Resource productivity, environmental tax reform and sustainable growth in Europe

Modelling Environmental Tax Reform in Germany and the United Kingdom with E3ME and GINFORS

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Work package 3.3:

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1. INTRODUCTION: THE PETRE PROJECT AND ETR IN EUROPE

This paper presents a contrast and comparison between the sectoral econometric models E3ME and GINFORS for the purpose of modelling environmental tax reform (ETR) in Germany, the UK and Europe. For a more detailed description of the GINFORS model, the reader is referred to Meyer *et al.* (2005, 2007, 2008). More information about the E3ME model can be found at the model website www.e3me.com and the full online manual http://www.camecon-e3memanual.com/cgi-bin/EPW_CGI.

1.1. THE PROJECT

Productivity and Environmental Tax Reform in Europe (PETRE) is a three-year project funded by the Anglo-German Foundation and forms part of the 'Creating Sustainable Growth in Europe' research initiative. The project is intended to generate new insights into the necessary conditions for sustainable economic growth and the scope for public policy to promote such conditions. In particular, the focus of the project is on the major issues relating to resource productivity and environmental tax reform, including the effects on both the economy and the environment. The project is currently divided into five work packages.

As part of the project, Cambridge Econometrics (CE) and GWS are analyzing the major impacts of ETR, taken to mean any policy that makes use of price instruments to combine meeting environmental objectives with welfare-related targets. By this definition, ETR includes future possible European emission trading schemes (ETS). The purpose of the study is to assess the likely policy impacts for Germany, the UK and the EU with regard to:

resource productivity

energy demand and greenhouse gas (GHG) emissions

economic output

labour productivity

This analysis constitutes Work Package 3 (WP3) of the PETRE project.

The final objective of WP3, 'Modelling the Single-country, European and Global Economic and Environmental Effects of Different ETR Regimes', is to identify the possible reasons for differences in the projections (up to 2020) between two EU-wide macro-econometric models: CE's Energy-Environment-Economy Model of Europe (E3ME) and GWS's Global Interindustry Forecasting System (GINFORS).

1.2. THE PURPOSE OF THIS PAPER

This paper is a precursor to the detailed scenario analysis and will serve to identify areas in which the models' results are likely to differ, particularly with regard to the intended impacts of ETR: energy demand and emissions (the environmental effects) and labour demand (the welfare effects). The paper considers how the treatment of revenues from environmental taxes and charges affects the results of modelling ETRs.

All models explicitly or implicitly recycle the revenues from taxes or charges. This form of recycling can be by lump-sum transfers to consumers, a form chosen to minimize the theoretical effects of the transfer on the economy (often implicit in CGE analysis) or by explicit reduction in a burdensome tax or charge, e.g. employers' social security charges. The form of revenue recycling has been shown to be a crucial factor in reducing the estimated macroeconomic costs of climate change mitigation (Barker et al., forthcoming).

Section 2 reviews the ETR theoretical and empirical literature, specifically the quantified studies using large-scale economic models. The treatment of the labour market in the modelling is important in any study of revenue use because it affects the outcome for employment and inflation, especially if the revenues are recycled by way of reductions in employment taxes. It appears that the use of active revenue recycling in the models (as opposed to lump-sum recycling by default) is one of the most important factors in reducing costs, so the treatment of revenue recycling is also likely to be important in explaining differences in results from E3ME and GINFORS. Section 3 of the paper outlines the ETRs in Germany and the UK in the general context of ETRs in the EU Member States. Section 4 discusses the key relationships likely to be important in the models in the analysis of ETRs in Germany and the UK.

In the Annex, extracts from technical papers describing E3ME and GINFORS have been adapted and are presented side-by-side, organised by model characteristics. A brief discussion of the differences and similarities between the models is then offered.

2. THE LITERATURE ON ENVIRONMENTAL TAX REFORM

The literature on the ETR developed in the 1990s, following government and NGO interest in the idea and the potential for a switch in taxation from being a burden on employment and other beneficial activities to becoming a disincentive on pollution and other environmentally damaging activities. The theoretical literature is very extensive and there have been several surveys: De Mooij (2000) develops the neoclassical model and explains how various departures from optimality permit the emergence of a double dividend; Kratena (2002) is more focused on the treatment of the labour market; and Ekins and Barker (2001) discuss the topic in the context of carbon taxation and permit trading.

While the concept of taxation to mitigate negative environmental effects is not new, ETR is a much broader application of such policies intended to simultaneously align agents' behaviour with environmental objectives and address welfare issues. In neo-classical equilibrium theory, an *environmental* tax wholly or partially corrects a distortion from a pre-existing environmental externality. ETR is therefore envisaged as an efficiency-improving redistribution of the tax burden, away from distortionary taxes on labour towards levies on resource use. A loss of marketed output is to be expected from such improvement, unless it is a component of an ETR in which other taxes and charges are also changed, so allowing for an improvement in economic performance, e.g. more employment. However, the theory behind the modelling described in this paper takes a different approach, partly because no economy is in equilibrium, distorted or otherwise. Depending on the type of model used, and the macroeconomic effect of an environmental tax reform will depend on the economy in question, its specific tax structures, the availability of under-used resources such as unemployed labour or equipment, and exactly when it is introduced, since the point in the trade cycle and key prices (e.g. for oil) will affect the results.

An example of a possible reform would be a decrease in income tax, potentially increasing both income and labour force participation, combined with an energy tax to internalize the externality costs of pollution. The price signal generated by this is sometimes cited as a more efficient mechanism of inducing a reduction in negative environmental behaviour compared to existing regulatory measures. ETR becomes a pure redistribution of the tax burden when it is revenue-neutral - the reduction in labour tax is such that the tax revenue lost is precisely offset by the value of the environmental taxes levied. However, this is not necessary to the function of ETR.

The theoretical literature also considers the so-called erosion or tax interaction effects[1]. The general conclusions are that the tax interaction effect in economies with significant pre-existing labour taxes can increase the costs of ETR, thereby reducing the optimal emission reduction, and that this effect is substantially greater where freely issued permits are the instrument of control, rather than a carbon tax with revenue recycling. However, the result depends on the degree of competitiveness in labour and product markets and on the functional forms chosen, as well as on the precise values of parameters in the models (Kratena, 2002). Different coverage of the economy, functional forms and assumed values of parameters can yield conflicting results, so that the existence of a double dividend is dependent on a specific tax reform in a country or region and the empirical estimation of a model.

The quantitative literature is also substantial. Gaskins and Weyant (1993) report the results of the EMF12 comparison in which four of the modellers considered how costs might be reduced by the active use of the revenues to reduce taxes that discourage economic activity. They found that the costs of a 20% reduction in CO_2 for the USA by 2010 were in the range 0.9 to 1.7% of GDP with lump-sum recycling, but were reduced by 35% to over 100%, particularly if the taxes on capital formation are reduced. Goulder (1995) has also examined the effects of changing the recycling assumption. The GDP cost for the USA as a result of a carbon tax of $25/tC is reduced by 40-55% over the long run when the revenues are recycled via reductions in marginal rates of personal income tax rather than lump sum. Also for the USA, the EIA (US EIA, 1998) finds that if the recycling assumption is changed from lump-sum so that revenues are used to reduce social security payments by employees and businesses, the costs fall from 4.1% to 1.9% of GDP in 2010 and then to a negligible 0.2% in 2020.

Meyer and Lutz (2002), using the COMPASS model to study the carbon taxes for the G7 countries, found that recycling revenues via social security contributions increased employment by nearly 1% by 2010 in France and Germany, but much less in US and Japan. Bach *et al.* (2002) using the models PANTA RHEI and LEAN found that the modest environmental tax reform enacted in Germany 1999-2003 increases employment by 0.1 to 0.6% by 2010, i.e. as much as an additional 250,000 jobs, with a 2-2.5% reduction in CO_2 emissions and a negligible effect on GDP. Masui *et al.* (2005) examine the effects of a carbon tax in Japan to meet the Kyoto target using the AIM (Asia-Pacific Integrated Model). By 2010, a carbon tax with lump-sum recycling leads to an average GDP loss of 0.16% and a tax of 115 US$/t$CO_2$. A tax and subsidy regime, with carbon tax revenue utilized to subsidize CO_2 reduction investments leads to an average GDP loss of 0.03% and a tax of 9 US$/t$CO_2$.

[1] See de Mooij (2000) for a discussion of the neo-classical analysis of the tax interaction effect.

Meta-analysis also supports the potential of ETR to improve economic performance. The World Resources Institute (WRI) (Repetto and Austin 1997) reports the results of a quantitative meta-analysis of the GDP costs of mitigation for the US economy. It estimates that a 30% reduction in US baseline emissions by 2020 would cost about 3% of GDP on worst case assumptions and an increase of about 2.5% in GDP on best case (both relative to baseline). Of the total difference of 5.5 percentage points (pp) (i.e. 3pp plus 2.5pp) of GDP in lower costs, 1.2pp can be attributed to the recycling assumption. More recently Barker *et al*. (2006) carried out a further meta-analysis of data from global models. The active use of revenues within the models brings about some 1 to 2 percentage points improvement in global gross world product by 2030, when the revenues are used to reduce distorting taxes, with perhaps even greater increases if used to provide incentives for low-carbon innovation.

It is worth emphasising that if recycling revenues are to prove beneficial, they must be used to reduce existing taxes that are in some way damaging to the economy by reducing employment opportunities or innovation. The ETR gives the opportunity for improving the tax system that would not be there otherwise.

There are currently six EU member states that have introduced ETR in some form (see Speck, 2006, for a review), plus Norway. Germany and the UK first implemented such policies in the late 1990s. Germany's interpretation of ETR has involved increasing existing energy taxes and introducing a new electricity tax. Exemptions and reductions were provided for the manufacturing and agriculture, fishing and forestry sectors but have been reduced in the second phase of the scheme. Reductions are also available for renewable energies and biofuels. Revenue from the taxes has been directed at a reduction in social security contributions divided evenly between employees and employers. The UK's main reform has been the institution of the Climate Change Levy (CCL), an energy tax on commercial and industrial use. Revenue from the CCL is recycled by lowering employers' tax contributions. An 80% discount is currently available for energy-intensive industries.

The remaining EU countries that have implemented some form of ETR are: Sweden, Denmark, Finland and the Netherlands. France and Italy had planned to roll out their own programmes in the 1990s but increasing oil prices in Italy and a failure to pass the legislation in France prevented this.

3. LIKELY ETR EFFECTS IN E3ME AND GINFORS

The possible effects of introducing a revenue-neutral ETR, first without and then with using revenues to reduce employment taxes, given the approach of E3ME and GINFORS can be summarised as follows.

Prices. The pollution taxes are very likely to raise prices of goods and services according to their pollution content, especially if the main producers (e.g. electricity generated by coal) are operating in competitive and unregulated markets.

Wage rates. Without any recycling of revenues, the increased prices are expected to lead to increases in wage rates, depending on the treatment of the labour market. When the labour market is characterised in terms of the "real wage bargaining" model, as in E3ME, with market power on both sides of the labour market, i.e. employers and trade unions, wage rates will rise. With recycling, the main factor determining the extent to which an efficiency dividend would arise is whether or not the reduction of employers' social security taxes combined with the higher wage costs leads to lower or higher overall labour costs per unit of output. The social-security component of unit labour costs will fall, but the wage payments to employees per unit of output will rise, because the higher price inflation will lead to higher wage inflation.

Employment. The outcome will depend on whether there is an overall increase in real incomes, especially for wage earners. Assuming that there is full employment, then the implications for employment are ambiguous: being negative because of inflation and macroeconomic deterioration, and being positive through some possible substitution effects in both production and consumption because prices of carbon-intensive products will rise, but prices of some employment-intensive products may fall. Assuming that there are unemployed resources, then the outcome may well be an overall increase in real incomes, especially for wage earners. If there is, then the real wage is increased and the wage inflation pressures will be lower. Employment would unambiguously increase, through both the substitution effects and firms' falling relative labour costs. The higher employment would probably mean that overall labour productivity in the economy was lower.

Output. The higher prices of the pollution-intensive products will lead to a loss in price competitiveness on export markets and some loss in the share of domestic markets to imports from other countries. This loss of price competitiveness will be offset by gains in the labour-intensive sectors if real wage costs per unit of output have fallen in the ETR through recycling of revenues to reduce employers' taxes. Any improvement in non-price competitiveness will also raise exports. The extra employment will raise incomes, raising consumption and output. The outcome in E3ME is likely to be an overall increase in output, with the structure changing such that the output of the pollution-intensive industries is reduced relative to that of other industries. But since there are counterworking effects, the result on output may also be slightly negative in GINFORS.

Trade. Trade in pollution-intensive products will be reduced, depending on the strength of any rebound effect: this is the response of the economy to income and output increases following the ETR. The higher incomes, for example, could be spent on road and air travel, increasing use of imported pollution-intensive fuels.

4. GENERAL PROPERTIES OF E3ME AND GINFORS

4.1. ARCHITECTURE

E3ME:

E3ME is a dynamic simulation econometric model, not a CGE, combining the features of an annual short- and medium-term sectoral model.

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.

The model is split into three modules: (1) economy, solved as an integrated regional model (2) energy, which has a two-way linkage with the economy module and also feeds into the (3) environment module, which calculates air pollution from end-use as well as energy industry primary use and feeds back into the economy module

GINFORS:

GINFORS is not a CGE model rather it is based on an evolutionary philosophy with imperfections and allowances for bounded rationality.

GINFORS is an integrated system that adds economics to industrial ecology and thus favours policy realism. The link between economic activity in the countries is given by international trade, which is the result of global competition in deep sectoral disaggregation.

A country model consists of a macro model, an input-output model, an energy model and a material model which are linked with each other. Whilst macro models by GINFORS are at hand for all countries, input-output models are available for 21 countries only. The economies of the remaining countries are solely displayed by a macro model.

Discussion

Both models are pioneering in that they are based on the "new economics" or "complexity economics" (Beinhocker, 2006), which looks to institutional, evolutionary and chaos theory rather than the traditional equilibrium-rationality theory of mainstream economics as represented in CGE models. Both models are multicountry/multisector integrated economic-energy-environment models. Combining these attributes is necessary for analyzing the implications of long-term energy policy and carbon mitigation options. The explicit modelling of countries is useful since policies are always related to specific countries and their individual structural properties. The sector approach, including the inter-industry relations, is unavoidable since the relations between the environment and the economy are sector specific with different sector focuses depending on the questions to be answered.

The models differ in country coverage. E3ME is a European system, which explicitly models all 25 EU (as of 2006) countries plus Switzerland and Norway. Activity elsewhere in the world is treated as exogenous. The closely related global model E3MG is less detailed in its treatment of EU institutions, but covers 20 world regions.

GINFORS is a global model covering all EU25, all OECD countries and their major trade partners. The system includes a total of 50 countries and two regions, including "OPEC" and "Rest of the World". The explicitly given 50 countries and the OPEC region have world coverage in terms of GDP and CO_2 emissions of 95%. The 21 countries with input-output models cover about 80% of world GDP.

Both E3ME and GINFORS simultaneously find solutions for all countries, but in both systems also single-country solutions are possible.

4.2. Parameterization

E3ME:

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). Generalised instrumental variable estimation is used and heterogeneity assumed.

GINFORS:

GINFORS combines econometric-statistical analysis with input-output analysis embedded in a complete macroeconomic framework.

Nearly all parameters of GINFORS are estimated econometrically using international time series data. The parameters are estimated by OLS.

Discussion

Both models are econometric models combining regression estimates with input-output coefficients and bilateral trade shares. E3ME extends the formal econometric methods to the estimation of private consumption in total and by function (e.g. housing), fixed investment by industry; exports, imports, their prices, product prices, employment and wage rates (22 sets of equations in all) by country and sector. In general GINFORS has the same flexibility, but relies on fixed shares of macro-aggregates for investment and the goods structure of consumption for energy on the one side and consumption for non energy use on the other side. The parameter estimation of E3ME is based on the econometrics of cointegration and error correction, with a shrinkage technique applied to compensate for the short time series in the ten countries that joined the EU in 2004.

For GINFORS the OLS method of econometric estimation was chosen. More adequate estimators could not be used for two reasons: In many countries the length of the time series is relatively short. Further, for the automatic estimation of the large amount of variables (e.g. price elasticities for 70304 trade shares); a robust and simple estimation technique is needed.

4.3. Data

E3ME:

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

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.

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.

When Eurostat data are not available or need to be improved, other internationally available sources such as the IMF are consulted.

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.

Energy data is taken from the IEA database.

GINFORS:

The database of GINFORS is supplied by five sources:

OECD

IMF

Eurostat

UN COMTRADE databanks

IEA

Furthermore, for two significant countries (China and Taiwan), national statistics are evaluated. The trade data resulted from a merging of OECD and UN data. The data for the macro model are based on the OECD (2004) "National Accounts of OECD Countries, Detailed Tables" and the dataset "International Financial Statistics" by the International Monetary Fund (IMF). Since a coherent level of data is necessary for the model, gaps within the datasets were filled by own calculations. In the majority of the cases, the input-output tables were taken from OECD publications and Eurostat. The energy models exclusively refer to the energy balances published by the IEA. For the material-input models, the data supply by the Sustainable Europe Research Institute (SERI) as part of the MOSUS project form the database.

Discussion

Both models are based on international sectoral data using OECD data as a first choice. The default currency is the euro in E3ME and the Dollar in GINFORS. Other data sources are UN, EUROSTAT, the AMECO database and IMF. National data sources have only been used when it was unavoidable. The models both use energy data provided by the IEA.

4.4. Technical Progress

E3ME:

The approach to constructing the measure of technological progress in E3ME is adapted from that of Lee et al (1990). It adopts a direct measure of technological progress by using cumulative gross investment, but this is altered by using data on R&D expenditure, thus forming a quality-adjusted measure of investment.

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.

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.

The two technical progress indicators appear together in the stochastic equations and separate long- and short-term parameters are estimated for each one.

GINFORS:

Technical progress is implicitly modeled. The technology is depicted in a two-stage approach. In the first stage capital, labour, energy and material are factors of a limitational technology; in the second stage the energy input is divided into the demand for the different energy carriers assuming substitution.

The dependency of the sectoral factor demand functions for labour, energy and material of the first stage on the relation of the factor price and the sector price is interpreted as the effect of cost push driven technical progress. Additionally time trends reflect autonomous progress. At the moment capital inputs are modeled at the macro level with constant sectoral structures. The GINFORS team is just working on a change explaining investment bottom up at the sector level.

On the second stage the shares of 11 energy carriers in the energy inputs of a sector are determined by price relations.

Discussion

E3ME explicitly models technical progress endogenously (through a function of accumulated investment enhanced by R&D spending) by industrial sector and its impact on the economy and energy demand through effects on trade, prices, employment, all at a sectoral level.

In GINFORS technical progress is modeled implicitly. It is assumed that relative prices are cost push determinants of technical progress. This reduced form approach is not avoidable, since R&D data is not available globally on the sector level. But nevertheless the direct and indirect effects of technical progress are also depicted.

5. CONCLUSIONS

Both models are pioneering in that they look to institutional, evolutionary and chaos theory rather than the traditional equilibrium-rationality theory of mainstream economics as represented in CGE models. Both models are multicountry/multisector models. Both models transmit effects between countries through flows of import and export volumes and import and export prices. The multicountry approach that explicitly models different countries is necessary, since countries and not "regions" are the relevant policy units. The sectoral focus is necessary, since the economic-environmental relations are very different at the sectoral level and the economies have very different sectoral structures. Both models are empirically based using econometric methods for the estimation of the parameters. Insofar as the models have central common properties, a comparison of simulation results is useful.

On the other side, there are differences in the specification and parameter estimation of the models, which may yield different simulation results. E3ME is modelling technical progress explicitly, whereas GINFORS does this implicitly. E3ME is focussing Europe whereas GINFORS is a global model. Trade in E3ME flows to and from a common pool. GINFORS uses a bilateral trade model with price dependent trade shares. GINFORS has a materials model; E3ME will incorporate one for the project. GINFORS has, compared with E3ME, a less flexible structure of consumption and investment. GINFORS provides macro-models with full SNA structures for the most important countries, whereas E3ME has a simplified accounting tool for the redistribution of income. For the estimation of the parameters, E3ME uses error-correction methods, whereas GINFORS is based on OLS estimations.

The identification of the impacts of these differences on the simulation results will be one major outcome of the project. Since the sets of endogenous and exogenous variables are not identical in the models, the formulation of the assumptions and scenarios has to be done very carefully so that identical model experiments can be guaranteed. The comparison of the results and the discussion of the differences will enlarge our knowledge about ETR and provide a check, given the two approaches and the common framework. Furthermore new ETR instruments like ETS with auctioning and recycling of the auction revenues can be discussed on a broad modelling base.

ANNEX: The Model Structure in Detail

A. TRADE MODEL

E3ME

Under E3ME, all trade is treated as if it takes place through a European 'pool', ie a transport and distribution network, into which each region supplies part of its production and from which each region satisfies part of its demand. The export and import volume equations are divided into those to the internal single market and those to markets external to the EU. They represent each region's exports into the internal and external pools and imports from them

The demand for a region's exports of a commodity is related to four factors: demand in the export markets using their GDP weighted by economic distance; own prices; competitor prices, also using distance weights; and the technology indicators.

Economic distance is measured by a special distance variable. For a given region, this variable is normalised to be one 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 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.

Trade volume is separated into intra- EU and extra-EU trade flows. For exports, income is determined separately for the EU and the rest of the world and price effects are split into three: export prices, export prices in other EU countries, and a 'rest of world' price variable.

In the case of imports, domestic activity is modelled by sales to the domestic market and the three price effects are: import price, price of sales to the domestic market and the relative price of the currency (the euro exchange rate).

Price homogeneity is imposed for both imports and exports and technical progress measures included to allow for innovations in trade performance. A synthetic variable to take account of the Internal Market programme is also included. The internal exports of each product are scaled to match the internal imports, allowing for errors in data.

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 such as oil have their prices set in global markets and are therefore treated exogenously, but the majority are set by producers as mark-ups on costs.

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, a 'rest of world' 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.

GINFORS

The trade model is the centre of the GINFORS system. For 25 commodities as well as the service trade, bilateral trade matrices for 50 countries, including all OECD countries and its major trade partners are provided. The coefficients of the trade matrices – the trade shares – are endogenous variables depending from the relation between the price of the commodity of the exporting country and the average price of the imports of that commodity in the importing country. Via this trade context, both quantities and prices are properly allocated to the countries.

The regions appear as unaffiliated actors within the trade model. Every national model provides import vectors and export price vectors; and receives export vectors and import price vectors in its interaction with the trade model. Values from the country models are given in national currency. These values must be converted to US$ before being passed to the trade model and the output from the trade model converted back into national currencies.

The aggregates are calculated in the following way: Import demand is an aggregate of sectoral imports which are determined in the input-output model. If the country has no input-output model, an aggregated import function is estimated with GDP and the relative import price serving as determinants. The vector of import prices in US$ is given by the trade model. By aggregation, a price for total imports can be calculated.

The exchange rates (for conversion into US$) are generally estimated as a function of the GDP deflator of the respective country and the GDP deflator of the USA. This generally yields good results, with elasticities ranging close to 1 which implicitly means constant real exchange rates – a robust hypothesis that allows for long-run projections of the exchange rates up to 2020. Some exchange rates are taken as scenario variables. This is the case for the Chinese currency, because it is not determined by markets. The EURO is taken as exogenous, because there is no experience for the long run behaviour.

Production prices are determined in the input- output- models by companies via a mark-up calculation from unit costs. Exceptions only occur when, due to the homogeneity of commodities in relation to the global market, companies are price takers, not price leaders. This is typically the case in primary commodity markets where a coherent global market has evolved.

Export prices implemented within the bilateral trade model are basically identical to production prices.

Discussion

Within E3ME, international trade is not modelled on a bilateral basis but by means of European pool and global pools or networks. The export and import volume equations describe each regions exports into and imports from these pools, with relative weights (or "economic distance") determined by OECD bilateral trade data.

GINFORS has a bilateral trade model that connects the countries directly. The share of exports of a delivering country in the imports of a receiving country for a specific good is dependent on relative prices and trends. The level of exports is then given by definition.

Both models allow for imperfectly competitive price structures – producers set prices as a mark-up on unit costs. Trade in commodities that exist in coherent global markets are taken to have an exogenously set price.

B. Input-Output Structures

E3ME

The accounting structure for the 42 products and industries in E3ME is based on the Eurostat System of Accounts 1995 (ESA95). The 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.

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. The input-output coefficients implicitly determine the production process of each of the 42 industries. The IO coefficients change over time to capture the effects of price changes and technological progress. They are typically fitted to a logistic trend line that is treated as exogenous by the model.

GINFORS

The input-output models consist of 41 sectors. They get the vector of export volumes and import prices from the trade model and aggregated investment and private and public consumption figures from the macro models and distribute it to 41 sectors. From the energy models they receive prices for the energy carriers. The input-output models calculate the vectors by industry of gross production, intermediate demand, the vector of imports and the vectors for the different components of primary inputs. The input-output models further estimate the vector of unit costs and the vector of prices.

Since there is only one observation of the input-output (IO) structures, non energetic input-coefficients cannot be endogenized and are treated as exogenous variables. The input coefficients of the energy rows of the input-output table are fully endogenous driven by the energy demand of the sector which is calculated in the energy model.

GINFORS uses private household consumption data published by the OECD to analyze consumption patterns but the absence of bridge matrices makes disaggregating consumption by sector problematic. Energy demand can however, be inferred for energy demand and converted into monetary units. The non-energy demand is then derived as the remaining unaccounted total private consumption.

The structure of government consumption and capital investment is kept constant or projected in scenarios by exogenous performance targets.

The structure of composite commodities for exports and imports is determined by the world trade data, so that import-functions can be calculated. The exports are generated by the trade model.

Discussion

In both systems the input-output models are based on IO-tables of the OECD. In general, all input coefficients but those for energy, which are driven by the energy models, are constant.

E3ME has a variable household consumption structure, depending on relative prices and demographic factors. GINFORS has this variability only between energy demand and all other consumption; within the two groups the consumption structure is constant.

Both systems convert investment into demand for goods and services. The structure of investment demand is variable in E3ME, depending on expected activities in the investing industries, and in GINFORS it is either held constant or assumed to follow an exogenously determined path. In E3ME, the investment is estimated and solved for each industry and country as a function of relative price and expected output.

Both systems explain goods prices by unit costs and other variables. Prices for fossil fuels are exogenous in both models, since they depend on the world market.

C. The Energy Models

E3ME

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. Aggregate energy demand is determined by a set of co-integrating equations, of which the main explanatory variables are economic activity for each fuel user, their average real fuel prices and technological progress indicators. 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. 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).

E3ME also incorporates a bottom-up representation of energy technologies to model the take-up of a number of energy supply options, including an array of low-carbon technologies. Learning curves, relating technology costs to experience and investment, allow for new technologies to become more competitive over time.

GINFORS

The energy emission models show the interrelations between economic developments, energy consumption and emissions. For this purpose, the variables of the corresponding macro model and of the IO Model – if available – are used as drivers. Vice versa, the expenditure for energy consumption has a direct influence on economic variables.

Final Energy Consumption of a sector is explained by output and the relation of the aggregate energy price – an average of the different carrier prices weighted with their shares in the energy consumption of that sector – and the sector price.

If a country does not have an input-output model, GDP is taken instead of the sector's output and the sector price is replaced by the GDP deflator.

Final demand of energy carrier i can be calculated by definition, multiplying the share of carrier i in the energy demand of sector j with final energy demand of sector j and summing up over all sectors. For residential, services, manufacturing and steel production these shares depend on the relation of the carriers' price and the aggregated energy price of that sector or from relative energy carrier prices. For other final demand sectors the carrier shares are exogenous.

Conversion from primary energy into final energy takes place for electricity and petroleum products. The demand of carrier i for conversion is given multiplying the production of the secondary energy carrier in question with the input coefficient of primary energy carrier i.

The energy models receive the vector of gross production by industry and final demand by branches as well as industry prices, energy import volumes from the input-output models. The trade model delivers energy import prices and energy export volumes to the energy models. Based on energy import prices the energy models further determine wholesale and retail prices for the energy carriers, which are delivered to the input-output models.

Discussion

Both systems use the energy balances of the IEA as the database for their energy models. The structure of the models is very similar. In the first step final energy demand is estimated for 19 demand sectors. Explanatory variables are activity variables of the demand sector and the relative energy price of the sector, and in the case of E3ME the technology variable. The carrier structure for 12 energy carriers of energy demand partly depends on relative carrier prices or has constant structures.

D. THE EMISSION MODELS

E3ME

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 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.

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.

GINFORS

The energy models calculate primary and secondary energy demand for 7 carriers in detail, the conversion of energy and CO_2 emissions of the different fossil energy carriers.

The energy-emission models are based on the energy balances of the International Energy Agency (IEA) and are, therefore, available for all countries and regions as well. They picture the energy consumption structured by the relevant energy carriers. The CO2 emissions are linked with the fossil energy carriers by constant carbon relations. Since the explicitly given 50 countries plus the OPEC region of the model cover 95% of world CO_2 emissions, the missing 5% are linked to the region Rest of World so that global coverage of CO_2 emissions is given.

The emissions of the other greenhouse gases are modelled by scenario.

Discussion

Emissions may be the result of fuel combustion or other economic activities. E3ME includes a detailed treatment of the emissions of the six GHGs. E3ME also includes emissions of eight other atmospheric pollutants. GINFORS has a global endogenous coverage for CO_2 emissions and scenario estimations for the other greenhouse gases.

E. The Material Models

E3ME

Work to incorporate materials flows analysis into E3ME is currently underway. The submodel of material inputs would comprise up to seven new equations, with one equation for each material. In a similar manner to the current fuel equations, the independent variables could include an activity indicator, a price level and a measure of innovation using the standard ECM methodology employed in E3ME's stochastic equations.

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 the 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.

GINFORS

In the course of the MOSUS project (www.mosus.net), material-input models were added to GINFORS. For all the countries displayed in GINFORS, material consumptions structured by six categories are ascertained. Those are linked either with the input-output model, or, for the countries lacking an input-output model, with the macro model.

It is only necessary to identify the dependency of materials from export and from domestic demand. If this is done, international trade and domestic production, which is also linked with trade, will drive material extraction in a globally consistent way following the global economic development.

For the extraction of materials coal, crude oil and gas the production figures are taken as drivers, which for each of them are given in physical terms from the energy models. Since the energy models are calculating in detail the determinants of production as domestic demand, imports and exports, the impact of exports of these materials on the extraction is automatically given.

For biomass it is known, that agriculture is the extracting sector. So for the countries with input- output models and bilateral trade, the production of this sector in local currency at constant prices is the driver for extraction of biomass. Since production is dependent on domestic demand and exports we automatically have the right dependency of extraction from exports.

For countries without input-output models we do not have the information about production of agriculture. Instead, we have the export figures for agriculture from the trade model, which can be used for driving the exports of extracted biomass. Extracted biomass, which is domestically used, is driven by GDP.

For metal ores we use the information about the demanders of metal ores, which are the sectors "iron and steel" and "non-ferrous metals". Their production can be aggregated in money terms to "metal production". Countries with input-output models represent about 90% of world metal production. We explain with the metal production in local currency and constant prices the local metal production in tons, aggregate over all countries and drive with this figure world extraction of metal ores. With the regional structure of the year 2002 the figures for the extracting countries can be calculated.

In the case of other materials, which are more or less non-metallic minerals, we have assumed, that trade has no important influence on extraction. Thus, for countries with input-output models, extraction of other materials can be explained by production of non-metallic mineral products. For the other countries the drivers are GDP in constant prices.

Resource productivities for fossil fuels are endogenously estimated in the energy models. For the other resources the problem arises that prices, which would be needed to identify cost pressure as a determinant of productivity growth, are not available for the different countries. Therefore for biomass, metal ores and other non metallic minerals productivity growth rates are exogenously given in relation to the historic trends.

Discussion

GINFORS has incorporated material models, in which material extraction, domestic demand, exports and imports for six different kinds of material are explained. During the project the influence of relative prices will be incorporated.

Price and technology dependent material models in E3ME are currently under construction and will cover seven materials as well as the flow of waste from production (treated as a demand for its disposal). As in E3ME's other stochastic equations, materials will be specified in the error correction form. Further details can be found in CE's scoping report for the integration of the models (CE, 2007b).

F. Treatment of Macro Variables

E3ME

E3ME does not have a macroeconomic component as such. The main macro aggregates (GDP, and its expenditure components, such as gross investment) are formed by summing the sectoral variables, with the exception of aggregate consumption, which is related to real disposable income by country. Other macro variables are used as signals in sectoral equations: the rate of inflation, the rate of interest in the eurozone, the level of global oil prices, the various currency exchange rates in the model.

Real personal disposable income is formed from wage income, other factor income (rents, dividends), social security transfers (pensions, unemployment benefits), less taxes, all deflated by the consumer price index.

GINFORS

The macro models in GINFORS aggregate primary income, import volumes and prices coming from the input-output models. They show the redistribution of income between the government, households, enterprises and foreign countries and calculate the disposable income for these institutions, which are important determinants of private and public consumption. The macro models further depict monetary markets and calculate the interest rate and other determinants of investment. The accounting system of the macro models further contains the balance of payments.

The macro model for each country consists of five modules: balance of payments, final demand, monetary market, labour market and the System of National Accounts (SNA). First, the balance of payments collects the monetary transactions between inlanders and foreigners. All flows of the current account, such as goods exports and imports and income paid and received as well as transfers paid and received are endogenous. Assuming flexible exchange rates, the balance of foreign exchange payments is zero and the balance of capital transactions can be calculated as a residual.

All components of final demand are endogenous variables and mainly explained by income figures. Interest rates play only a minor role. Population, next to GDP, is one important determinant for public consumption. Prices of the different components of final demand are estimated by aggregated prices from the input-output model. If there is no input-output model, aggregated labour unit costs explain aggregated macro prices.

The structure of government consumption and capital investment is kept constant or projected in scenarios by exogenous performance targets.

With respect to the monetary market, a reduced form of equilibrium is estimated in which the government bond yield is explained by the discount rate and GDP. The discount rate is explained as a policy rule by the rate of inflation. For the countries of the Euro area, the interest rates are exogenous, since there are not enough observations for econometric estimations.

The supply of labour is linked to the rate of population growth, taken as exogenous from the 2005 UN forecast. Labour demand can be calculated by dividing real GDP by labour productivity, which is dependent on the real wage rate and technological trends.

The modules for the System of National Accounts (SNA) display the macroeconomic accounting of a country. Their prime objective is the ascertaining of available income and financial accounts for the private sector and government. The available income, being a determinant of demand for consumption, is a significant variable as well as net lending for the calculation of budgetary constraints.

Discussion

Both models include aggregated final demand functions, such as consumer expenditure, where disposable income of private households is the main explanatory variable. In E3ME there is no accounting system with payments and receipts, which allows obtaining disposable income from primary income. The difference between wages and disposable income (corrected for taxes and benefits) is therefore estimated by a regression. In GINFORS a complete accounting system is given for the twelve most important countries of the model. For the other countries a constant relation between primary income and disposable income is assumed.

GINFORS further has a complete representation of the balance of payments for all countries.

Global macroeconomic closure in GINFORS is given in the following way: Investment functions and savings are independent in the countries. Gaps between investment and savings in a country are closed by the current account balance. Since globally exports equal imports and transfers paid equal transfers received, it is guaranteed that globally investment equals savings. It is assumed for the region ROW (Rest Of the World) that the trade balance is zero, which means that the imports are following the exports of ROW, which are endogenously determined in the trade model. For the other transactions of the current account – international transfers – world totals are zero, so that the balances of ROW equal with opposite sign the totals of the balances of the 50 countries and the OPEC region, which are explicitly part of the system. Further the difference between savings and investment of ROW equals the sum of the balances of transfers of the 50 countries. This kind of global closure is a Keynesian feature. A rise in investment in a country will push income of that country, induce imports and in this way income in other countries. The system attains a global equilibrium with higher investment and higher savings.

G. THE TRANSPORT MODELS

E3ME

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.

GINFORS

GINFORS does not have a transport submodel.

Discussion

E3ME has a basic freight transport module, in which physical transport variables can be deduced from the level of economic development.

H. Wages and Labour Demand and Supply

E3ME

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 prices (exogenous world 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.

In the income loop, industrial output generates employment and incomes, which leads to further consumer expenditure, increasing total demand. The changes in output are used to determine changes in employment as well as changes in real wage costs. With wage rates explained by price levels and labour market conditions, the wage and salary payments by industry can be calculated from the industrial employment levels.

Hours worked is a simple equation, where average hours worked by industry and region is a function of 'normal hours-worked', technological progress and the level of output compared to expected 'normal' output which takes into account cyclical effects. It is assumed that 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.

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, available benefits 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. 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 wage rates, unemployment rates and benefits. 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 an 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. This is an important factor in determining unemployment, which in turn feeds into wages and back to labour market participation.

GINFORS

On the level of sectors, labour demand and the respective wages are ascertained for six combined economic sectors. For this purpose, the necessary explanatory factors from the input-output model are combined by aggregation in order to form these six economic sectors. The wages in the economic sectors, defined as the annual wages per employee, result from a 'shift-share' regression with the average wage, which again is the result of a Phillips curve with reference to the labour market situation.

The number of employees depends on the production, the real wages and an autonomous trend of technological progress.

The labour input coefficients are given by definition as quotients of the employment and the gross production, whilst the sum of wages results from the multiplication of the annual wage per employee by the number of employees. On the labour market, the supply – measured as labour force – is dependent on the development of population, which is exogenous according to the UN (2005) forecast. Labour productivity, defined as the ratio of real GDP and employment, is dependent on the real wage rate and technological trends. Labour demand, i.e. employment, can be calculated by multiplying the inverse of labour productivity by real GDP. The aggregated wage rate is dependent on labour productivity and the development of consumer prices. For countries with input-output models, labour demand and wage determination is described for six sectors, which are consistently linked with the 41 sectors of the input-output model.

Discussion

Sectoral labour demand measured in heads depends in both models on gross production, real wages per head and other variables. Wages per head are explained in both models using Phillips curve specifications. In E3ME additionally the hours worked and the participation of male and female persons is estimated.

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