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Extending the E3ME Model to 2050

An Introduction to E3ME, Version 4.7

Cambridge Econometrics Working Paper

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Revision and Authorisation History

Version	Date	Authorised for release by	Description
1.0	April 09	Ben Gardiner	First version

Contents

1 Overview

1.1 Introduction

Introduction to E3ME

E3ME is a large-scale model of Europe's economies, energy systems and environment. The model is used to inform policy making and for forecasting. Recent examples of applications include:

- Impact Assessments of changes to the European Emission Trading Scheme (ETS) and Energy Taxation Directive
- labour-market forecasting
- an assessment of the economic effects of 1990s environmental tax reform in Europe and of future tax reforms
- predicting future ETS carbon prices
- analysis of the impacts of increasing R&D spending

The original version of E3ME was constructed through EU research funding but the model has more recently been developed to meet specific project requirements. For example, E3ME now incorporates detailed treatments of the transport and power-generation sectors and covers all of the EU27 member states.

This document outlines a further major development to the basic model structure, extending the forecast horizon of the model to the year 2050 (annually). For further information about E3ME, including data sources, model classifications and econometric specification, the reader is referred to the main model website, www.e3me.com, and full online manual, www.camecon-e3memanual.com.

1.2 Policy background

Global warming is often described as the biggest challenge facing mankind today. Many solutions, or partial solutions, have been proposed by members of the scientific community and a few of these have been implemented as policy (examples include fuel-efficiency standards for motor vehicles and the European ETS). Each policy instrument has an associated cost, which may in some cases be negative, but there is often a lot of uncertainty surrounding these costs.

The role of modelling

Unlike the natural sciences, economists are usually unable to carry out real-world experiments so must rely on alternative methods for assessing the likely benefits and costs of environmental policy. Modelling, and in particular E3 (Energy-Environment-Economy) modelling, provides such a means of assessment.

To be useful and comprehensive analytical tools, E3 models must meet a basic set of criteria. For example, they must:

- have explicit two-way linkages, including feedbacks, between the economic and energy systems, and the environment
- be able to explain behavioural patterns across different parts of the economy
- be able to address long-term environmental outcomes as well as the short-term economic costs

At the European level E3ME is an example of such a model, being able to assess the impacts of environmental policy in a detailed set of economic sectors in each member state. Version 4.6 of the model is able to assess short-term impacts and long-term

outcomes in the period up to 2030 (in comparison, more common Computable General Equilibrium models can assess long-term impacts but have no short-term specification). However, as climate-change policy typically considers a longer-term time frame than has previously been used for policy analysis, the cut-off point of 2030 is no longer adequate. At both national and European levels, targets are now being considered for 2050 so clearly the modelling capabilities need to reflect this.

The following chapters discuss some of the issues with extending E3ME's forecast horizon to 2030. The model is solved for a baseline and a simple carbon tax scenario. A similar exercise is currently being carried out with Cambridge Econometrics' MDM-E3 model of the UK. The global E3MG model (www.e3mgmodel.com), which is similar in structure to E3ME but was designed to address climate-change issues from the outset, currently covers the period up to 2100, but solves annually only up to 2020 and every ten years thereafter.

2 Technical Updates and Baseline Forecast

2.1 Technical updates

This section discusses the main technical developments in extending E3ME's forecast horizon. The basic model-development task was relatively straight forward as the model already solves year-by-year, so an extension in the time horizon did not involve anything more than adjusting an existing iterative process. Therefore there were not many changes to the model's core Fortran code. The main changes were to the model inputs (discussed in Section 2.2) and the model outputs.

Changes for model outputs

In several places in the model source code there are references to the year 2030 as being the final year of solution where, for example, results are prepared for output tables. In each case it was checked that this was the only reason 2030 was given and the year was changed to 2050.

More substantive are the increased computer requirements to solve for a longer time period, which go beyond the capabilities of the current internal storage system. The current solution is to use two files but this has caused some further issues with the automated data-analysis routines. These have mainly been overcome but it is still not clear how to easily display results after 2030 in the user-friendly model front end.

2.2 Baseline forecast and other inputs

Baseline forecast

Although E3ME can be used for forecasting its more common use is for policy scenario-based, analysis. This requires a baseline forecast that is credible and widely accepted. For most tasks there is a requirement that the baseline forecast is calibrated to match an existing published forecast that has been verified by external sources; currently E3ME uses the *Energy and Transport: Trends to 2030* publication that is produced by the European Commission's Directorate General for Energy and Transport.

With some additional processing, this publication provides the model with most of its required inputs up to 2030 but does not include any developments beyond 2030. The procedure to estimate values for years after 2030 was relatively simplistic; growth rates were extrapolated up to 2050 and then results were checked for large imbalances, such as GDP deviating from the sum of its component parts.

This approach provides a reasonable estimate of future long-term developments and is adequate for the task of producing a baseline. However, when future baseline forecasts are developed it is expected that they will also operate with a longer time horizon and E3ME's own forecast will be updated to match.

Exogenous inputs

E3ME's exogenous inputs, referred to as assumptions, were also extended to cover the period up to 2050. These mainly include government spending and tax rates, demographic development and growth rates outside Europe. Tax rates were assumed to remain unchanged, while growth rates for the other inputs were extrapolated.

Model fixes

The term 'fixes' is used to refer to places in the model where the user must step in to obtain a stable solution. This tends to occur when:

- historical data are of poor quality so estimated parameters do not produce stable outcomes;

- a key indicator such as output in a particular industry or unemployment goes to zero.

The extension to 2050 does not have any bearing on the first of these issues as the same parameters were already used in the period up to 2030. However, there were some cases where longer-term trends could start to push model variables towards zero. For example, a small sector with declining output could become negligible in size by 2050 if current trends continue. This leads to problems with logarithmic values and small denominators.

Appropriate measures were taken in each instance on a case-by-case basis, including some adjustments to the baseline forecast described above. Overall there was not a sizeable increase in the number of model fixes.

2.3 Solution time

Inevitably there is an increase in the time required for each model run. A full solution of E3ME version 4.7 takes 110 seconds compared to 51 seconds previously.

3 The Carbon Tax Scenario

3.1 Introduction and scenario definition

To test the properties of the new version of E3ME a carbon tax scenario was set up. The scenario was intentionally designed to be simplistic, meaning that the outcomes could be easily traced and any errors or modelling issues could be identified immediately.

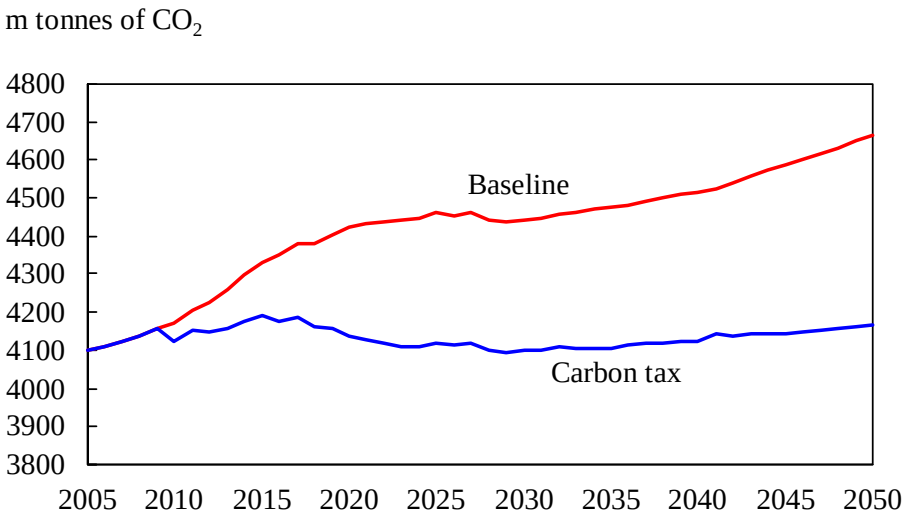
The carbon tax was set to start at a low level in 2010 and increased gradually up to a value of 64€/tCO_2 (2008 prices) in 2050. There was no revenue recycling, meaning that revenues could be interpreted as being used to pay government debt (although no knock-on effects to interest rates were included either). This is not therefore a fully-specified scenario; a sensitivity test may be more a appropriate terminology.

3.2 Energy and environment outcomes

The carbon tax causes a reduction in CO_2 emissions of 11% by 2050. In levels terms, this is approximately equivalent to 493m tonnes of CO_2 less emissions.

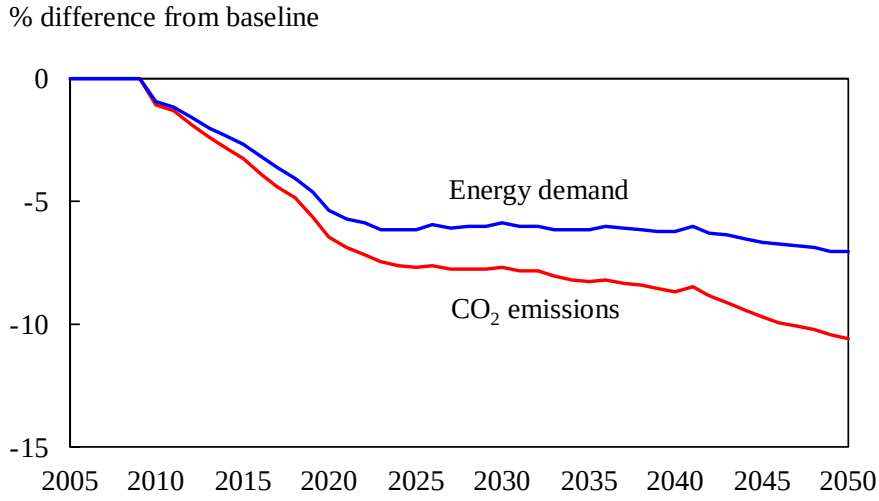
Energy demand, measured in tonnes of oil equivalent, falls by around 7% by 2050 compared to the baseline. This is a slightly smaller reduction due to fuel switching, for example from coal to gas.

FIGURE 3.1: EU27 CO2 EMISSIONS



Source(s) : E3ME47, Cambridge Econometrics.

FIGURE 3.2: ENERGY & ENVIRONMENT RESULTS FOR EU27 CARBON TAX SCENARIO



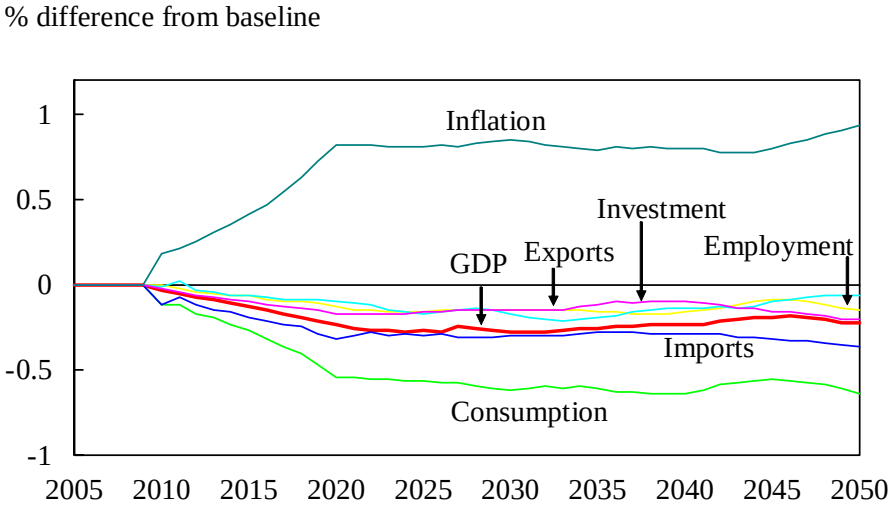
Source(s) : E3ME47, Cambridge Econometrics.

3.3 Economic outcomes

Since there is no revenue recycling, the economic results are expected to be negative. Overall the results from the carbon tax scenario suggested that EU27 GDP falls by 0.2% from the baseline, a very small reduction over a 40 year period.

Carbon taxation increases price levels in the economy. There are three ways which price levels are affected by carbon taxation; a) directly to consumer energy prices, b)

FIGURE 3.3: ECONOMIC RESULTS FOR EU27 CARBON TAX SCENARIO



Source(s) : E3ME47, Cambridge Econometrics.

through industries passing on the increases in their production cost through their final output prices, and c) through imports of goods and services from those countries subjected to carbon taxation. Inflation results, defined by the consumer price index, show that in the carbon-tax scenario prices are higher by about 0.9% by 2050 when compared to baseline. As a result of higher prices, consumer spending falls by 0.7%. Impacts on trade are relatively small, imports decreases by 0.4% (due to lower demand) while exports decrease by 0.2%. Investment falls very slightly by 0.1%. Employment results follow GDP results but to a lesser degree. Employment falls slightly by 0.2% compared to the baseline by 2050.

4 Conclusions

4.1 Modelling to 2050

This document presents the first results from version 4.7 of the E3ME model. This is the first version of E3ME to consider outcomes to the year 2050 and makes the model a more suitable tool for long-term climate-change analysis. At the same time the model's annual, dynamic, specification makes it more suitable for addressing short-term costs or benefits of climate-change policy.

The technical requirements to extend the model were not great although there are some costs in terms of computation time and storage requirements. The flexibility of the software means that there are many ways of displaying results but some of the standard methods currently used are less appropriate for long time series.

A simple sensitivity scenario was set up to test the properties of the new model. As expected, the results showed that there were no major differences to outcomes from the previous version of E3ME. Version 4.7 therefore presents a clear improvement in terms of modelling capability.