of the variable. This usually means that the units of measurement follow those in the data source. The principle of comparability is taken to imply that most current values are measured in millions of rupees and most constant values in millions of rupees at 2010 prices.

The price indices are calculated by dividing current by constant values in rupees.

### **Cross-sectional data**

By cross-sectional data we mean data that are not usually available in time-series format. Historically, this has meant input-output tables. Other cross-sectional data include converters between model classifications that do not normally change over time.

### *Input-output tables in E3-India*

Input-output data in E3-India remains a key challenge as state-level input-output tables are not generally available. India's input-output table from the OECD database has been used in all states but there is an adjustment to make sure that economic input-output relationships are consistent with the energy balances in physical terms at state level.

Input-output flows are converted to coefficients by dividing the columns by industry output. These coefficients give the number of units of input required to produce one unit of output.

## Energy and emissions data

State-level energy and emissions data for E3-India come from various sources. Where state-level data are not available, national data are used as proxies.

**Table 1-2: E3-India data sources for energy variables**

Variable	Source
Coal consumption	MOSPI Installed capacity, generation and consumption 2007-2013 E3ME National coal consumption data E3ME Output Data E3-India Population data E3-India Output data
Oil consumption	Indian Petroleum and Natural Gas statistics (Ministry of Petroleum & Natural Gas) E3ME National oil consumption data E3ME Output Data E3-India Population data E3-India Output data
Gas consumption	MOSPI Installed capacity, generation and consumption 2007-2013 E3ME National gas consumption data E3ME Output Data E3-India Population data E3-India Output data
Electricity consumption	MOSPI Electricity sold to ultimate consumer: 2007-2013 E3ME National electricity consumption data E3ME Output Data E3-India Population data E3-India Output data
Biomass Consumption	MOSPI renewable generation capacity data E3ME National biomass consumption by fuel user E3ME Output Data E3-India Population data E3-India Output data
Energy Prices	E3ME National Fuel prices
MOSPI – Indian Ministry of Statistics and Programme Implementation	

### Energy use data in E3-India

Detailed fuel usage information was not available at state level. To estimate fuel usage, the capacity of power plants using different fuel types was used to estimate the majority of fuel use and then estimates of fuel usage by industry were made given the profile of sectors operating in each state.

### Energy price data in E3-India

State-level energy prices for each fuel are also not available. Instead, energy prices for each state are assumed to match the national Indian prices obtained from the IEA Energy Statistics which provide prices (before and after taxes) in



USD per tonne of oil equivalent by country and by fuel. Global fossil fuel price data for oil, coal and gas also come from the IEA.

### *CO<sub>2</sub> emissions in E3-India*

Time-series data for CO<sub>2</sub> emissions, disaggregated by energy user, are calculated using national emission coefficients.

### **Correcting for missing data points**

The team at Cambridge Econometrics has developed a software package to fill in gaps in any of the E3-India time series. The approach uses growth rates and shares between sectors and variables to estimate missing data points, both in cases of interpolation and extrapolation. Some time series have specific rules for filling gaps in the data, but the general procedures are described here.

The most straightforward case is when the growth rates of a variable are known and so the level can be estimated from these growth rates, as long as the initial level is known. Sharing is used when the time-series data of an aggregation of sectors are available but the individual time series is not. In this case, the sectoral time series can be calculated by sharing the total, using either actual or estimated shares.

In the case of extrapolation, it is often the case that aggregate data are available but sectoral data are not; for example, government expenditure is a good proxy for the total growth in education, health and defence spending. A special procedure has been put in place to estimate the growth in more disaggregated sectors so that the sum of these matches the known total, while the individual sectoral growth follows the characteristics of each sector. Interpolation is used when no external source is available, to estimate the path of change during an interval, at the beginning and end of which data are available.

Under different assumptions, time-series forecasts are created for each country and each aggregated variable: consumption, employment, GDP, trade and investment (see Section 4).

### **Naming conventions**

E3-India's software limits model variables to four character names. These characters are typically used to identify first the dimensions of the variable (excluding time, which is a dimension for all the variables) and then the indicator. In particular, Q indicates disaggregation by product, Y by industry, F by energy (fuel) user and R by region. If a variable name starts with P then it usually indicates a price. S and O can be used to identify sums.

These conventions are used in the data processing and in the model itself. Some examples of common variables names are provided below:

- QR: (Gross) output by product and by region
- YR: (Gross) output by industry and region
- YRE: Employment by industry and region
- YRW: Wage rates by industry and region
- YRVA: Gross value added by industry and region
- CR: Consumption by consumption category and region
- PCR: Consumption prices by category and region
- RSC: Total consumption by region
- PRSC: Aggregate consumer price by region

- KR: Investment by investment category and region
- FR0: Total energy consumption by energy user and region
- FRET: Electricity consumption by energy user and region
- FCO2: CO<sub>2</sub> emissions by energy user and region
- RCO2: CO<sub>2</sub> emissions by region

### 1.3 Econometric parameters

The econometric techniques used to specify the functional form of the equations are the concepts of cointegration and error-correction methodology, particularly as promoted by Engle and Granger (1987) and Hendry et al (1984).

In brief, the process involves two stages. The first stage is a levels relationship, whereby an attempt is made to identify the existence of a cointegrating relationship between the chosen variables, selected on the basis of economic theory and a priori reasoning, e.g. for employment demand the list of variables contains real output, real wage costs, hours-worked, energy prices and the two measures of technological progress.

If a cointegrating relationship exists then the second stage regression is known as the error-correction representation, and involves a dynamic, first-difference, regression of all the variables from the first stage, along with lags of the dependent variable, lagged differences of the exogenous variables, and the error-correction term (the lagged residual from the first stage regression). Due to limitations of data size, however, only one lag of each variable is included in the second stage.

Stationarity tests on the residual from the levels equation are performed to check whether a cointegrating set is obtained. Due to the size of the model, the equations are estimated individually rather than through a cointegrating VAR. For both regressions, the estimation technique used is instrumental variables, principally because of the simultaneous nature of many of the relationships, e.g. wage, employment and price determination.

**Software used** E3-India's parameter estimation is carried out using a customised set of software routines based in the Ox programming language (Doornik, 2007). The main advantage of using this approach is that parameters for all sectors and countries may be estimated using an automated approach.

The estimation produces a full set of standard econometric diagnostics, including standard errors and tests for endogeneity.

**Estimation results** A list of equation results can be made available on request and parameters are stored on the X databank. For each equation, the following information is given:

- summary of results
- full list of parameter results
- full list of standard deviations

## 1.4 Baseline forecast

**Overview** The E3-India model can be used for forming a set of projections but it is usually used only for policy analysis. Policy analysis is carried out in the form of a baseline with additional policy scenarios, with the differences in results between the scenarios and the baseline being attributed to the policy being assessed.

This section describes how the baseline is formed.

*Role of the baseline* Usually results from E3-India scenarios are presented as (percentage) difference from base, so at first it may appear that the actual levels in the baseline are not important. However, analysis has shown that the values used in the baseline can be very important in determining the outcomes from the analysis. For example:

- If a scenario has a fixed emission target (e.g. 20% below 2005 levels) then the baseline determines the amount of work that must be done in the scenario to meet the target.
- If a scenario adds a fixed amount on to energy prices, then baseline energy prices determine the relative (percentage) impact of that increase.

It is therefore important to have a baseline that does not introduce bias into the scenario results. A common requirement of E3-India analysis is that the baseline is made to be consistent with official published forecasts. Since we do not have access to state-level economic and energy projections, the E3-India baseline is calibrated to national projections from the World Energy Outlook (IEA, 2015). State-level projections have been set to match.

### Methodology for calibrating

The first stage in matching the E3-India projections to a published forecast is to process these figures into a suitable format. This means that the various dimensions of the model must be matched, including:

- geographical coverage (i.e. each state and territory)
- annual time periods
- sectoral coverage (including fuels and fuel users)
- National Accounts entries

CE uses the Ox software for carrying out this process, and saves the results on to the forecast databank, F.db1.

The next stage is to solve the model to match the results on the forecast databank. This is referred to as the 'calibrated forecast'. In this forecast, the model solves its equations and compares differences in results to the figures that are saved on the databank. The model results are replaced with the databank values but, crucially, the differences are stored and saved to another databank, S.db1. These are referred to as 'residuals' although the meaning is slightly different to the definition used in econometric estimation.

### *Endogenous baseline and scenarios*

The final stage is the 'endogenous solution' in which the model equations are solved but the residuals are added on to these results. In theory, the final outcome should be the same as for the calibrated forecast, although in practice there are calibration errors so it is not an exact match.

The key difference, however, is that inputs to the endogenous baseline may be changed in order to produce a different outcome (as opposed to the calibrated forecast where the model would still match databank values). The final outcome

is thus a baseline forecast that matches the published projections, but which can also be used for comparison with scenarios.

### Operational example

Consider an example for the aggregate consumption equation. If in the first year of forecast, E3-India predicts a value of 100bn rupees but the published forecast suggests 101bn rupees then the calibrated forecast will estimate a residual of 1.01 (i.e.  $101/100$ ).

If we then test a scenario in which consumption increases by 2% in this year, the model results will be 100bn rupees (endogenous baseline) and 102bn rupees (scenario). These will be adjusted (multiplied) by the residual to become 101bn rupees and 103.02bn rupees.

When these results are presented as percentage difference from base, the figure that is reported is still 2% ( $103.02/101$ ), so the calibration does not affect directly the conclusions from the model results.

### When are results influenced by calibration?

In this example, there is no impact on the results relative to baseline from the calibration exercise. This is typically true for any log-linear relationship within the model structure, as the calibration factors are cancelled out when calculating differences from base.

However, there are relationships in the model that are not log-linear, most commonly simple linear factors. These include the construction of energy prices but also identities for GDP and for (gross) output, and the calculation for unemployment (as labour supply minus demand).

For example, if the calibration results in higher trade ratios in a certain country, then the effects that trade impacts have on GDP will increase in the scenarios.

It is therefore important that the baseline provides a reasonable representation of reality, otherwise it is possible to introduce bias into the results.

## 1.5 Other model data inputs

In the current version of the model there are two additional text files that are used as inputs (asides from the instruction file, see Volume 2). These are the assumptions file and the scenario file, both of which can be modified by the model user.

The reason for having these inputs as text files rather than databank entries is that it allows easy manipulation, including through the Manager software (see Volume 2, Section 2.). No programming expertise is therefore required to make the changes.

### Assumptions file

The assumptions file contains basic economic information that is necessary for any model run. It consists mainly of exogenous model variables that are set by the model user.

The nature of the Fortran read commands means that the structure of the assumptions text files is very rigid, for example with the right number of white spaces (not tabs) and decimal places required for each entry.

The assumptions files cover the period 2000 to 2050 although historical values will get overwritten by the data stored on the model databanks and the last year of the model is 2035.

*Commodity prices* At the top of the assumption file is a set of global commodity prices, with a focus on the energy groups that are covered by the model classifications. The figures are annual growth rates, in percentage terms.

*Other world economies* Also at the top of the assumption file there is a set of twelve other countries' GDP assumptions that form demand for Indian exports. The E3-India model assumes that rates of growth in the rest of the world are exogenous, matching the numbers in the assumptions file. The figures are annual growth rates, in percentage terms.

*National and regional assumptions* This is followed by a set of assumptions that are specific to each state. They are:

- Market exchange rate (not used)
- Long-run interest rate
- Short-run interest rate (only used for comparative purposes)
- Change in government final consumption, year on year
- % of government consumption spent on defence, education and health
- Standard VAT rate
- Aggregate rate of direct taxes
- Average indirect tax rates
- Ratio of benefits to wages (giving implicit rate)
- Employees' social security rate
- Employers' social security rate

**Scenarios file** The scenario file contains a set of policy inputs that relate to basic model scenarios (see examples in Volume 2, Section 4). It can also be modified through the model Manager. Most of the policies in the scenario files are absent in the baseline. Policy inputs in the scenario file are categorised to three main groups: CO<sub>2</sub> emissions policies, energy policies and options to recycle the revenue generated from market-based instruments.

*CO<sub>2</sub> emissions policies* The following CO<sub>2</sub> emissions policies are available in the scenarios file:

- annual CO<sub>2</sub> tax rate, rupees per tonne of carbon
- switches to include different energy users in the policies
- switches to include different fuel types in the policies

*Energy policies* The following energy policies are available in the scenario file:

- annual energy tax rate, rupees per toe
- switches to include different users in policies
- switch to include different fuel types in policies
- households implied price of electricity subsidies (see Volume 5, Section 3)

*Revenue recycling options* The scenario file includes options to recycle automatically the revenues generated from carbon taxes and energy taxes (so that government balances

remain unchanged). There are three options in the scenario file for how the revenues are recycled:

- to lower employers' social security contributions, switch  $0 < X < 1$ : 1=all, 0=none
- to lower income tax rates, switch  $0 < X < 1$ : 1=all, 0=none
- to lower VAT rates, switch  $0 < X < 1$ : 1=all, 0=none

These revenue recycling options do not differentiate sources of revenues. The model automatically sets the revenues to be recycled from the policies so that they are overall 'revenue neutral'. Specific values for offsetting tax reductions can be entered through the assumption file discussed above.

## 1.6 Model outputs

### Overview

The model produces relatively few results automatically. It instead stores results internally so that they can be accessed separately. The separation of model solution, (1) writing the results year by year to a large file (the 'dump'), and then (2) accessing this file to generate time series of results, is necessary because of software constraints and the logic of the model.

Because of the scale of the solution, the model does not hold all the time series of each variable, but only the current and past values necessary for the current year's solution; this reduces the storage requirements dramatically (one year plus lags instead of up to 50 years of values). At the completion of each year's solution, the solved values of most variables are written to the dump where they may be later accessed.

### Data analysis files

The files that access the model results are called data analysis files. They are instruction files that are run after the model has finished solving (see Volume 2).

The file produced contains matrix output. These files are designed as inputs to further processing, for example by other programming languages, or interpretation by the model manager software (see Volume 2, Section 2). They appear in the output directory with a '.MRE' extension.

The data analysis files must start with a RESTART command with a year that matches the PUT ALL statement in the IDIOM instruction file (usually the first year of solution). A SELECT command then determines the output stream and format:

- SELECT OUTPUT 7 CARDS – MRE output

The syntax is then relatively straight forward. The VALUE command is followed by the variable name, start year and end year to give a table in time series format. The CHANGE command gives the equivalent output as annual growth rates. For variables with two dimensions (excluding time) it is necessary to say which column is required. So, for example, the command:

- VALUE CR(? : 03) 2013 2020

would give a time series for household consumption in Assam (region 3) between 2013 and 2020. The following command will print out results for all states:

- VALA CR(?:01) 2013 2020

**Other model  
outputs**

The other model outputs are created for diagnostic purposes. A small text file (diagnostics.mre) is created automatically, which contains summary information about whether the model has solved and, if not, which equation caused the breakdown in solution. A longer 'verification' text file contains automatically generated outputs from the model, including warnings and possible non-convergences in the solution (see Volume 2, Section 4), which can be returned to Cambridge Econometrics to assist with problems in solution. The verification files are by convention given names that start with the letter Q and are stored in the verification folder in the output directory.



## 2 Model Validation

### 2.1 Introduction

Validation is an important part of the model-building process and especially so for a tool as large and complex as E3-India. There are several steps to the validation process:

- reviewing model data and the gaps in the data that have been filled out
- assessing the results of the econometric estimation
- validating the model as a system against the historical data
- running test scenarios and comparing results with expectations

Each of these steps is described in the following sections.

### 2.2 Reviewing model data

Compiling the E3-India database was an extensive exercise that included many checking phases along the way. Standard checks were carried out on the time series, for example to identify breaks in the series.

#### The data as part of a system

The review of the data focused more on how the different series fit together, which is less easy to identify from simple plots of the data. Examples include cases where output appears to be different from the sum of its component parts. While the data would not be expected to match up exactly, large discrepancies could be the source of bias in the results.

The model itself provides a useful framework with which to carry out these tests, as it reports some of the key differences. Where large discrepancies were found, the team went back to assess the original data. For example, one instance of two states being entered in the wrong order was found.

#### External reviewing

The data in the E3-India database are also fully available to anyone who uses the model. Individuals with expertise on particular sectors or states are therefore able to further assess the data, and send any queries to the team. This part of the validation is especially important where gaps in the data have been estimated, as the software algorithms that are used may not always take into account local context.

### 2.3 Assessing the results of the econometric estimation

Our estimation system is using the AIC to select the most appropriate set of significant parameters in each equation. The explanatory factors in each equation are selected based on the specification in the E3ME model. Outputs from the estimation include the usual R-squared tests and tests of significance. The more difficult bit to the evaluation is aggregating the tests over equations that are estimated for each state and sector, i.e. managing the amount of information that comes out of the estimation process.



We face two issues in the estimation – a lack of degrees of freedom, and a data set that covers a period of transition and change in India. The estimation results reflect both of these factors, although we anticipate that over time the time series for estimation will be extended to improve the basis for the estimation.

### Restrictions on the estimated parameters

Three types of restrictions are placed on the coefficients that are estimated:

- Theoretical constraints – In a few cases restrictions are added to the equations for theoretical reasons, e.g. to ensure a one-to-one relationship.
- ‘Right sign’ – For example, price elasticities are not allowed to be positive.
- Model stability – Maximum values are set to ensure the model remains operable.

If the econometric estimation yields results that are overly constrained by these restrictions then it could be an indication of issues in the data.

Figure 2.1 shows an example of a set of estimation results, from the equations for employment (long-run part only, wages shown on an inverted scale). The chart shows that 525 equations were estimated (x axis); that is all sectors/states where there is employment. In around 50 cases no significant relationship between wage rates and employment was found, and in around 100 cases no significant relationship between output and employment was found.

At the other end of the scale, around 25 cases were found where the relationship between output and employment was greater than one (i.e. a 1% increase in output leads to more than a 1% increase in employment). For wages, slightly more instances were found.

However, for the large majority of equations estimated, a relationship between zero and one was found in both cases, giving impacts both in line with expectations and stable enough to use in modelling.

Figure 2.1: Example estimation results (long-run employment equation)

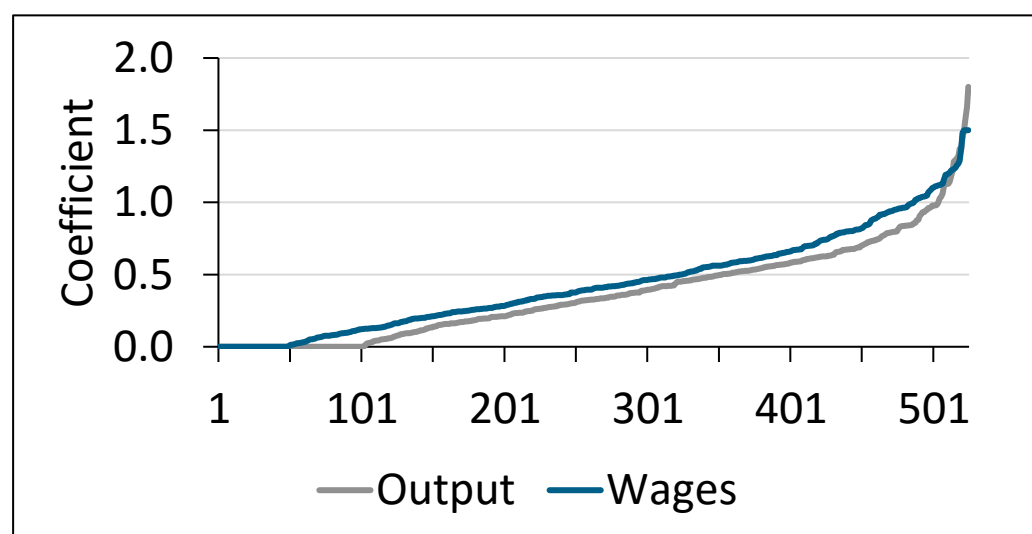


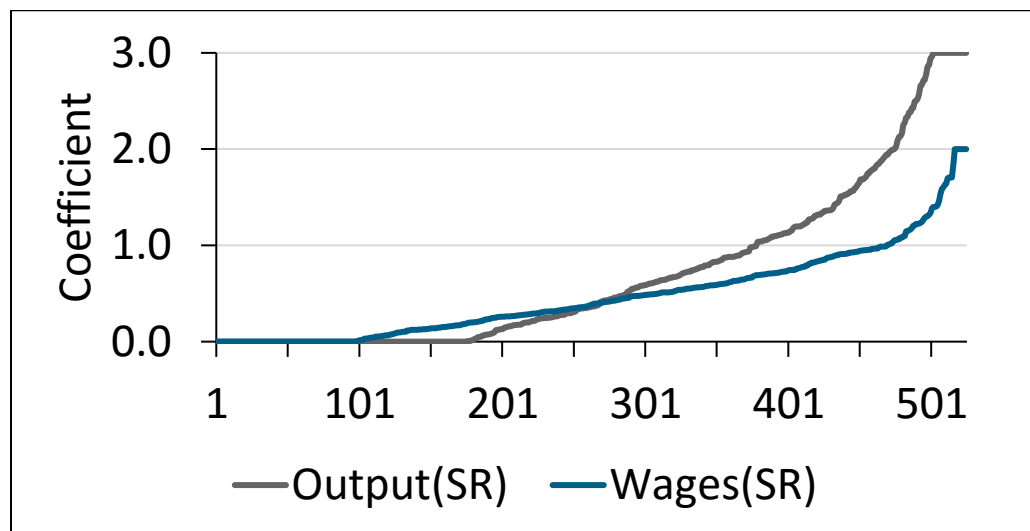
Figure 2.2 shows the same distribution of estimation parameters, but for the short-run, differenced equation. Here there is a much wider variation in results, reflecting a wider range of short-run outcomes.

Between 100 and 200 of the equations show no significant impact in the short run. This finding is not unsurprising for employment equations, where there are often strong lagged effects, for example due to fixed contracts. At the top end of the scale, around 150 equations have short-run output-employment coefficients greater than one and there are 50 short-run wage-employment coefficients greater than one. We can also see the imposed maximum values (3 for output and 2 for employment), although relatively few equations hit these constraints.

Many of the equations that hit the constraints are for the energy sectors, where output and employment levels can be highly volatile. For this reason, a simpler specification is used in these sectors, effectively linking output and employment in a one-to-one relationship.

Overall, however, there is again a linear fit across most of the equation sets, indicating that the estimated parameters appear in line with expectations.

**Figure 2.2: Example of short-run estimation results**



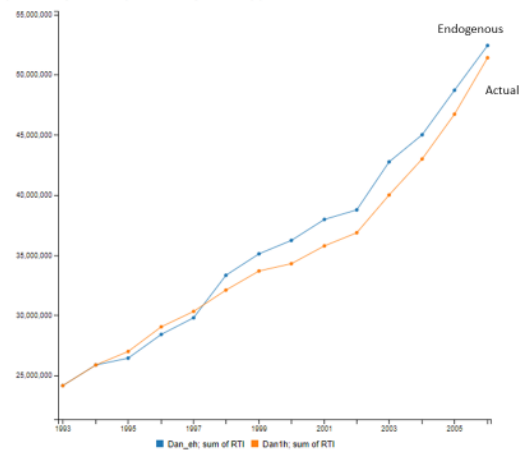
## 2.4 Validating the model against historical data

While the analysis in the previous section considers some of the equations in isolation, this section looks at the system as a whole. The test that is carried out is to run the model over the historical period, and see how well its results match the actual data. If the equations do not fit the data well or are biased on some way then we would expect substantial divergence between the model results and the data.

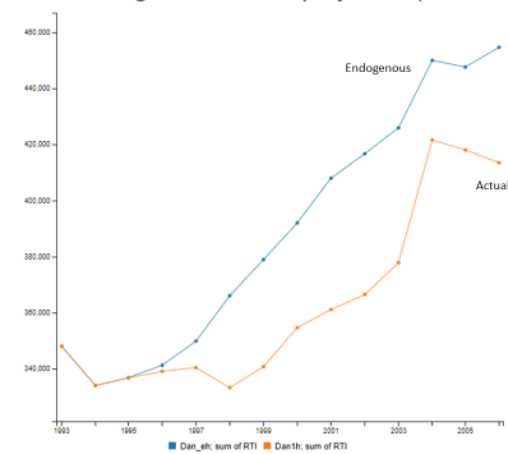
The following figures are taken from the manager interface and show the results from the experiment. The blue lines show the model results and the orange lines actual data. Charts are shown for GDP, employment and CO<sub>2</sub> emissions levels.

**Figure 2.3: Historical validation, national level**

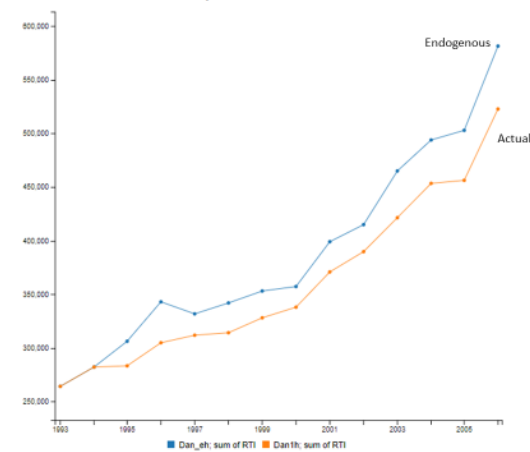
RGDP - GDP expenditure measure at market prices  
(RSC+RSG+RSK+RSS+RSX-RSM+RSS)  
(mRupees(2010 price))



REMP - regional total employment (thousands)



RCO2 - emissions of carbon dioxide th tonnes carbon (th tonnes of carbon)



Solving the model over the historical period is a considerable exercise, as in general the model is designed to reproduce historical data rather than solve the equations. In some cases the discrepancies reported may reflect limitations in how the model solves historically rather than issues with model equations but this section reports results as they are.

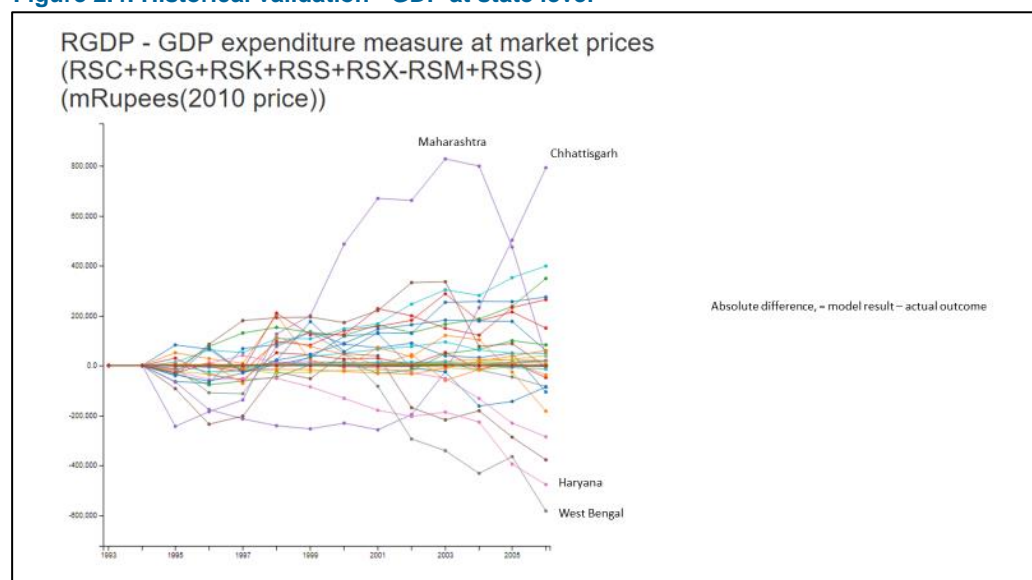
Overall, the model matches GDP closely but the chart shows a bigger discrepancy for employment, led by differences in 1997-1999. The overall difference amounts to about 10%. For CO<sub>2</sub>, the model results are also consistently higher and again the difference is around 10%.

One important point to note for CO<sub>2</sub>, however, is that the power sector is not included in the historical analysis, as the FTT model cannot be run over history. FTT has its own structural validation, which is described in Mercure (2012).

In general, however, results are encouraging in that they show some differences (as expected) but no persistent bias. It is clear that there are some developments just before 2000 that the model has not accounted for as well as changes in other time periods but the general directions of the relationships are consistent.

Figure 2.4 shows the pattern across states in terms of absolute difference between model result and actual data. A few states stand out, which can usually be traced to individual equations but the results are generally consistent with those found at national level.

**Figure 2.4: Historical validation - GDP at state level**



## 2.5 Validating the model with residual corrections

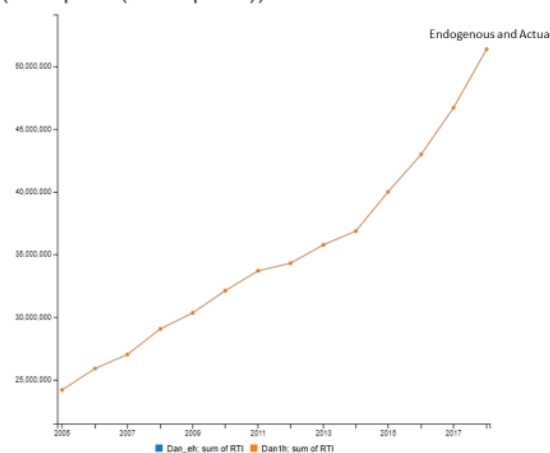
The final test compares model results against actual data if we account for the errors in the individual equations. The errors, which are referred to as residuals, in the model interface are stored and added back into the endogenous model solution; this is the same mechanism that is used by the model to match baseline forecasts.

If the errors from the equations are large, then this approach could introduce bias into the modelling, but this would have been picked up in the tests in the previous section. This final test is more an assessment of the model's mechanics; we would expect it to very closely match the actual data. However, the test is also important, because this is the closest approximation to how the model is used for analysis.

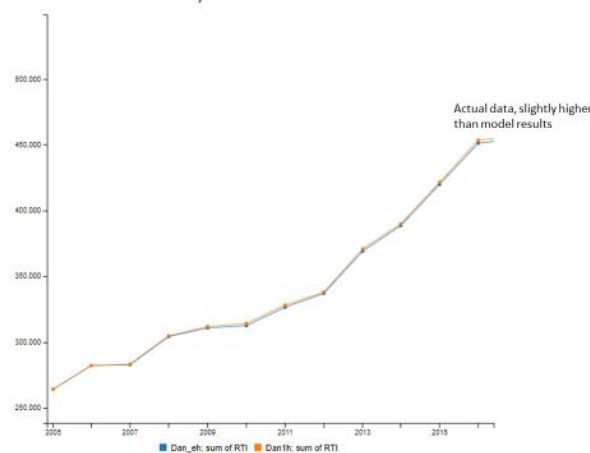
Figure 2.5 confirms that this is the case, with no difference at all in the GDP (and employment) results and only a very small difference in emissions.

**Figure 2.5: Historical validation, including residual correction**

RGDP - GDP expenditure measure at market prices  
(RSC+RSG+RSK+RSS+RSX-RSM+RSS)  
(mRupees(2010 price))



RCO2 - emissions of carbon dioxide th tonnes carbon (th tonnes of carbon)



Similar results were found at state level, with the discrepancies between model results and actual data being only a fraction of a percent. These small differences are likely due to rounding errors in the model solution process and not an indication of issues in the underlying data and equations.

## **2.6 Running test scenarios**

The final stage of the testing is for the model to be used as widely as possible by individuals with a range of expertise to consider a range of different policies. This part of the validation is still ongoing and we anticipate that some of the exercises will be added as case studies to Volume 8 of this manual. Any issues that are uncovered in this process will be investigated by the modelling team.

## **2.7 Summary**

In conclusion, extensive testing has been carried out as part of the model validation and is still ongoing through an interactive process. Several issues, relating to both data and features of the model code, have been identified along the way and have been addressed.

The results presented in this chapter summarise the main findings of the validation. While there is still work to be done in some of the individual equations, we expect this to move forward over time as additional data become available. Longer time series should improve the accuracy of the parameter estimation and may allow for additional explanatory variables to be added to the equations, without reducing degrees of freedom too much.

The focus now is on developing additional test scenarios to continuously further model validation.

## Appendix A Model Classifications

E3-India Classifications		
Regions	Sectors	Fuel Users
1 Andhra Pradesh	1 Agriculture	1 Power generation
2 Arunachal Pradesh	2 Forestry & Logging	2 Other transformation
3 Assam	3 Fishing	3 Manufacturing
4 Bihar	4 Coal Extraction	4 Transport
5 Chhattisgarh	5 Oil Extraction	5 Households
6 Gujarat	6 Gas Extraction	6 Services
7 Haryana	7 Non-Energy Mining	7 Agriculture
8 Himachal Pradesh	8 Manufacturing	8 Non-energy used
9 Goa	9 Electricity	
10 Jammu & Kashmir	10 Gas	<b>Fuels</b>
11 Jharkhand	11 Water	1 Coal
12 Karnataka	12 Construction	2 Oil
13 Kerala	13 Transport & Storage	3 Natural Gas
14 Madhya Pradesh	14 Communication	4 Electricity
15 Maharashtra	15 Trade, Hotels & Restaurants	5 Biomass
16 Manipur	16 Banking & Insurance	
17 Meghalaya	17 Real Estate	
18 Mizoram	18 Other Business Services	
19 Nagaland	19 Public Administration	
20 Orissa	20 Other Services	
21 Punjab		
22 Rajasthan		
23 Sikkim		
24 Tamil Nadu		
25 Tripura		
26 Uttar Pradesh		
27 Uttarakhand		
28 West Bengal		
29 Andaman & Nicobar		
30 Chandigarh		
31 Delhi		
32 Puducherry		

<b>E3-India Classifications</b>		
<b>Consumers' Expenditure</b>	<b>Labour Groups</b>	<b>Population groups</b>
1 Food	1 Male 15-19	1 Male Children
2 Drink	2 Male 20-24	2 Male 15-19
3 Tobacco	3 Male 25-29	3 Male 20-24
4 Clothing etc.	4 Male 30-34	4 Male 25-29
5 Rent	5 Male 35-39	5 Male 30-34
6 Water etc.	6 Male 40-44	6 Male 35-39
7 Electricity	7 Male 44-49	7 Male 40-44
8 Gas	8 Male 50-54	8 Male 44-49
9 Liquid fuels	9 Male 55-59	9 Male 50-54
10 Other fuels	10 Male 60-64	10 Male 55-59
11 Durable goods	11 Male 65+	11 Male 60-64
12 Other consumables	12 Female 15-19	12 Male OAPs
13 Medical	13 Female 20-24	13 Female Children
14 Transport services	14 Female 25-29	14 Female 15-19
15 Other services	15 Female 30-34	15 Female 20-24
16 Recreational	16 Female 35-39	16 Female 25-29
17 Unallocated	17 Female 40-44	17 Female 30-34
	18 Female 45-49	18 Female 35-39
	19 Female 50-54	19 Female 40-44
<b>Government sectors</b>	20 Female 55-59	20 Female 45-49
1 Defence	21 Female 60-64	21 Female 50-54
2 Education	22 Female 65+	22 Female 55-59
3 Health	23 Total 15-19	23 Female 60-64
4 Other	24 Total 20-24	24 Female OAPs
5 Unallocated	25 Total 25-29	
	26 Total 30-34	
	27 Total 35-39	
	28 Total 40-44	
	29 Total 45-49	
	30 Total 50-54	
	31 Total 55-59	
	32 Total 60-64	
	33 Total 65+	



## Appendix B Model Inputs and Outputs

### B.1 Model inputs

#### Assumptions file

In the assumptions file there are two types of inputs, commodity prices and GDP in other parts of the world. Both are expressed as annual growth rates. The categories are:

- 02 CPRICE\_FOOD\_FEED – prices for food and animal feed
- 03 CPRICE\_WOOD – prices for wood as a raw material
- 04 CPRICE\_CONS\_MIN – prices for aggregates and other construction minerals
- 05 CPRICE\_IND\_MIN – prices for minerals used for industrial purposes
- 06 CPRICE\_FER\_ORES – prices for ferrous ores
- 07 CPRICE\_NFER\_ORES – prices for non-ferrous ores
- 08 CPRICE\_COAL – coal prices
- 09 CPRICE\_BRENT\_OIL – oil prices
- 10 CPRICE\_GAS – natural gas prices
- 11 CPRICE\_OTHERS – prices for other commodities

The countries for which GDP growth can be adjusted are India's main trading partners. Other countries are included in the final rest of world category.

#### Scenarios file

The inputs in the scenarios file are:

Input	Units	Dimensions	Definition
RTEA	Rup/toe	State x Year	Energy tax levied on energy consumption
RTCA	Rup/tC	State x Year	Carbon tax levied on CO2 emissions
FEDS	Share	Fuel User x State	Exemptions from RTCA and RTEA, 0 = exempt
JEDS	Share	Fuel x State	Exemptions from RTCA and RTEA, 0 = exempt
RRTE	%	State x Year	Carbon/energy tax revenues used to reduce employers' social contributions
RRTR	%	State x Year	Carbon/energy tax revenues used to reduce income taxes
RRVT	%	State x Year	Carbon/energy tax revenues used to reduce VAT
PESH	Share	Income Group x State	Implied subsidies to each group (1 = none)

**Other inputs  
(through the  
instructions  
files)**

Additional flexibility is added when using the instructions files. Some of the most commonly used inputs here are shown below.

- FRCH (fuel user by state) – exogenous reduction in coal consumption, in thousands of tonnes of oil equivalent.
- FROH, FRGH, FREH – exogenous reductions in oil, gas and electricity consumptions (same dimensions and units).
- KRX (sector by state) – exogenous increase in investment, millions of rupees at 2010 prices.

Almost all the variables in E3-India can be shocked exogenously. For further information on this please contact the modelling team.

## B.2 Model outputs

The interface provides a long list of potential outputs (and more can be added). The key ones are listed here.

### Economic outputs

Output	Units	Dimensions	Definition
RGDP	mR (2010)	State	GDP at market prices
RSC	mR (2010)	State	Household consumption
RSK	mR (2010)	State	Investment (GFCF)
RSX	mR (2010)	State	Export volumes
RSM	mR (2010)	State	Import volumes
PRSC	2010=1.0	State	Consumer price index
RRPD	mR (2010)	State	Real household incomes
CR	mR (2010)	Product x state	Disaggregated consumption
KR	mR (2010)	Sector x state	Investment
QRX	mR (2010)	Sector x state	Exports
QRM	mR (2010)	Sector x state	Imports
PYH	2010=1.0	Sector x state	Domestic production prices
PQRD	2010=1.0	Sector x state	Domestic consumption prices

### Labour market outputs

Output	Units	Dimensions	Definition
YRE	thousands	Sector x state	Employment
YRW	thR/year	Sector x state	Wage rates (current price)
RWPP	thousands	State	Labour supply
RUNE	thousands	State	Unemployment
RUNR	%	State	Unemployment rate

**Energy system  
outputs**

Output	Units	Dimensions	Definition
FR0	th toe	Fuel user x state	Energy consumption
FRCT	th toe	Fuel user x state	Coal consumption
FROT	th toe	Fuel user x state	Oil consumption
FRGT	th toe	Fuel user x state	Gas consumption
FRET	th toe	Fuel user x state	Electricity consumption
PFR0	R / toe	Fuel user x state	Aggregate energy price
PFRC	R / toe	Fuel user x state	Coal prices
PFRO	R / toe	Fuel user x state	Oil prices
PFRG	R / toe	Fuel user x state	Gas prices
PFRE	R / toe	Fuel user x state	Electricity prices
MEWG	GWh	Technology x state	Electricity generation
MEWK	GWh	Technology x state	Electricity capacity

**Emissions  
outputs**

Output	Units	Dimensions	Definition
RCO2	th tC	State	CO <sub>2</sub> emissions
FCO2	th tC	Fuel user x state	CO <sub>2</sub> emissions
RCTT	mR	State	Carbon tax revenues