Resource productivity, environmental tax reform and sustainable growth in Europe

E3ME: An Energy–Environment–Economy Model for Europe

Version 4.2: A Technical Description for petrE WP3

Hector Pollitt, Unnada Chewpreecha, Philip Summerton

March 2007

Cambridge Econometrics Limited
Covent Garden
Cambridge, CB1 2HS

Tel: +44 (0)1223 460760
Hector Pollitt: hp@camecon.com
Web page: www.camecon.com
E3ME web page: www.e3me.com

petrE (see http://www.petre.org.uk/papers.htm) is part of the Anglo-German Foundation research policy initiative: *Creating sustainable growth in Europe* (see http://www.agf.org.uk/currentprogramme/CreatingSustainableGrowthInEurope.php)

Revision and Authorisation History

Version	Date	Authorised for release by	Description
1.0	02/03/2007	Ben Gardiner	First Version UC&PS

Contents

1 Introduction

This paper provides a short technical description of the Energy-Environment-Economy Model for Europe (E3ME), developed by Cambridge Econometrics (CE). The model version described is number 4.2. Information about the most recent version of the model may be found at the main model website, www.e3me.com.

For a more detailed description of the model and a full list of acknowledgements, please see the online manual at: http://www.camecon-e3memanual.com/cgi-bin/EPW_CGI.

Users are requested to report any errors to the authors.

2 Objectives of E3ME

Short and long-term effects of E3 policies

E3ME is intended to meet an expressed need of researchers and policy makers for a framework for analysing the long-term implications of Energy-Environment-Economy (E3) policies, especially those concerning R&D and environmental taxation and regulation. The model is also capable of addressing the short-term and medium-term economic effects as well as, more broadly, the long-term effects of such policies, such as those from the supply side of the labour market.

The European contribution

The E3ME model has been built by an international European team under a succession of contracts in the JOULE/THERMIE and EC research programmes. The projects 'Completion and Extension of E3ME'[1] and 'Applications of E3ME'[2], were completed in 1999. The 2001 contract, 'Sectoral Economic Analysis and Forecasts'[3] generated an update of the E3ME industry output, products and investment classifications to bring the model into compliance with the European System of Accounts, ESA 95. This led to a significant disaggregation of the service sector. The 2003 contract, Tipmac[4], led to a full development of the E3ME transport module to include detailed country models for several modes of passenger and freight transport and Seamate (2003/2004)[5] resulted in the improvement of the E3ME technology indices. The COMETR[6] (2005-07) and Matisse[7] (2005-08) projects allowed the expansion of E3ME to cover 27 regions, including the ten accession countries. E3ME is the latest in a succession of models developed for energy-economy and, later, E3 interactions in Europe, starting with EXPLOR, built in the 1970s, then HERMES in the 1980s. Each model has required substantial resources from international teams and each model has learned from earlier problems and developed new techniques[8].

The E3ME approach

E3ME combines the features of an annual short- and medium-term sectoral model, estimated by formal econometric methods, with the detail and some of the methods of the Computable General Equilibrium (CGE) models that provide analysis of the movement of the long-term outcomes for key economic indicators in response to policy changes. It can be used for dynamic policy simulation and for forecasting and projecting over the medium and long terms. As such, it is a valuable tool for economic policy analysis in Europe. E3ME has the following advantages over many competing models:

Model disaggregation

The detailed nature of the model allows the representation of fairly complex scenarios, especially those that are differentiated according to sector and to country. Similarly, the impact of any policy measure can be represented in a detailed way.

Econometric pedigree

The econometric grounding of the model makes it better able to represent and forecast performance in the short to medium run. It therefore provides information that is closer to the time horizon of many policy makers than pure CGE models.

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[1] European Commission contract no: JOS3-CT95-0011

[2] European Commission contract no: JOS3-CT97-0019

[3] European Commission contract no: B2000/A7050/001

[4] European Commission contract no GRD1/2000/25347-SI2.316061

[5] European Commission contract no. IST-2000-31104

[6] European Commission contract no. 501993 (SCS8)

[7] European Commission contract no. 004059 (GOCE)

[8] See www.e3me.com for a description of some of the recent EU projects involving E3ME.

E3 linkages An interaction (two-way feedback) between the economy, energy demand/supply and environmental emissions is an undoubted advantage over other models, which may either ignore the interaction completely or only assume a one-way causation.

Model data sources Like its predecessors, E3ME is an estimated model. Version 4.2 (E3ME42) is based on international data sources such as Eurostat and the OECD (Stan). See Section 3.2 for more details about the available data sources and the order of preference.

European sectoral analysis E3ME is a detailed model of 42 product/industrial sectors (see Appendix A Table A.1), compatible with ESA95 (Eurostat, 1995) accounting classifications, and with the disaggregation of energy and environment industries for which the energy-environment-economy interactions are central. It also has a linked set of 19 fuel-using sectors, including the energy-intensive sectors.

3 Classification and Main Data Sources

3.1 The System of Accounts and E3ME classifications

The accounting structure within IDIOM (International Dynamic Input-Output Modelling language) on which E3ME is based is that of the Eurostat System of Accounts 1995 (ESA95). The IDIOM functional classifications can be identified with accounts in the ESA95 with the exception of investment, area, employment and energy-use classifications. One of the characteristics of the ESA and E3ME is the disaggregation of economic variables. The industry and commodity classifications are in terms of industries or their principal products and are defined on the NACE Rev.1.1 (see Appendix A table A.1) and cover the EU 25 member states plus Norway and Switzerland (see Appendix A table A.2).

Input – output tables

For the latest version of E3ME a new set of input-output tables was obtained from Eurostat, the OECD and the GTAP database. For each region, an input-output table for 2000 was estimated if this was not already available. E3ME's input-output tables include:

- domestic production
- imports from EU member countries
- imports from third countries

Evolution of E3ME classifications

The evolution of the E3ME classifications and databases has been characterised by the desire to cover more disaggregated sectors on one hand and the adoption of several additional classifications (energy-environment as mentioned above) on the other hand. E3ME classifications and datasets evolved (and continue to evolve) according to the objectives of the specific projects and policy applications (usually Commission-funded) involving the model.

3.2 Main data sources

The data need to be consistent across countries and in the same units. For monetary data the euro is used. The data are updated as and when new data become available. For each set of the model variables there are four possible groups of data sources with the following ranking:

Primary choice

Eurostat and the OECD (Stan) are always the preferred choice which establishes a comparable basis across member states. Even where Eurostat data are incomplete or believed to be of poor quality, the Eurostat definitions are adopted and the data are improved via other sources. This allows the inclusion of improved Eurostat data on an annual basis.

Second choice

Data from the AMECO database are used in order to make the Eurostat total consistent with an accepted macroeconomic total, and also to provide limited sectoral information.

Third choice

When Eurostat data are not available or need to be improved, other internationally available sources such as the IMF are consulted. International sources are also important for data covering the world areas outside the E3ME regions.

Fourth choice Once these international data sources have been exhausted, national statistical agencies and other data sources are used to update the remaining missing series and gaps in the data.

As indicated above data from official sources are always preferred and are used in the most comprehensive possible way. There are also several sets of variables in E3ME that are calculated, and special variables that use different sources.

Trade data Due to the way in which trade is modelled within E3ME, via a European pool rather than as a series of bilateral relationships, an aggregated version is used in equation estimation. The importance of one country's trade to another country's economic activity is determined using OECD bilateral trade data. This information is also used to construct trends for filling gaps in data for trade in services.

4 Assumptions in E3ME

4.1 Overview of E3ME's treatment of assumptions

Setting exogenous variables

E3ME has been developed for medium- and long-term forecasting and for the purpose of analysing economic policy effects on a regionalised European basis. Model results for these regions (ie mainly the member states of the EU) partly depend on what is assumed about the developments of economic variables outside the scope of the model, ie exogenous variables.

The clearest case for making assumptions in the model is for variables related to the developments outside the EU which nevertheless affect Europe's economic prospects. For example, world growth rates (measured in GDP) in the 20 world areas adopted for E3ME are used to construct (via trade weighting) world activity variables relevant for the 27 European regions in the model to use in export equations. Similarly, developments in world prices (and exchange rates) will affect trade by changing competitiveness levels. Inflation in the world prices of traded commodities, including food and metals etc, will help to explain import prices.

Most exogenous variables directly related to the EU are connected with government policy such as tax rates, interest rates and government spending, so analysis of the EU members' spending plans and views on future development are necessary. Other variables included are demographic baseline assumptions for population and the potential labour force.

4.2 Determination of E3ME's key assumptions

Data sources

The determination of the base-line assumptions supplied with version 4.2 of the model requires the following:

- The annual historical data for all of the assumptions variables are drawn from the E3ME and E3MG databanks (A). See Chapter 3 for a more detailed description of the data sources for E3ME. More recent and frequent, eg quarterly data, are reviewed to inform the short-term view imposed in the assumptions.
- World commodity price assumptions are made on the basis of data from International Financial Statistics (IFS) and the International Monetary Fund (IMF).
- The setting of country specific assumptions requires advice from teams within the particular country. This includes assumptions about fiscal policy to help guide the short-term model projections. Assumptions for exchange rates and interest rates are made on the basis of data from the International Financial Statistics (IFS). Projections for output and inflationary pressure are based around the team's own experience and evidence from other publications, eg OECD Main Economic Outlook. Longer-term trends are set to approximate historical averages.
- Demographic assumptions are drawn from the baseline forecast taken from DG Tren's *Energy and Transport: Trends to 2030* (DG Tren, 2005). The data comprise baseline projections for population, for each of the E3ME European regions and the other world areas, between 1990-2100. The data are identified by gender and age cohorts, ie male/female and child/working-age/old-age pensioner respectively.

5 Structure of E3ME

5.1 The theoretical background to E3ME

The economic system

Economic activity undertaken by persons, households, firms and other groups has effects on other groups after a time lag, and the effects persist into future generations, although many of the effects soon become so small as to be negligible. But there are many actors, and the effects, both beneficial and damaging, accumulate in economic and physical stocks. The effects are transmitted through the economy and the price and money system (via the markets for labour and commodities), and through the global transport and information networks. The markets transmit effects in three main ways: through the level of activity creating demand for inputs of materials, fuels and labour; through wages and prices affecting incomes; and through incomes leading in turn to further demands for goods and services. These interdependencies suggest that an economic model should be comprehensive, and include many linkages between different parts of the economic system.

The economic system has the following characteristics: economies and diseconomies of scale in both production and consumption; markets with different degrees of competition; the prevalence of institutional behaviour whose aim may be maximisation, but may also be the satisfaction of more restricted objectives; and rapid and uneven changes in technology and consumer preferences. Labour markets in particular may be characterised by long-term unemployment. A model capable of representing these features must therefore be flexible, capable of embodying a variety of behaviours and of simulating a dynamic system. This approach can be contrasted with that adopted by general equilibrium models: they typically assume constant returns to scale; perfect competition in all markets; maximisation of social welfare measured by total discounted private consumption; no involuntary unemployment; and exogenous technical progress following a constant time trend (see Barker, 1998, for a more detailed discussion).

5.2 E3ME as an E3 model

The E3ME model comprises:

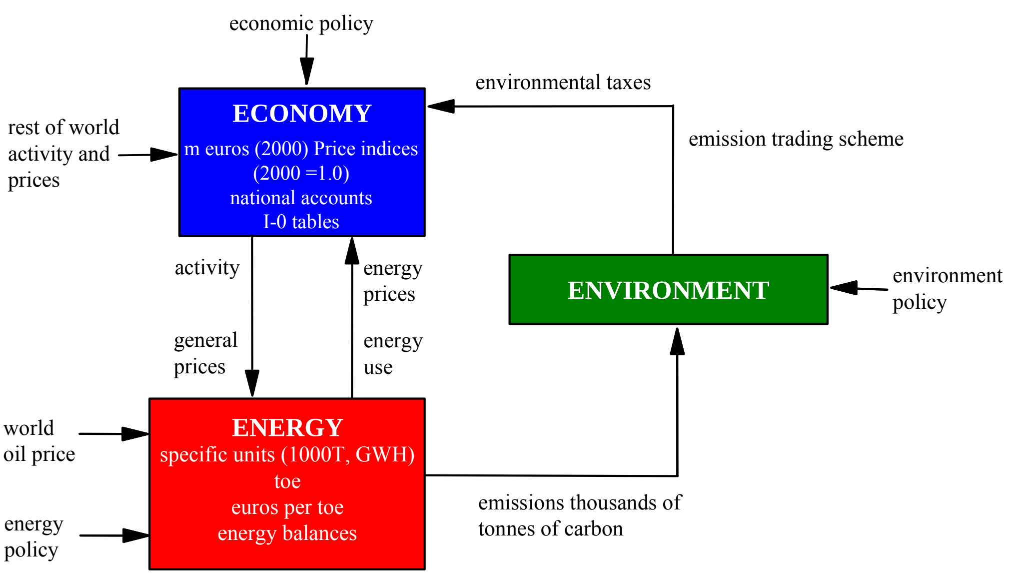
- the accounting balances for commodities from input-output tables, for energy carriers from energy balances and for institutional incomes and expenditures from the national accounts
- environmental emission flows
- 22 sets of time-series econometric equations (see section 5.5)

Energy supplies and population stocks and flows are treated as exogenous.

The E3 interactions

Figure 5.1 below shows how the three components (modules) of the model - energy, environment and economy - fit together. Each component is shown in its own box with its own units of account and sources of data. Each data set has been constructed by statistical offices to conform with accounting conventions. Exogenous factors coming from outside the modelling framework are shown on the outside edge of the chart as inputs into each component. For the EU economy, these factors are economic activity and prices in non-EU world areas and economic policy (including tax rates, growth in government expenditures, interest rates and exchange rates). For the energy system, the outside factors are the world oil prices and energy policy (including regulation of energy industries). For the environment component, exogenous factors include policies such as reduction in SO2 emissions by means of end-of-pipe filters from large combustion plants. The linkages between the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components.

FIGURE 5.1: E3ME AS AN E3 MODEL



The economy module provides measures of economic activity and general price levels to the energy module; the energy module provides measures of emissions of the main air pollutants to the environment module, which in turn gives measures of damage to health and buildings (estimated using the most recent ExternE[9] coefficients). The energy module provides detailed prices levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy.

5.3 E3ME as a regional econometric input-output model

Figure 5.2 below shows how the economic module is solved as an integrated EU regional model. Most of the economic variables shown in the chart are at a 42-industry level. The whole system is solved simultaneously for all industries and all 27 regions, although single-region solutions are also possible.

Figure 5.2 shows interactions at three spatial levels: the outermost area is the rest of the world; the next level is the European Union outside the country in question; and finally, the inside level contains the relationships within the country.

[9] http://www.externe.info/tools.html

The income loop

FIGURE 5.2: E3ME AS A REGIONAL ECONOMETRIC INPUT-OUTPUT MODEL

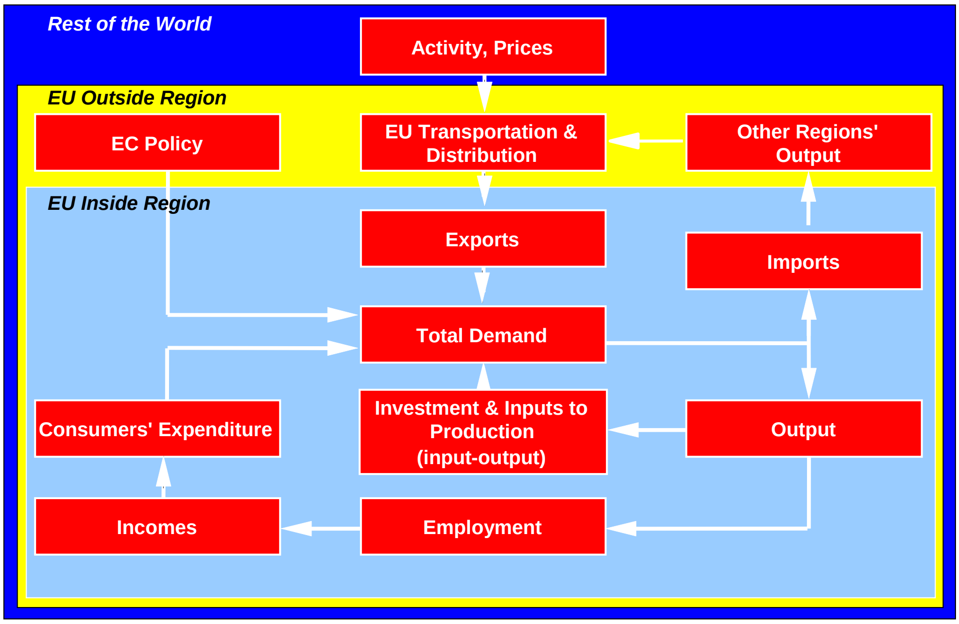
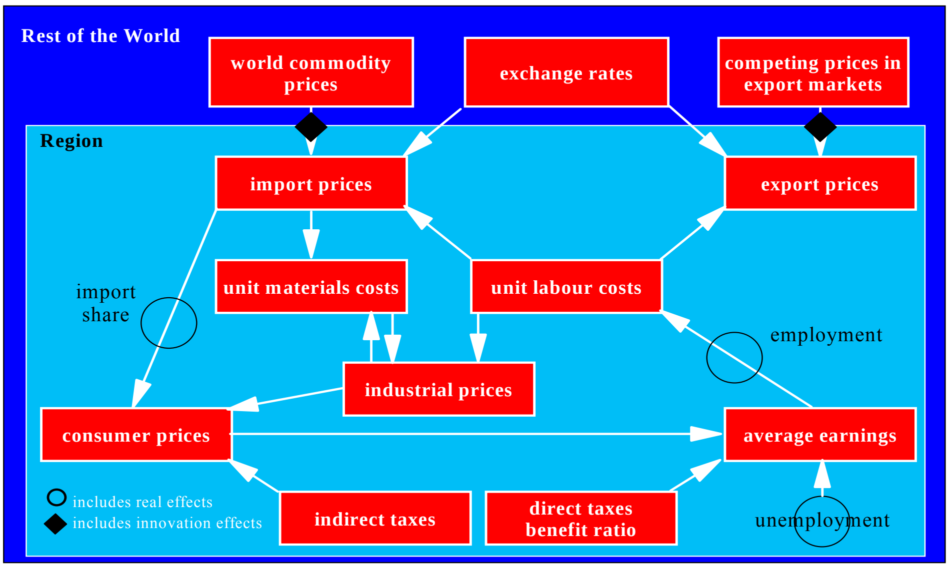


Figure 5.2 also shows the three loops or circuits of economic interdependence, which are described in some detail below. These are the income loop, the export loop and the output-investment loop.

In the income loop, industrial output generates employment and incomes, which leads to further consumers' expenditure, adding to total demand. Changes in output are used to determine changes in employment, along with changes in real wage costs, interest rates and energy costs. With wage rates explained by price levels (see Figure 5.3) and conditions in the labour market, the wage and salary payments by industry

FIGURE 5.3: PRICES AND WAGES IN E3ME



can be calculated from the industrial employment levels. These are some of the largest payments to the personal sector, but not the only ones. There are also payments of interest and dividends, transfers from government in the form of state pensions, unemployment benefits and other social security benefits. Payments made by the personal sector include mortgage interest payments and personal income taxes. Personal disposable income is calculated from these accounts, and deflated by the consumer price index to give real personal disposable income.

Determination of consumers' demand

Totals of consumer spending by region are derived from consumption functions estimated from time-series data (this is a similar treatment to that adopted in the HERMES model). These equations relate consumption to regional personal disposable income, a measure of wealth for the personal sector, inflation and interest rates. Sets of equations have been estimated from time-series data relating the spending per capita to the national spending using the CBS[10] version of the consumption allocation system. The incorporation of this system into the solution is complex: the allocation system has been adapted to provide the long-run income and relative price parameters in a two-stage procedure, with a standardised co-integrating equation including demographic effects providing the dynamic solution. The substitution between categories as a result of changes in relative prices is achieved at the regional level.

The export loop

The export loop runs from the EU transport and distribution network to the region's exports, then to total demand. The region's imports feed into other EU regions' exports and output and finally to these other regions' demand from the EU pool and back to the exports of the region in question.

Treatment of international trade

An important part of the modelling concerns international trade. The basic assumption is that, for most commodities, there is a European 'pool' into which each region supplies part of its production and from which each region satisfies part of its demand. *This might be compared to national electricity supplies and demands: each power plant supplies to the national grid and each user draws power from the grid and it is not possible or necessary to link a particular supply to a particular demand.*

The demand for a region's exports of a commodity is related to three factors:

- domestic demand for the commodity in all the other EU regions, weighted by their economic distance from the region in question
- activity in the main external EU export markets, as measured by GDP or industrial production
- relative prices, including the effects of exchange rate changes (see Figure 5.3)

Economic distance

Economic distance is measured by a special distance variable. For a given region, this variable is normalised to be 1 for the home region and values less than one for external regions. The economic distance to other regions is inversely proportional to trade between the regions. In E3ME regional imports are determined for the demand and relative prices by commodity and region. In addition, measures of innovation (including spending on R&D) have been introduced into the trade equations to pick up an important long-term dynamic effect on economic development.

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[10] Centraal Bureau voor de Statistiek (CBS, Bracke and Mayermans, 1997) allocation of consumption, where consumption of any one good is a function of its price, the average real consumption and the price of each of the other (n-1) commodities.

The output-investment loop

The output-investment loop includes industrial demand for goods and services and runs from total demand to output and then to investment and back to total demand. For each region, total demand for the gross output of goods and services is formed from industrial demand, consumers' expenditure, government consumption, investment (fixed domestic capital formation and stockbuilding) and exports. These totals are divided between imports and output depending on relative prices, levels of activity and utilisation of capacity. Industrial demand represents the inputs of goods and services from other industries required for current production, and is calculated using input-output coefficients. The coefficients are calculated as inputs of commodities from whatever source, including imports, per unit of gross industrial output.

Determination of investment demand

Forecast changes in output are important determinants of investment in the model. Investment in new equipment and new buildings is one of the ways in which companies adjust to the new challenges introduced by energy and environmental policies. Consequently, the quality of the data and the way data are modelled are of great importance to the performance of the whole model. Regional investment by the investing industry is determined in the model as intertemporal choices depending on capacity output and investment prices. When investment by user industry is determined, it is converted, using coefficients derived from input-output tables, into demands on the industries producing the investment goods and services, mainly engineering and construction. These demands then constitute one of the components of total demand.

Accumulation of knowledge and technology

Gross fixed investment, enhanced by R&D expenditure in constant prices, is accumulated to provide a measure of the technological capital stock. This avoids problems with the usual definition of the capital stock and lack of data on economic scrapping. The accumulation measure is designed to get round the worst of these problems. Investment is central to the determination of long-term growth and the model embodies a theory of endogenous growth which underlies the long-term behaviour of the trade and employment equations.

5.4 Energy-Environment Links

Top-down and bottom-up methodologies

E3ME is intended to be an integrated top-down, bottom-up model of E3 interaction. Although E3ME is a complex econometric, simulation model, it originally lacked a representation of the array of non-carbon energy options that could potentially emerge in the future. To fill this gap, an annual, dynamic technology model, referred to here as the ETM model, will be linked with E3ME. The ETM sub-model will be built to generalise earlier work by Anderson and Winne (2004) to form the basis of a new energy technology component of E3ME. Although the ETM is not specifically regional and is not estimated by formal econometric techniques, it does model, in a simplified way, the switch from carbon energy sources to non-carbon energy sources over time.

The ETM model was designed to account for the fact that a large array of non-carbon options is emerging, though their costs are generally high relative to those of fossil fuels. However, costs are declining relatively with innovation, investment and learning-by-doing. The process of substitution is also argued to be highly non-linear, involving threshold effects. The ETM models the process of substitution, allowing for non-carbon energy sources to meet a larger part of European energy demand as the price of these sources decrease with investment, learning-by-doing, and innovation.

One component of the ETM is the learning curve. The importance of including a learning curve in the model cannot be underestimated, as the technology costs do not simply decline as a function of time, but decrease as experience is gained by using a particular technology.

As investment is made in 'new' technologies, learning takes place and the cost of the new technology lowers so that it becomes competitive with the 'old' technologies. For each type of energy demanded there is usually a technology or fuel 'of choice'—what might be termed a 'marker' technology—against which the alternatives will have to compete. In the ETM, the total capital and operating costs of using this fuel per unit output will be used as a basis or numeraire for expressing the relative costs of the alternatives.

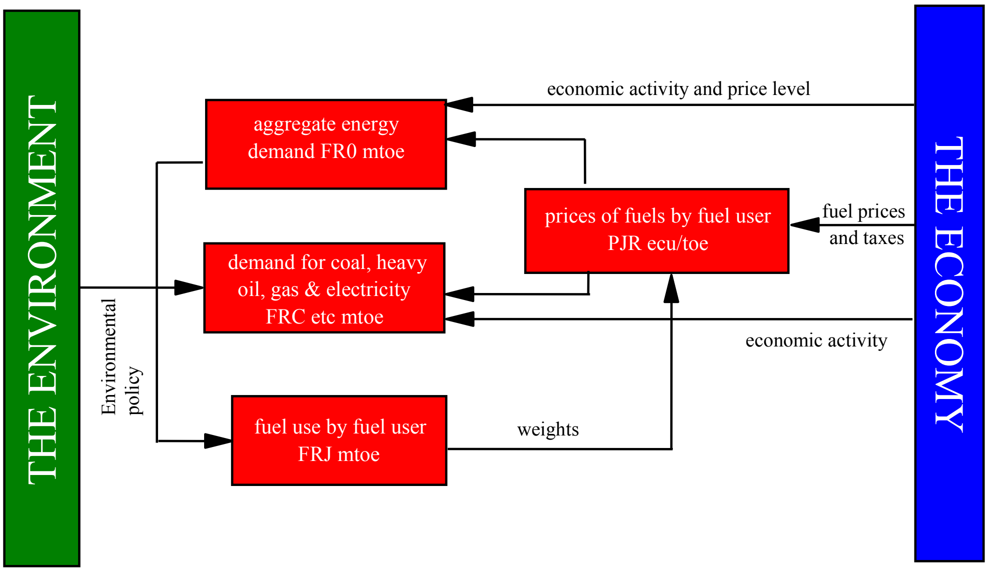
Even though the numeraire technology may comprise the majority of the market, there are always so-called niche markets and opportunities where the non-carbon technology is cheaper than then numeraire. Such applications may be limited, but the point is that, while it may be generally true that the costs of a marker technology may be lower or higher than those of its substitute, this is not true in every case. Even with hydrogen, there have been small niche markets for a century, for instance in oil refineries and for the chemical industry; hydrogen surpluses have been used for co-generation for several years

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 Barker, Ekins and Johnstone, 1995).

A top-down submodel of energy use

The energy submodel in E3ME is constructed, estimated and solved for 19 fuel users, 12 energy carriers (termed fuels for convenience below) and 27 regions. Figure 5.4 shows the inputs from the economy and the environment into the components of the submodel and Figure 5.5 shows the feedback from the submodel to the rest of the economy.

FIGURE 5.4: INPUTS TO THE ENERGY SUB-MODEL



Determination of fuel demand

Aggregate energy demand, shown at the top of Figure 5.4 below, is determined by a set of co-integrating equations[11], of which the main explanatory variables are:

- economic activity in each of the 19 fuel users
- average energy prices by the fuel users relative to the overall price levels
- technological variables, represented by R&D expenditure in key industries producing energy-using equipment and vehicles

Fuel substitution

Fuel use equations are estimated for four fuels - coal, heavy oils, gas and electricity – and the four sets of equations are estimated for the fuel users in each region. These equations are intended to allow substitution between these energy carriers by users on the basis of relative prices, although overall fuel use and the technological variables are allowed to affect the choice. Since the substitution equations cover only four of the twelve fuels, the remaining fuels are determined as fixed ratios to similar fuels or to aggregate energy use. The final set of fuels used must then be scaled to ensure that it adds up to the aggregate energy demand (for each fuel user and each region).

Emissions submodel

The emissions submodel calculates air pollution generated from end-use of different fuels and from primary use of fuels in the energy industries themselves, particularly electricity generation. Provision is made for emissions to the atmosphere of carbon dioxide (CO2), sulphur dioxide (SO2), nitrogen oxides (NOX), carbon monoxide (CO), methane (CH4), black smoke (PM10), volatile organic compounds (VOC), nuclear emissions to air, lead emissions to air, chlorofluorocarbons (CFCs) and the

[11] Cointegration is an econometric technique that defines a long-run relationship between two variables resulting in a form of ‘equilibrium’. For instance, if income and consumption are cointegrated, then any shock (expected or unexpected) affecting temporary these two variables is gradually absorbed since in the long-run they return to their ‘equilibrium’ levels. Note that a cointegration relationship is much stronger relationship than a simple correlation: two variables can show similar patterns simply because they are driven by some common factors but without necessarily being involved in a long-run relationship.

other four greenhouse gases: nitrous oxide (N2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF6). These four gases together with CO2 and CH4 constitute the six greenhouse gases (GHGs) monitored under the Kyoto protocol. Using estimated damage coefficients, E3ME may also estimate ancillary benefits relating to reduction in associated emissions e.g. PM10, SO2, NOx.

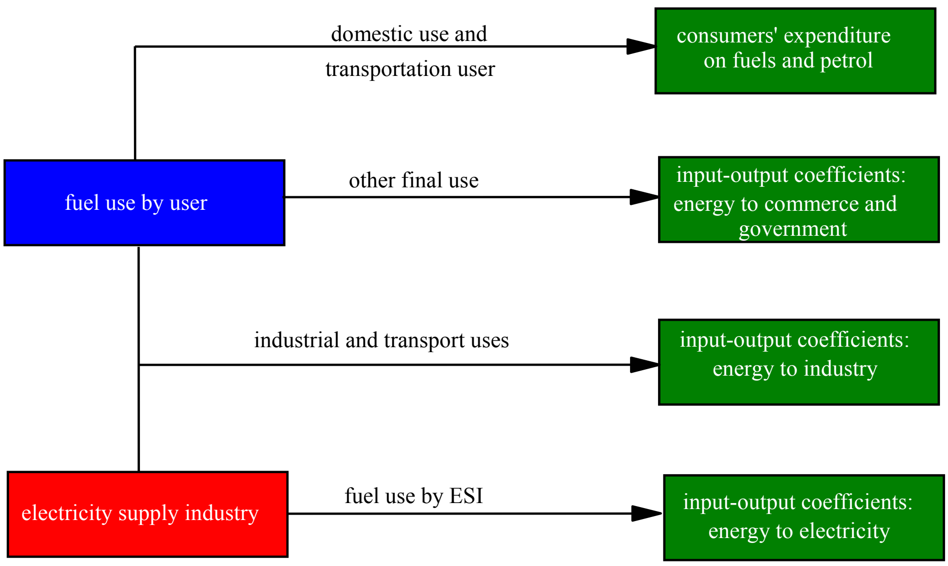
CO2 emissions

Emissions data for CO2 are available for fuel users of solid fuels, oil products and gas separately. The energy submodel estimates of fuel by fuel user are aggregated into these groups (solid, oil and gas) and emission coefficients (tonnes of carbon in CO2 emitted per toe) are calculated and stored. The coefficients are calculated for each year when data are available, then used at their last historical values to project future emissions. Other emissions data are available at various levels of disaggregation from a number of sources and have been constructed carefully to ensure consistency.

Feedback to the rest of the economy

Figure 5.5 shows the main feedbacks from the energy submodel to the rest of the economy. Changes in consumers' expenditures on fuels and petrol are formed from changes in fuel use estimated in the energy submodel, although the levels are calibrated on historical time-series data. The model software provides an option for choosing either the consumers' expenditure equation solution, or the energy equation solution. Whichever option is chosen, total consumer demand in constant values matches the results of the aggregate consumption function, with any residual held in the unallocated category of consumers' expenditure. The other feedbacks all affect industrial, including electricity, demand via changes in the input-output coefficients.

FIGURE 5.5: FEEDBACK FROM THE ENERGY SUB-MODEL



5.5 Material Flow Analysis

Extending E3ME

A separate paper 'Extending E3ME to include Material Flows' (Pollitt, 2007) describes how material flows analysis will be integrated into E3ME.

A submodel of material inputs would comprise of up to seven new equations, with one equation for each material. Similarly to the current fuel equations, the independent variables could include an activity indicator, a price level and a measure of innovation. Equations 5.1 and 5.2 illustrate this for each material user, i (see Section 2.2), and each region, j, using the standard ECM methodology employed in E3ME's stochastic equations.

Equation 5.1: Long-run specification

$$LN(MU_{i,j}) = \alpha_1 + \beta_1 * LN(MURY_{i,j}) + \beta_2 * LN(PMUR_{i,j}) + \beta_3 * LN(YRMU_{i,j}) + ECM_{i,j}$$

Equation 5.2: Short-run specification

$$DLN(MU_{i,j}) = \alpha_2 + \beta_4 * DLN(MURY_{i,j}) + \beta_5 * DLN(PMUR_{i,j}) + \beta_6 * DLN(YRMU_{i,j})$$
$$+ \beta_7 * DLN(MU(-1)_{i,j}) + \beta_8 * ECM(-1)_{i,j} + \varepsilon_{i,j}$$

where:

- MU = Material demand
- MURY = Activity indicator
- PMUR = Price of material relative to other inputs
- YRMU = Measure of Innovation
- ECM is the error in the long-run specification
- LN indicates logs, DLN log-differences, (-1) lagged terms and alpha and beta are estimated coefficients.

We would expect the activity indicator to have a positive effect on material demand and the prices to have a negative effect. Innovation should also have a negative effect on material demand as it is assumed to boost resource efficiency.

Following the template of the energy demand equations, the activity indicator would be defined as sectoral gross output converted into the material users classification. The price variable would be determined by prices of the sector that produces the material (eg water supply for water) so, unless sector-specific price data are available (which seems unlikely), would be the same across the material using groups. This is the treatment used in the energy submodel. Finally, any measure of innovation will be determined by levels of investment and R&D, again converted from the 42-sector industrial classification to the material using groups.

Other than the dependent variable, all of included variables are already present in the E3ME model, so do not require further data processing.

As described above, sectoral gross output and investment/R&D in each sector will affect the material demands of each material using group, and price changes will affect the demand for each material. However, just as important is how changes in material demands feed back to the wider economy through the industries that produce the materials.

With the exception of water (and waste), the materials are almost exclusively inputs to the production processes of various industries and so are part of intermediate, rather than final, demand. In E3ME intermediate demands are determined by input-output relationships and it is the coefficients in the input output table that adjust to reflect changes in demand. The relationship is fairly straight-forward with a 10% increase in demand for a particular material leading to roughly a 10% increase in IO coefficients, although in some cases it would be necessary to apply a correction for heterogeneous output in a given industry (eg forestry makes up only a small part of the agriculture industry).

The same principle can be applied to consumer demand for water, with a direct link between household material demand for water and consumption of water, although the situation is complicated by the fact that in the E3ME consumers' expenditure classification demand for water forms only a small part of the 'Gross rent and water' category.

6 Specification of E3ME's Stochastic Equations

This section provides the specifications for the main macro equations and sets of structural equations in E3ME, together with a summary of the parameters and some properties of the equations.

6.1 Specification of E3ME's stochastic equations

The aggregate energy demand equations

The original equation is based on work by Barker, Ekins and Johnstone (1995) and Hunt and Manning (1989). The work by Serletis (1992), and Bentzen and Engsted (1993) has helped in the cointegrating estimation. Since there are substitutable inputs between fuels, the total energy demand in relation to the output of the fuel-using industries is likely to be more stable than the individual components. This total energy demand is also subject to considerable variation, which reflects both technical progress in conservation, and changes in the cost of energy relative to other inputs. The aggregate energy equation considers the total fuel used (summation of 12 fuel types) in thousand tonnes of oil equivalent (th.toe) by 19 fuel users. The demand for energy by a fuel user is dependent on the 'activity' for the fuel user. This is chosen as gross output for most sectors, but household fuel demand is a function of total consumers' expenditure and for road transport is linked to overall economic activity. A restriction is imposed such that as activity increases then demand for energy use will not decline.

The average price ratio captures the effect of prices relative to the fuel used, and is deflated by unit costs. The long-run price elasticity for road fuel is imposed at -0.7 for all regions, following the research on long-run demand (Franzen and Sterner, 1995) and (Johansson and Schipper, 1997, p. 289).

The measures of research and development expenditure and investment capture the effect of new ways of improving fuel efficiency (energy saving technical progress) and the elimination of inefficient technologies, such as energy-saving techniques replacing the old inefficient use of energy. Research and development expenditure in industries 16-18 (machinery) and 19 (motor vehicles) for the EU as a whole take into account the spill-over effects. R&D expenditure of an industry measures the quality improvements of the products.

The disaggregate energy demand equations

The equations for disaggregate energy demand have been specified for four fuels: coal, heavy fuel oil, natural gas, and electricity. The fuels have the characteristic that in many industries they are highly substitutable inputs to the process of heat generation. The specification of the equations follows similar lines to the aggregate energy equations. The equations contain the same R&D and investment variables, with the same restrictions imposed, although the measure of transport R&D, is only used in the oil equation. The price term is a ratio of the price for the particular fuel in question to that of the aggregate fuel. The relative fuel prices have changed dramatically over the estimation period: there has been a marked fall in real oil prices up to 1973 being followed by abrupt increases as the world price increases; gas prices follow a similar path whereas coal prices remained relatively constant between 1978 and 1991. These price changes have had corresponding changes on the consumption of fuel. Consumption of coal has decreased over the past 40 years, but much more slowly since the first oil crisis. Crude oil consumption increased dramatically until the first oil price shock in 1973, and remained at a very high level over the subsequent six years. The second oil crisis in 1979 led to a fall in consumption of oil in most countries. Gas consumption increased up to 1979, since when it has remained stable.

The aggregate consumption equations

Research on the equations for aggregate consumption is ongoing. As consumption accounts for between 50-60% of final demand the equation is very important in completing the model.

Most studies have followed those of Hendry et al (Davidson, Hendry, Sbra and Yeo, 1978) which have examined the dynamic links between consumption, income and wealth in an error correction model. In more recent studies, attention has focused more upon the role of wealth (housing wealth in particular) and financial liberalisation (Muellbauer and Murphy, 1994; Carruth and Henley, 1993).

The specification of the equation is similar to those used in HERMES which generalise the permanent income and the lifecycle theories in an error correction model. Indeed the long-run elasticity of consumption in relation to income has been set equal to one to ensure the lifecycle theory is fulfilled.

These equations relate total consumption to regional personal disposable income, a measure of wealth for the personal sector, inflation and interest rates. Variables covering child and old-age dependency rates are also included in an attempt to capture any change in consumption patterns caused by an aging population. The unemployment rate is used as a proxy for the degree of uncertainty in the economy. Due to lack of available data on household wealth, cumulative investment in dwellings was used as a proxy for the housing stock.

The disaggregate consumption equations

The CBS (Centraal Bureau voor de Statistiek) allocation system (Bracke and Mayermans, 1997) is used in E3ME to determine disaggregate consumption. Consider for each country a representative economic agent who allocates his total available means between n commodities. Assume also that the preference ordering of this agent satisfies the regular assumptions so that a differentiable set of demand functions exist.

In the long run, consumption of any one good is a function of the multiplicative average of real consumption, its own price and the price of each of the other (n-1) commodities. We have also included two demographic variables, the child and OAP dependency ratios in each region. The dynamic equations are then estimated using a simpler specification rather than a CBS dynamic system due to difficulties brought about by the hierarchical structure of the latter.

A rather simpler specification of disaggregate consumption is used for regions where long-run elasticities have not been estimated within a CBS framework. This model has a logistic form, primarily because the equation is one of budget share, which should be bounded within the [0,1] interval. In this simple model, disaggregate consumption is determined by real gross dependable income and the relative price of consumption. In the long run additional independent variables include; the real rate of interest, consumer price deflator and child and OAP dependency ratios. Any restrictions on adding up are imposed within the model code by a scaling device, and not by theoretical construct.

The industrial investment equations

Investment is a very important and very volatile component of effective demand and so its treatment in the model is of central importance to model simulation and forecasting performance. Ideally, the treatment of investment in a sectoral model such as E3ME should disaggregate by asset (eg vehicles, plant and machinery, and buildings and work) as well as by investing industry, but this has not proved possible due to data limitations.

The specification of the investment equations in E3ME has built upon earlier work published in Barker and Peterson (1987). The theory behind the choice of variables that explain the long-run path of investment is a mix between the neoclassical tradition, whereby factor demands are explained solely in terms of other factor prices, and the accelerator model, which recognises the importance of output as a determining influence. For the dynamic representation, other variables are added, including the real rate of interest and the ratio of actual to normal output, the latter being designed to capture the decision to invest for increased capacity, as opposed to solely for replacement needs.

Trade volume equations

Under E3ME, all trade is treated as if it takes place through a European 'pool', i.e. a transport and distribution network. The export and import volume equations represent each region's exports into this pool and imports from it.

The original specifications for total exports and imports have been separated into two sub-components, one for intra-EU trade and one for extra-EU trade. This was performed as data became available on trade flows to the two areas, thus allowing the model to focus more closely on intra-EU trade flows, which form a large portion of the total trade to and from EU countries.

The export volume equation can be separated into two effects, income and prices. The income effect is captured in the form of two variables, the first dealing with economic activity in the rest of the EU, the other concerning activity in the rest of the world. Price effects are split into three forces, the price of exports, the price of exports in other EU countries and a 'rest of the world' price variable. All prices are converted to euros. Homogeneity is imposed between the price effects, such that the combined value of the external price coefficients (other EU and rest of world) are set equal to the overall export price. This is another way of combining the price terms in a relative, rather than absolute, form.

Two indicators of technical progress are also included to help capture the role of innovations in trade performance. These variables could be measured relative to that of competitors, but since this would imply no effect on trade if competitors undertook equal proportions of investment/R&D this did not seem to be a worthwhile exercise.

The weighting mechanism used for calculating external demand and prices is a matrix built up from the level of trade between the regions, i.e. trade intensity.

Domestic activity, an important determinant of import volumes, is modelled by sales to the domestic market, while the three price effects are import price price of sales to the domestic market and the relative price of the currency i.e. the euro exchange rate. Aside from the restrictions on sign and significance, price homogeneity is imposed between the price of imports and price of sales to the domestic market. As with the export equation, this has the effect of making the price relative, removing the long-term effect of the exchange rate variable. The technical progress measures are again included to allow for the effects of innovations on trade performance.

An additional variable, has been added to the equations to take account of the Internal Market programme. The variable is a synthetic variable that for most EU15 countries has a value of zero until 1985, then gradually increases (following an exponential pattern) to a value of unity in 1992. The EU10 and countries that joined the single market after 1992 are assumed to follow a single path, albeit starting at a later date.

The hours worked equations

Hours worked is a simple equation, where average hours worked by industry and region is a function of "normal hours-worked" (expected hours worked, formed from hours worked in other industries and regions), technological progress and the level of output compared to expected "normal" output which takes into account cyclical effects. It is assumed the effects of technical progress gradually reduce average hours worked over time as processes become more efficient. The resulting estimate of hours worked is an explanatory variable in the employment equation (see below).

Hours worked is defined as an average across all workers in an industry, so incorporates the effects of higher levels of part-time employment in certain regions and industries.

The industrial employment equations

Employment is modelled as a total headcount number for each industry and region as a function of industry output, wage costs, average hours worked, technological progress, and energy (oil) prices. Industry output is assumed to have a positive effect on employment demand, while the effect of higher wages and longer working hours is assumed to be negative. The effects of technical progress are ambiguous, as investment may create or replace labour; this will vary between sectors.

The industrial prices equations

Industrial Prices are defined as a price index for each industry and region. It is modelled as function of unit cost, import price, energy price, technical progress , and the level of output compared to the expected "normal" level of output.

Labour costs and raw material prices are combined in a measure of unit costs, which makes use of a region's input-output structure to add together the input prices from other industries and labour costs, per unit of output. Although import prices are included in unit costs, depending on the import content of production, import prices are added separately in the equation to allow for the effects of international competition on domestic price formation. In the long-term relationship, homogeneity is imposed between these two price measures and industrial prices. In the E3ME equation, the capital stock is measured by the measures of technological progress described at the end of this chapter.

The extent to which an increase in unit costs may be passed on to customers is dependent on the level of competition within the specified industry and country. Under perfect competition (a common assumption of general equilibrium models) firms are price takers and would not be able to pass on increases in unit costs to their customers. However, this is rarely the case and in general an increase in unit costs would be expected to be partially compensated by higher product prices.

With the advent of the single currency, and the single market programmes of the 1990s, many of the product markets included in E3ME have become so integrated that a single EU price for the product is more realistic than many country prices, especially where internal trade for a product is greater than MS domestic trade (i.e. overall more of a product is imported from other member states than is produced domestically).

In E3ME such price formation is represented by the estimation of EU internal prices for products by means of equations relating those prices to EU domestic costs, prices of imports from the rest of the world to the EU, world oil prices (in euro), enhanced accumulated investment (for innovation) and (in the short-term equation), deviations from normal output. The theory behind the equations follows that of the regional price equations.

The export price equations and import price equations

The basic model of trade prices used in E3ME assumes that the EU regions operate in oligopolistic markets and are each small economies in relation to the total market. Certain commodities, e.g. crude mineral oil, have their prices set in global markets and are therefore treated exogenously, but the majority are treated in the following manner. Following from the assumption on market structure, prices are set by producers as mark-ups on costs, i.e. unit costs of production. Aside from this, the same variables are used for both import and export prices, within a general log-log functional form.

Alongside the unit cost variable, there are four price terms included in each regression to deal with developments outside the region in question. They are an 'other EU' price, (created in the same manner as described in the trade volume equations), a 'rest of world' (i.e. outside EU) price, a world commodity price variable and the euro exchange rate. The measures of technical progress are also included to cope with the quality effect on prices caused by increased levels of investment and R&D.

Restrictions are imposed to force price homogeneity and exchange rate symmetry on the long-term equations, again in much the same manner for the trade volume equations.

The industrial average earning equations

In E3ME wages are determined by a complex union bargaining system that includes both worker productivity effects and prices and wage rates in the wider economy. Other important factors include the unemployment rate, benefit rates and cyclical effects. Generally it is assumed that higher prices and worker productivity will push up wage rates, but rising unemployment will reduce bargaining power and therefore wages. A single average wage is estimated for each region and sector.

The estimates of average wages are a key input to both the employment equations and the price equations in E3ME. In the absence of growing output, rising wages will increase overall unit costs and industry prices. These prices may get passed on to other industries (through the input-output relationships), building up inflationary pressure.

The labour market participation equations

Labour market participation is estimated as a rate between 0 and 1 for male, female and total working-age population. Labour market participation is a function of industry output, real retained wages rates, unemployment and benefit rates. Participation is assumed to be higher when output and wages are growing, but falls when unemployment is high, or benefits create a disincentive to work. In addition, there is economic structure variable which measures the relative size of the service sector of the economy; this has been found to be important in determining female participation rates.

The participation rates determine the stock of employment available (by multiplying by working-age population, which is exogenous). This is an important factor in determining unemployment, which in turn feeds into wages and back to labour market participation.

The residual income equations

To complete the income loop, a method had to be devised to cope with the difference between income from wages and salaries and gross disposable income less social security benefits. The solution was an equation that models the residual income between the two; the long-run equation relationship includes the real wage, the index of output price, current price GDP, and the real rate of interest as explanatory variables.

This equation set is by its nature, a temporary one, and will be replaced when a complete accounting structure for institutional payments and receipts can be established.

The investment in dwellings equations

For the long-run equation the demand for housing will expect to have a positive relationship with the real gross disposable income. Since most of the housing market is financed through borrowing, e.g. mortgages, the demand for housing also seems likely to be sensitive to variations in the real rate of interest. Variables covering child and old-age dependency rates are included to capture changes in investment in dwellings caused by changing demography. For the dynamic equation the unemployment rate is included, to capture the variation in the labour market, as well as the total consumer price deflator.

The normal output equations

Output level in sector i for a specific region, is modelled as a function of the output level for the rest of the sectors within the same region, (i.e. nation-wide output effect) and the level of output in the same sector for the rest of the regions, (i.e. external regional output effect). Nation-wide output is constructed as the simple arithmetic average of industrial output in the same region (excluding the specific sector), whereas external regional output is constructed as the simple arithmetic average of industrial output in the same sector across the rest of the regions. A positive relationship between sectoral output and nation-wide output points to spill-over effects from the rest of the regions. A unit long-run elasticity with respect to the external regional output reflects the belief that there is a large amount of spill-over sectoral output effects across different EC regions (Lee and Shields, 1997). The fitted values of this equation are used as a proxy for normal output.

The transport equations

These equations form the transport submodel in E3ME, which was built as part of the TIPMAC project for DG Energy and Transport. The transport submodel consists of four equations: Total passenger travel, Passenger travel by mode, Total freight demand and Freight travel by mode.

The dependent variables are bn person kilometres for passenger transport, and bn tonne kilometres for freight transport. The explanatory variables include real incomes and gross output and price variables.

6.2 Parameter estimation

The econometric model has a complete specification of the long-term solution in the form of an estimated equation that has long-term restrictions imposed on its parameters. Economic theory, for example the recent theories of endogenous growth, informs the specification of the long-term equations and hence properties of the model; dynamic equations that embody these long-term properties are estimated by econometric methods to allow the model to provide forecasts. The method utilises developments in time-series econometrics, in which dynamic relationships are specified in terms of error correction models (ECM) that allow dynamic convergence to a long-term outcome. The specific functional form of the equations is based on the econometric techniques of cointegration and error-correction, particularly as promoted by Engle and Granger (1987) and Hendry et al (1984).

6.3 Endogenous technical progress indicators

Specification

Expenditure on investment and innovation mainly enter E3ME's equations indirectly, by their use in formulating a measure of technical progress. The approach to constructing the measure of endogenous technological progress in E3ME is adapted from that of Lee et al (1990). It adopts a direct measure of technological progress (Tt) by using cumulative gross investment, but this is altered by using data on R&D expenditure, thus forming a quality-adjusted measure of investment. The equation for Tt is written as

$Tt = c + adt(\tau 1)$ (3.1)

where $dt(\tau 1)$ satisfies the following recursive formula

$dt(\tau 1) = \tau 1dt\text{-}1 - \tau 1 + (1 - \tau 1)\log(GIt + \tau 2RDt)$ (3.2)

where

GIt = the level of gross investment

RDt = constant price research and development expenditure

$\tau 1$ = a measure of the impact of past quality adjusted investment on the current state of technical advance, while

$\tau 2$ = a measure of the weight attached to the level of R&D expenditure.

To initialise the recursive process for dt, the assumption is made that in the pre-data period the process generating log(GIt) is characterised by a random walk. Under this assumption the first value of dt can be written as

$d0 = \log(GI)$ (3.3)

where the right hand side represents the average of gross investment over the first five year sample period. The values of $\tau 1$ and $\tau 2$ were set at 0.3 and 1.0 respectively, while noting that more sophisticated procedures could have been adopted, ie a grid search method based on log-likelihood values. The series $dt(\tau 1)$ is then calculated by working the recursive procedure forward given the initial value, d0.

In E3ME there are two technical progress indicators, one which measures technical progress related to ICT investment in the new economy, and one which is related to all other investment. The construction of the two indicators is similar, with investment split up into ICT and non-ICT related investment, and $\tau 2$ set to 0 in the non-ICT investment measure (ie All R&D expenditure influences the ICT measure).

The two technical progress indicators appear together in the equations outlined in Section 6.1, and separate long- and short-term parameters are estimated for each one. Due to a lack of data, a single indicator is maintained for the EU's new member states.

7 Main Assumptions and Limitations

The structure of E3ME follows that of the National Accounts and is compatible with the European System of Accounts (ESA95). Unlike most Computable General Equilibrium (CGE) models, parameters and results are largely determined by relationships estimated from historical data, rather than economic theory. Nevertheless, it is important to understand the underlying assumptions behind any modelling exercise, and this section aims to highlight the main assumptions and limitations with the E3ME model.

7.1 Limitations of econometric models

Econometric models are resource-intensive

Econometric models are often regarded as being very resource-intensive and for this reason alone, there use tends to be somewhat limited. E3ME is no exception and, as a sectoral econometric model, perhaps has even more requirements than most other models. E3ME is a very detailed model with 42 economic sectors and a disaggregation of the energy system into 19 fuel users and 12 energy carriers. The model is designed to be estimated and solved for up to 27 regions simultaneously, for 22 stochastic equations. This requires the construction and maintenance of a time series database with the necessary disaggregation, covering a sufficient time period to estimate reliable parameters (currently 1970-2004).

While this high level of disaggregation allows E3ME to accurately represent fairly complex scenarios and a wide range of policy instruments it is undoubtedly true that the model has high resource requirements: The gathering of and processing of data, and also monitoring outcomes and results are all substantially time-consuming and labour-intensive.

Econometric models are dependent on high-quality data

Another common criticism of econometric models and, more generally, models whose outcomes rest on empirically-estimated parameters is that they are subject to the Lucas Critique. This states that it is naïve to try to predict the effect of a future policy experiment based on relationships estimated from historical data. This is even more true in highly-disaggregated bottom-up models such as E3ME, where behaviour in a particular sector could change considerably in a relatively short period of time.

In contrast to this, CGE models are not generally subject to the Lucas Critique as their results tend to be shaped by their underlying theory. However, even CGE models rely to some extent on historical data (often just a single year) to calibrate their parameters.

Finally, as econometric models are heavily reliant on historical time series data to formulate relationships, a reliable data set is crucial in producing accurate results. Again, as a sectoral model, E3ME is open to criticism about the reliability of some parts of its historical database; many data points near the start of the time period are estimated and, while every attempt is made to do this as accurately as possible (for example using proxy series), it would always be preferable to have accurate raw data.

Other examples of data problems include the inclusion of the EU10, which have short time series (currently 1993-2004) and therefore limited degrees of freedom in the equations, and the structural break caused by German unification.

7.2 E3ME's main model assumptions

As a simplification of reality, all economic and energy (and any other kind of) models are based around a set of assumptions. The main assumptions behind E3ME are defined by the system of National Accounts; however, there are three areas where assumptions are explicitly entered to the model.

Activities of government

Some economic models have attempted to model government behaviour in a limited manner. In E3ME it is treated as exogenous. For example, this means that if there was an increase in national income, tax receipts would increase but government spending would not. As E3ME does not assume equilibrium, this is possible, with the extra revenue being used to reduce government debt. However, as interest rates and monetary policy (including exchange rates) are also treated as exogenous, there is no feedback from this to other model variables.

Demographics

E3ME treats population and other demographic factors as exogenous. The reason for this is that migration and other population trends (including births and deaths) are to a large extent independent of economic activity. However, it is undoubtedly true that migration is affected by economic performance. This is particularly important in terms of the labour market, especially in economies close to full employment, where wages tend to be pushed up rather than there being an increase in immigration.

Activities outside the modelled regions

E3ME is a European, rather than global, model and activities outside Europe are treated as exogenous. This means that E3ME cannot fully address global issues such as climate change. This is a clear limitation of the modelling as efforts to reduce emissions in Europe often coincide with efforts taken on behalf of other countries such as the US. In this respect it is also impossible to model any feedback to world oil and energy prices.

7.3 Limitations in energy modelling

The top down approach

One of the key features of E3ME is the integration of the economic and energy systems. This disaggregated approach includes sectoral demands for energy and feedback to the rest of the economy through changing consumer demand and adjustments to input-output coefficients in the energy sectors.

The E3ME energy submodel in its current form is top-down in approach. This has certain advantages (see the model manual) but means it lacks many of the features of a dedicated energy model. This is a particular limitation in the electricity supply industry, in which the potential of renewable technologies is currently being assessed in many European countries. To compensate for this an annual dynamic technology model, referred to here as the ETM model, will be implemented in E3ME. Although the ETM is not specifically regional and is not estimated by formal econometric techniques it does model, in a simplified way, the switch from carbon energy sources to non-carbon energy sources over time.

The ETS

The European Emission Trading Scheme (EU ETS) is modelled in E3ME, but in a very stylised manner of what, in reality, is a complex system. E3ME calculates only one allowance price per year. The market in permits is assumed to clear and the costs of permits are passed on to fuel prices in accordance with their CO2 emissions. There is no special effect of the allocation of permits to fuel users, and CDM and JI mechanisms are not explicitly included. There are no awareness effects or other forward-looking indicators in the scheme.

Finally, E3ME uses energy data from the IEA database. While energy demand from IEA has a high degree of disaggregation both in terms of fuel types and sectors, energy price data from IEA is more limited in detail. In particular, energy prices are only disaggregated into three sectors: electricity generation, industry and households. These are then applied to the 19 fuel user groups through converters. Recent studies in the COMETR (DG Tax) project showed that there is a loss of accuracy compared to using sector-specific prices; although growth rates over time tend to be similar, levels often show large differences, and are dependent on the average size of firms in the industry.

8 Further Information and Relevant Projects

For more information about E3ME, please refer to the model website www.e3me.com. The full model manual is also available online at http://www.camecon-e3memanual.com/cgi-bin/EPW_CGI.

The list below shows a selection of recent projects in the field of sustainable development that used the E3ME model for analysis.

Matisse Matisse (Methods and Tools for Integrated Sustainability Assessment). The objective of MATISSE is to achieve a step-wise advance in the science and application of Integrated Sustainability Assessment (ISA) of EU policies. In order to reach this objective the core activity of the MATISSE project is to improve the tool kit available for conducting Integrated Sustainability Assessments. E3ME is seen as one of these tools and provides a key input to the energy-environment modelling from the perspective of technical progress. The project runs over 2005-08. Webpage: http://www.matisse-project.net/projectcomm/

DROPS DROPS (Development of macro and sectoral economic models aiming to evaluate the role of public health externalities on society). DROPS aims to provide a full-chain analysis related to impact of health protection measures for priority pollutants as identified by the Environment and Health Action Plan (EHAP), and to support the development of cost effective policy measures against pollution related diseases and their wider impacts. The project aims to achieve this through extending and further developing existing methodologies, models such as E3ME, and data to provide an impact-pathway-based model for evaluation of the role of public health externalities on society. DROPS runs over 2005-07. Webpage: http://www.nilu.no/DROPS/

COMETR COMETR (Competitiveness Effects of Environmental Tax reforms). is a Specific Targeted Research Project (STREP) supported by financing from the EU's Sixth Framework Programme for Research (FP6). COMETR is coordinated by the Department of Policy Analysis at the National Environmental Research Institute in Denmark and has 6 partners. COMETR ran from December 2004 through to November 2006. The project aim was to advance the debate on competitiveness effects by undertaking the first comprehensive sectoral analysis of Europe's environmental tax reforms from an ex-post perspective. It used modelling frameworks as well as case studies concerning the existing tax reforms which have taken place in the EU and Candidate countries. Webpage: http://www2.dmu.dk/cometr/index.htm.

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Appendix A: Classification Tables

TABLE A.1 - E3ME: INDUSTRIES

	Full industry heading	2-letter ID	NACE REV 1.1
1	Agriculture etc	AG	01,02,05
2	Coal	CO	10
3	Oil & Gas etc	OG	11,12
4	Other Mining	MI	13,14
5	Food, Drink & Tobacco	FD	15,16
6	Textiles, Clothing & Leather	TC	17,18,19
7	Wood & Paper	WP	20,21
8	Printing & Publishing	PP	22
9	Manufactured Fuels	MF	23
10	Pharmaceuticals	PH	24.4
11	Chemicals nes	CH	24(ex24.4)
12	Rubber & Plastics	RP	25
13	Non-Metallic Mineral Products	NM	26
14	Basic Metals	BM	27
15	Metal Goods	MG	28
16	Mechanical Engineering	MA	29
17	Electronics	IT	30,32
18	Electrical Engineering & Instruments	EI	31,33
19	Motor Vehicles	MV	34
20	Other Transport Equipment	TE	35
21	Manufacturing nes	OM	36,37
22	Electricity	EL	40.1
23	Gas Supply	GS	40.2,40.3
24	Water Supply	WA	41
25	Construction	CN	45
26	Distribution	DT	50,51
27	Retailing	RT	52
28	Hotels & Catering	HC	55
29	Land Transport etc	LT	60,63
30	Water Transport	WT	61
31	Air Transport	AT	62
32	Communications	CM	64
33	Banking & Finance	BF	65,67
34	Insurance	IN	66
35	Computing Services	CS	72
36	Professional Services	PS	70,71,73,74.1-74.4
37	Other Business Services	OB	74.5-74.8
38	Public Administration & Defence	PA	75
39	Education	ED	80
40	Health & Social Work	HS	85
41	Miscellaneous Services	OS	90 to 93,95,99
42	Unallocated	UN	

TABLE A.2 - E3ME: 27 EUROPEAN REGIONS (R)

1	Belgium	(BE)
2	Denmark	(DK)
3	Germany	(DE)
4	Greece	(EL)
5	Spain	(ES)
6	France	(FR)
7	Ireland	(IE)
8	Italy	(IT)
9	Luxembourg	(LX)
10	Netherlands	(NL)
11	Austria	(AT)
12	Portugal	(PT)
13	Finland	(FI)
14	Sweden	(SW)
15	UK	(UK)
16	Czech Republic	(CZ)
17	Estonia	(EN)
18	Cyprus	(CY)
19	Latvia	(LV)
20	Lithuania	(LT)
21	Hungary	(HU)
22	Malta	(MT)
23	Poland	(PL)
24	Slovenia	(SI)
25	Slovakia	(SK)
26	Norway	(NO)
27	Switzerland	(CH)