TCH-GEM-E3

THE ROLE OF INNOVATION AND POLICY DESIGN IN ENERGY AND ENVIRONMENT FOR A SUSTAINABLE GROWTH IN EUROPE

RESEARCH PROJECT ENG2-CT-1999-00002

PUBLISHABLE FINAL REPORT

Report Editor: CES-KULeuven

August 2002

PARTNERS: BUES, CES KULEUVEN, ERASME, MERIT, NTUA, PSI, ZEW

Project funded
by the European Community
under the 5th Framework Programme (1998-2002)

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REPORTING PERIOD : FROM February 2000 TO January 2002

PROJECT START DATE : February 2000 DURATION : 24 months

Date of issue of this report : August 2002

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I. EXECUTIVE PUBLISHABLE SUMMARY

The objective of this research project was the further development of the GEM-E3 model and the analysis of policy design and of specific policy case studies with the aid of the model. The GEM-E3 model is a general equilibrium model for the EU, consisting of 14 inter-linked country-modules. Each module is a general equilibrium model that covers consumption and production (18 sectors, of which 4 are energy sectors). Intra-European trade flows are represented in detail. The model also represents the emissions, transfrontier pollution flows and damages of all major pollutants linked to energy use.

The project covers modelling research work, database update and geographical extension, analysis of policy design and specification of case studies for energy and environmental policies. The modelling research work mainly consists of two activities, the full implementation of model developments to improve its realism and the development of the endogenous representation of the dynamics of innovation and technological progress. The model improvements consist in the integration of bottom-up/top-down modelling for the electricity sector, modelling of the supply of energy and modelling of imperfect competition on product, input and tradable permits markets. Their specifications have been defined and experimented at a small scale. The second activity develops the representation of endogenous growth and of basic and public research, including the knowledge externalities from this research. The new specification has been tested with scenarios aiming at evaluating the impact of R&D expenditure on climate change policies. Regarding the database, the EU15 database is updated to 1995, a full database for potential Eastern Europe member states (Hungary, Poland, Slovenia) is set up, and Switzerland is fully integrated and its database updated to 1995. The model was also adapted to integrate these new countries. The component regarding policy design focuses on the implications for the design of energy/environmental policies of elements such as the market structure and transaction cost and on the role of R&D policies in the development of efficient energy or environmental-friendly technologies. Finally, specific case studies on Energy/Environment policies, covering a wide range of topics such as the phasing out of nuclear, Kyoto policies and the impact of the enlargement to Eastern Europe were done with the model featuring the new aspects developed.

The update and extension of the database and the newly implemented specifications widen the scope for policy-oriented research activities and therefore the range of potentially interested organisations. The multi-purpose nature of GEM-E3 (national, EU-wide, world wide applications, endogenous innovation, alternative assumptions about expectations of agents, new instruments etc.) makes it an appropriate tool for the evaluation of policies in many domains, also outside energy and environment.

Therefore, with these new developments of the model GEM-E3 it can have a significant contribution to the EU policies. The quantitative information resulting from the model analysis may help the European Commission to choose an environmental/energy policy that minimises the economic burden for the EU as a whole. It can also contribute to clarify the role of the EU in the policy definition, to the allocation of the task of policy design between the EU and national governments. The rational choice of policy instruments ensures maximal industrial competitiveness and economic and social growth for the EU member-states.

II. PUBLISHABLE SYNTHESIS REPORT

A. *Objectives*

The primary objective of this project was the further development of GEM-E3, an applied general equilibrium for the EU, and its application for energy/environmental policies analysis. More specifically, the project aimed at:

- The improvement of the realism of the GEM-E3 model (through the integration bottom-up and top-down modelling for the electricity sector and modelling of the supply of energy), the maintenance and update of the model and the extension of its geographic coverage to Eastern European countries and to Switzerland.

- The modelling of endogenous technology evolution and the role of innovation and R&D strategies and evaluation of the model development through policy studies.
- The modelling of imperfect competition in the goods market and the evaluation of environmental policy design and choice of policy instruments under various assumptions for the goods and permit market structure.
- Case-studies on energy/environment policies and their effect on sustainable growth, covering the following topics: the phasing out of nuclear, Kyoto policies, impact of extension to Eastern Europe.

The implementation of integrated top-down/bottom-up modelling for the electricity sector and of specific modelling of the supply of fossil fuels contributes to the development of GEM-E3 into a fully integrated Energy/Economy/Environment general equilibrium model. With the EU enlargement and the increasing economic integration forthcoming, it became a priority to extent the GEM-E3 model to Eastern European countries to allow for policy analysis covering the EU and the Accession countries in a fully consistent manner. With the full implementation of endogenous technical progress, including the role of R&D strategies in GEM-E3, the model allows a better representation of the impact of energy/environmental policies on the technology characteristics and dynamics and can also analyse how a R&D policy that gives incentives to develop efficient energy or environmental-friendly technologies, could enhance European competitiveness on the world markets. The choice of policy instruments is a highly debated issue and the evaluation of policy instruments with a full scale multi-country applied general equilibrium model as GEM-E3 can give valuable insights compared to analysis with stylised models. As the effectiveness of energy and environmental policies will depend on the presence of market imperfections, the GEM-E3 was to be extended to allow for market imperfections and evaluate policy cases under alternative market structures. Finally, through case studies with the fully extended model, GEM-E3 was to contribute to policy evaluations for the EU and for national governments around energy and environmental issues.

Using an applied general equilibrium model such as GEM-E3 gives a consistent evaluation of policies in terms of economic (growth, employment, competitiveness) and environmental welfare (incl. the transboundary effects). As the results are disaggregated by countries, by sectors and by economic agents, equity consideration can be taken into consideration in the evaluation of policies.

A technical description of the main tasks of the project and the results obtained are given in the next section. Then the anticipated benefits and exploitation plans are briefly described. In annex a full technical report of the activities and the model documentation is given.

B. Description of the Main Tasks and Results

1. Improvement of the realism of GEM-E3 (CES, NTUA and ZEW)

The implementation of integrated top-down/bottom-up modelling for the electricity sector and of specific modelling of the supply of fossil fuels contributes to the development of GEM-E3 into a fully integrated Energy/Economy/Environment general equilibrium model.

a) Integrating bottom-up and top-down within the GEM-E3 model (ZEW)

The hybrid modelling approach, integrated in GEM-E3 by ZEW, combines a bottom-up activity analysis for the electricity sector with the regular top-down functional forms belonging to the constant-elasticity-of-substitution family (CES) for the other production sectors. With respect to the empirical economic assessment of environmental/energy policy measures, this hybrid approach strengthens the credibility of CGE analysis as key technological options have an engineering foundation rather than being represented by „vague“ continuous production functions. This can be particularly important for the electricity sector as it exhibits the highest potential for CO_2 mitigation through fuel-switching and energy efficiency improvements.

The modelling approach uses the formulation of the general equilibrium problem as a complementarity problem (CP) in order to accommodate the hybrid description of production possibilities where the electricity sector is represented by bottom-up linear activity analysis and the remaining production sectors of the economy are characterised by top-down CES functions.

The static prototype model, developed in a previous research project, was extended along two dimensions. First it was set-up as a dynamic-recursive model, the dynamic structure in GEM-E3, to assess adjustment processes induced by policy changes over time. This is a straightforward extension of the static model setting, where the static model is solved for a sequence of temporary equilibria. Secondly, it required data collection for the different EU countries and calibration of the bottom-up technologies for electricity generation. For the activity analysis representation of the electricity generation, it is sufficient to specify a few key technologies to give a realistic picture on the range of available technological options.

Table 1: Representative Technologies for Electricity Generation

HCO_B	Hard coal	Base Load
OIL_B	Fuel oil	Base Load (CCGT)
SCO	Soft coal and lignite	Base Load
NUC	Nuclear	Base Load
HCO_B_N	Hard coal	Base Load (new technology)
NGS_B_N	Natural gas	Base Load (CCGT)
NGS_B_N2	Natural gas	Base Load (CCGT / CHP)
HCO_M	Hard coal	Middle Load
HYD	Hydro	Middle Load
HCO_M_N	Hard coal	Middle Load (new technology)
NGS_M_N	Natural gas	Middle Load (CCGT)
BIO	Solid Biomass	Middle Load
OIL_P	Fuel oil	Peak Load (turbine)
NGS_P	Natural gas	Peak Load (gas turbine)
WND	Wind	Peak Load
SOL	Solar	Peak Load

Parameterisation of the hybrid model requires the reconciliation of top-down data and bottom-up data stemming from different data sources. The top-down data comes in the form of social accounting matrices (SAM) for the 15 GEM-E3 countries. The SAMs summarize the benchmark data to which the model is calibrated. It distinguishes 4 energy inputs, 14 non-energy inputs, labor and capital which is in the model assumed to be sector-specific. The bottom-up data for the different electricity generation technologies are specified through the generic cost structure, physical capacity constraints and the output shares in the benchmark equilibrium. Cost shares for the different technologies in each GEM-E3 country are calculated based on techno-economical data from the technological database IKARUS. The technologies for which the input costs exceed the market price of electricity are not active initially. The market share of the active technologies in the different countries is calculated from OECD/IEA energy balances. Given the output quantities and the cost structure of active technologies the aggregate production data of the electricity sector as provided by the SAM is split down to accommodate a consistent bottom-up representation of electricity generation and match the electricity mix. For the data reconciliation of the engineering data with aggregate input-output data, a data adjustment procedure has been developed.

b) The depletable resources module in GEM-E3 (CES and NTUA)

To improve the realism of the supply behaviour of the energy sectors in GEM-E3, a energy supply sub module incorporating a depletable resource mechanism was developed by NTUA for the oil and gas sectors. The energy sectors were modelled as any other industrial sector and therefore certain crucial features, such as resource depletion, were not taken into account.

The specification of a full depletable resources module was developed. For this purpose the energy sectors were disaggregated into two subsectors, one for the primary production and one for the derived production and distribution. The supply of crude oil and natural gas is modelled through a production function with, besides labour, capital, energy and material as production factors as for the other sectors in GEM-E3, also reserves as an additional factor. From this a demand for reserves is derived which is confronted to the supply of reserves. The supply of reserves depends on past production and new reserves, which are a function of the 'yet to find reserves' (from geological surveys) and the rate of discovery.

The full module was finally not integrated in GEM-E3 for two reasons. There were difficulties to obtain a full dataset needed for the EU countries and since very few countries in the European Union are oil and gas producers, adding a depletable resource mechanism into the GEM-E3 would greatly increase the complexity of the model for little gains. Consequently a reduced form module has been implemented allowing for interaction between international energy prices and EU supply/demand: the energy import price from the Rest of the World was endogenised through implementing empirically estimated ROW supply functions for the energy sectors. The model development was tested with a climate policy scenario for the EU, illustrating clearly the impact of the supply/demand interaction for the depletable resource on the welfare evaluation of the policy through the terms of trade effect which benefits to the EU consumers.

2. The maintenance and update of the GEM-E3 database (CES and NTUA)

The objective was to update the GEM-E3 database (with base year 1985) to the latest EUROSTAT data to take into account all recent structural changes in the EU economies. Constructing a consistent database for an economy-wide multi-regional and multi-sectoral model is a difficult task since a great number of separate accounts (which in most cases come from different sources) must balance in the accounting framework. The final database of the model mainly consists of **S**ocial **A**ccounting **M**atrices (**SAM**) estimated at the base year of the model and the corresponding investment, consumption and trade matrices. The most recent year for which available and complete data could be obtained was 1995. The main consideration during data collection and reconciliation was their compatibility with the ESA 95[1] methodology.

The data required for GEM-E3 cover the following categories:

1. Final demand.
2. Intermediate consumption.
3. Government revenues.
4. Bilateral trade matrices.
5. Investment matrices and consumption matrices.
6. Transfer payments among institutional agents.
7. Interest rates and inflation rates.
8. Employment.

and this for the model nomenclature, which distinguishes 18 sectors based on NACE R25 (with a disaggregation of energy into four subsectors), 13 consumption categories (by purpose) and four economic agents (household, firms, government and the rest of the world).

[1] European System of Accounts 1995.

The data sources used for the implementation of this task were: EUROSTAT, New CRONOS Database, the European Central Bank and in certain cases the respective statistical offices of each country. Besides the data provided directly by the statistical offices, the following data were obtained from the different sources:

- Projected Input Output tables 1995 (Source: EUROSTAT).
- Data on National Accounts – Main Aggregates 1995 (Source: EUROSTAT).
- Bilateral trade matrices, on products. (Source: COMEXT).
- Consumption by purpose and by product. (Source: New CRONOS Database).
- Investment by product and by branch (Source: New CRONOS Database).
- Transfers between institutional agents (Source: New CRONOS Database).
- Capital Transfers (Source: New CRONOS Database).
- Employment (Source: New CRONOS and EUROSTAT National Accounts).
- Interest rates (Source: New CRONOS and European Central Bank).

Moreover the statistical offices of Belgium, Germany, United Kingdom and Ireland provided the full sequence of national accounts. It should be noted that complete data sets were only available for Greece and Denmark. When a complete data set was not available and data from different sources were obtained, these data were combined in a consistent way in order to arrive at a Social Accounting Matrix for each country, with the disaggregation level required in GEM-E3. One of the main difficulties encountered in this update was the reconciliation of the different dataset, especially as no official EUROSTAT Input–Output table were available and the compatibility of the projected tables with the national accounts data seems far from guaranteed. As the new data are based on the ESA95 methodology, a complete new data building framework has to be set up.

As in the SAM obtained from the available economic data the energy branch was aggregated, a specific procedure was set-up to disaggregate the energy branch into the four energy branches of GEM-E3, coal, oil, gas and electricity. The procedure, written in GAMS, aims at reconciling the energy balance data with the Input-output data of the energy branch. This is however provisional and will be adapted when the new IO tables are available from EUROSTAT.

The environmental data needed for GEM-E3 cover four types of data, emission coefficient per type of activity and marginal abatement cost functions for the pollutants in the model, CO_2, SO_2, NO_x, VOC and PM, pollutants' transformation and transportation between countries coefficients to arrive at air concentration and deposition and damage per pollutant and its monetary valuation. The update of the database has been concentrated on the developing of a GAMS procedure to generate the data needed and on the update of the damage and valuation figures coming from ExternE because new estimates were available from ExternE. The GAMS program simplifies greatly the update of the database when new data becomes available. Also the environmental data have been extended to the Accession countries.

The calibration model of GEM-E3 was also adapted to the new data. A full documentation on the model and its use with all the policy simulation possibilities was written to facilitate the transfer of the model to new collaborators and partners. The GAMS code of the model was further developed to allow for more possibilities regarding policy instruments and permit trade schemes and to speed-up the solution time of the model.

3. The geographic extension of GEM-E3 (BUES and PSI)

The geographic extension of the GEM-E3 model covers its extension to a few Eastern European countries and a full integration of Switzerland. Increasing economic integration and cross-boundary pollution made it important to develop the model in that direction. With it modular structure (one module per country) and the explicitly modelling of transboundary pollution flows, GEM-E3 is well suited for that.

a) Extension to Eastern European candidate member countries (Hungary, Poland and Slovenia) (BUES)

The planned activities of the project included the geographic extension of the model to East/Central European (ECE) potential accession countries. Three countries were chosen: Hungary, Poland and Slovenia. The project also aimed at building up and strengthening the capacity in the target ECE countries to use the model in policy studies analysing the potential gains of pollution policy co-ordination and effects of enlargement. An international expert group, headed by Prof. Zalai (Budapest, BUES) was put up with experts from the three countries. The main task of the BUES-team was to adopt, as close as data availability and regime similarity permits it, the general framework of GEM-E3 to the selected ECE countries, so that their country models could be fully integrated into the overall model of the EU countries.

The first task of the project was to acquire, process and standardise data for the accession candidate countries in question. 1995 was selected as the benchmark year for the model and the comparative analysis. It turned out that despite of the many efforts to harmonise their system with that of the EU, the statistical and economic systems of the EU-applicant (and already associated) countries are still not readily comparable either with each other or with the EU countries. The experts involved had thus to overcome at times serious statistical problems during the compilation of the standardised data sets. The full dataset for GEM-E3 was constructed for the three countries considered and integrated in the modelling framework.

As far as national accounts are concerned, one may generally express satisfaction with the progress made in the 1990s with the implementation of the most recent SNA Guidelines (of 1993) and ESA (of 1995) accounting standards into the official statistics of the former centrally planned economies. National accounts are available for every year and they exhibit a growing degree of consistency with the recommendations of respective handbooks and possess increasing scope of information. Hungary, Poland and Slovenia produce basically the same type of SNA accounts. The main aggregates and categories of national accounts, both with regards to the content and terminology, are in complete harmony with the SNA93 and the ESA95 standards.

As far as other data sources, typically used in SAM and CGE exercises, such as consumption statistics (trade statistics and household budget survey), or balance of payments or trade statistics, are concerned, they are also published regularly in the three countries concerned. Many problems emerge, however, when one combines these data with the independently produced national accounts and input-output table data. There was no official I-O table available in Slovenia for 1995, so it had to be estimated on the basis of the official 1993 I-O table. In Hungary too, there was only a RAS update I-O table (based on the 1991 „large" I-O table) available, with 21 sectors, and the reclassification of it to the required 18 sector breakdown took much consideration and work. A detailed (54 sectors) I-O table for the year 1998 was available for Hungary, which could be used as reference and for updating the data 1991 base. For Poland a partial input-output table was available for 1995. The emerging inconsistencies and gaps had to be eliminated by means of often rather ad hoc assumptions and estimates. One should also borne in mind when evaluating results based on the 1995 data, that all countries have gone through some major structural changes as a result of the free trade agreements and the EU association agreements made after 1995 that made their economies more open and changed their trade structures and directions.

As the choice of 1995 as a base year was not very good from the point of view of the accession candidate countries because the structure of their economies was still very much in transition and it does not properly reflect the structure at the beginning of this century, the social accounting matrices of Poland and Hungary[2] for 1998 were compiled. This effort served two purposes. First, it is of special interest to see the intertemporal differences of the economic structures reflected by the SAM tables. Second, 1998 SAM tables provided us with country specific information about the subsequent changes

[2] For Slovenia it was not possible.

that could be used in designing the scenarios. The comparison of Hungarian and Polish SAM's compiled for 1998 confirmed that the estimates are reliable, however it was concluded that it would be more appropriate to prepare a complete new base year data set (including the SAM) for the year 2000.

After the data work, the focus shifted on scenario design and policy simulation work. For that purpose, some specific adjustment to the model structure were made for the Accession countries regarding the external trade specification. It allows a better modelling of the possibilities of reorientation of the external trade of these countries towards the EU after accession. The extended model was tested with two scenarios, one concerning the climate policy of the EU and the Accession countries and the second on the potential economic impact of the Eastern enlargement on the EU and the accession countries. The results are described in the policy scenario section.

The co-operation between the Western and Eastern experts has been mutually beneficial. The joint work has strengthened the data compilation and policy analysis skills of the Eastern participants. This experience will raise the level of research and modelling quality not only in the institutions directly involved, but will have effect on the wider modelling community of the countries involved. The outputs produced by this project (especially the SAM tables) fill in some important gaps present in the official statistical work of the ECE countries. In addition, the members of the BUES team have contributed to the development of the GEM-E3 model structure and software.

b) Update of the Swiss database (PSI)

A Swiss GEM-E3 model had been developed in a previous project by PSI and its database has now been updated to the new base year of GEM-E3, 1995. A 1995 Swiss SAM, compatible with the GEM-E3 format, has been constructed using data and structural information from:

- The Swiss National Accounts (Swiss Federal Statistical Office—SFSO, 1999) as well as various economic statistics compiled by SFSO (2000);
- External trade data from the Swiss Customs (1998);
- The 1990 GEM-E3 Swiss SAM adapted from a Swiss SAM developed by Guillet and Antille (1998).

The environmental database, consisting of the energy balance and emission coefficients, has also been updated. The transboundary parameters for the different pollutants have been updated by CES in the general update of the GEM-E3 database.

4. Modelling of endogenous technology evolution and the role of innovation and R&D strategies (ERASME and MERIT)

The contribution of the development regarding R&D is threefold:

- the implementation of the full prototype for endogenous growth in GEM-E3
- the design of policy cases for R&D linked to energy and the environment to evaluate the model with endogenous growth
- further development for the endogenous growth properties of GEM-E3, at a more theoretical and stylised level.

a) The endogenous growth modelling framework (ERASME)

ERASME developed further the endogenous growth module and its integration in GEM-E3. This model follows the semi-endogenous growth model of Jones, in which the exhaustibility of innovations prevents increasing returns to scale in the long run. The core of the growth module is the innovation process in which two types of innovations are considered: process innovations that increase total factor productivity and quality innovations that increase the efficiency of production goods or the utility of consumption goods. By simplification, it is assumed that sectors achieve only one type of innovation:

raw materials and energy sectors process innovation, others sectors quality innovations. The link between R&D and innovation depends on a knowledge variable and on fishing out effect which defines an exhaustion of inventions. The technological knowledge accumulation is a phenomena resulting from a complex game of inter-sectoral and inter-national spillovers, the “knowledge spillovers effects”. For one given sector, cumulated R&D expenditure will give a R&D stock, which combined to knowledge diffusion of all others sectors gives the knowledge variable of the considered sector. Combining inter-sectoral and inter-national diffusion using a Cobb-Douglas function, a knowledge variable is built which impacts positively on research productivity. On the contrary, the accumulation of past innovations will get innovations production more difficult, following the “fishing-out” principle of Jones and Williams and thus will decrease the research productivity. This vision has allowed Jones to built his “semi-endogenous” growth models, refuting the existence of an eternal endogenous growth process. This allows to define an innovation production function which depends positively on knowledge variables and negatively on the "fishing out" effect.

The innovation incentive, i.e. the innovation demand, is derived from the maximisation of profit by a sector’s representative firm. All factor prices, including the R&D price, will play a role in the incentive to innovate. In fact, every increase of production costs will lead to an increase of R&D expenditures (and thus of innovations), which in turn will decrease these costs for two reasons: in sectors with process innovations, it will lead to a TFP improvement and in sectors with product innovations, the output will be of a better quality, which for a given utility will be made with less production factors.

For the integration of the endogenous growth module into the 14 European countries version of GEM-E3, R&D data for all countries and all sectors were collected. The module was calibrated on the basis of empirical observations and studies on the links between R&D expenditures and sectoral innovation growth rates on the one hand, and on the relative strength of the knowledge spillovers and the fishing out effects on the other hand. The sources we used to collect R&D data are the OECD databases ANBERD and BSTS. These databases provide R&D expenditures by sector and country in a more detailed nomenclature than GEM-E3. The data were consequently re-aggregated into GEM-E3’s nomenclature.

The integration of this endogenous growth module in GEM-E3 allows to provide new model outputs:

- R&D Investment by sector.
- A “Consumer Goods Quality Index”, measuring to what extent the innovations made by European firms increase the consumer utility.
- An “Investment Goods Quality Index”, representing the improvement of productive characteristics of investment goods.
- A “Technological Innovation Index”, showing the innovation rate (in process or product) of each sector of the model
- A “Technological Diffusion Index” which measures to what extent the different production sectors profit of innovations made in Europe, under the form of price decreases.

The stability of the endogenous growth module was verified over different values for the parameters, representing the relative strengths of the fishing-out and knowledge spillovers effects in the innovation production function. The strengthening of the fishing-out effect makes new innovations always more difficult to produce, and thus reduces the arrival rate of new innovations. Consequently, the innovation price increases, and innovators must spend more R&D in order to sustain their innovation rate. The increase of the knowledge spillovers elasticity parameter rises the innovation rate of sectors and countries and lowers R&D spending. It makes new innovations always easier to produce, as knowledge accumulates. This rise the arrival rate of innovations whose price decreases, and finally decreases R&D spending. With the values chosen for the baseline scenario the GEM-E3’s endogenous growth module is very stable.

b) R&D policies linked to energy and environment for the evaluation of the model development (ERASME)

The design of the policy studies to undertake with the newly developed GEM-E3 had two objectives: determine to what extent endogenous R&D is important for climate policies assessment and address new policy cases in the area of R&D allowed by the new module of GEM-E3. It must be mentioned that only recently modellers have began to introduce endogenous growth in applied models and never in a so large scale and detailed model as GEM-E3. It was thus particularly important to examine precisely to what extent endogenous growth modify the cost assessment of energy and environmental policies, and consequently to what extent the introduction of such mechanisms in applied models must be pursued.

First a comparison of traditional climate policies scenarios with the two versions of GEM-E3 were made. The responses of firms to a CO2 emission constraint, limited to factor substitutions in the case of exogenous technical progress, are enlarged with the endogenous growth version of the model to R&D decisions of firms with all their consequences on productivity and quality innovations and on knowledge diffusion between sectors and countries. All these mechanisms have a positive impact on the cost of these policies, total activity and welfare decreasing less with endogenous technical progress. The total effect depends however on the recycling strategy assumed for the CO2 tax revenue and the increase in production cost it implies. The higher the abatement cost for the firms, the higher the incentive for innovation and the more the policy cost assessment is diminished, compared to the version of the model with exogenous growth.

Secondly, the climate policy was combined with a new design for R&D by considering the recycling of part of the tax revenue into R&D subsidies to firms, the remaining being used to reduce employers' social security contributions. The results of this policy case show that it allows to cumulate the previous positive employment effects of the recycling on social contributions, with the additional benefits of the new growth induced by R&D subsidies. They suggest that environmental regulation associated with R&D can stimulate substantial technical progress and lead to long-run macro-economic gains which could imply strong double dividend. The positive results of this endogenous growth module for the case of environment regulation must nevertheless be qualified as there may exist crowding-out effects of private R&D on both public and specific environmental R&D, assessment of which was out the scope of the present simulations.

c) Possible new developments for endogenous technical change (MERIT)

MERIT focussed on two issues important for the modelling of technical change: the labour-skill bias in technical change and the uncertainty inherent to R&D projects, without considering yet their integration in GEM-E3.

Labour, like capital, is a heterogeneous factor of production: the one person has skills that differ from another person's skills. And it's the skills that count in providing productive services. Moreover, skill-differences between people make for asymmetries in employment perspectives: while high-skilled people could be employed on both high- and low-level jobs, this is generally not the case for low-skilled people. In addition to this, these asymmetries may be aggravated by the existence of endogenous skill-biases in technical change. Because of the issues involved, and because the policy constraints that (energy-)policy induced developments in unemployment, wages and so on pose to policy makers, it is necessary to extend the GEM-E3 model to allow for different skills and also for endogenous technology biases between these skills. To this end a simple stylised simulation model was built that describes skill-biased technical change as the result of technologies passing through their lifecycles at an endogenously determined rate. New products are created through endogenous product R&D. Each new product has its own production technology. New production technologies start out as high-skilled intensive and end up as low-skilled intensive as long as the wage differential between high- and low-skilled workers is positive. The results of the model show that wage divergence in favour of the high-skilled, even in the face of a rising relative supply of high-skilled workers, is possible, since the additional supply of high-skilled workers creates a surge in future demand for high skilled workers due to induced product and process R&D activities, first because R&D itself is a high-skilled intensive activity, and secondly because new products, at the beginning of their life cycle, are produced in relatively high-skilled intensive ways. Low-skilled workers do not profit from ‘Say’s Law’ in this respect: they can stimulate their own employment only by accepting lower wages, since those provide the incentive to engage in process R&D that creates the jobs necessary to employ the low-skilled. So, in order to stimulate the employment of low-skilled workers, if and when required, one could promote process R&D but this has a negative effect on product R&D, the ultimate source of growth of consumer utility. What the simulations show, is that it is important to take into account the long term technology reactions of (and repercussions on) the economic system resulting from short-term policies designed to cure acute policy problems like unemployment.

On the second issue, the uncertainty linked to R&D projects, MERIT studied the effects of uncertainty and of various policy instruments on the length and attractiveness of private research projects with a simple extendable model. The structure of the framework allows for a multi-dimensional evaluation of policy measures. Not only the effects of a policy measure on total private spending on R&D can be determined, the implications of economic policy for a variety of privately funded research projects and the ‘patent-shelving’ behaviour of firms are also made visible. The policy instruments discussed include various types of subsidies, patent duration, competition policy in the energy market, public research, and the prohibition of currently used technologies. The difference between knowledge accumulation and the actual implementation of accumulated knowledge is explicitly accounted for. This is an important feature of the framework, as knowledge about conversion of energy that is environmentally safe has to be implemented before society can benefit from it. Firms that postpone the actual use of a technology, that is, firms that ‘shelve’ their patents, may act in way that is not optimal from an environmental perspective.

The effects of a number of instruments as implied by the model are summarised below.

Subsidy on research expenditure - a reduction of the cost of doing research will cause the length of the research project to increase. This has two important implications. First, the capital intensity of new energy conversion capacity will be higher. Second, it will take longer before new technology is introduced.

Subsidy on development expenditure - a reduction of the costs of development will shorten the duration of research projects. It has thus the opposite effect of a subsidy on research expenditure.

Subsidy on capacity - A subsidy on capacity will increase the current value of research projects while leaving their optimal value unaffected. As a result, development of the technology will be started earlier and the capital intensity of the resulting plants will be higher.

All subsidies will increase the value of research projects. Subsidies will make research projects feasible that were previously considered to be unattractive. Therefore, subsidies will increase the variety of directions in which research is done.

Increase the duration of patents – it raises the current value of a patent, but shortens the research project, as the current value of a patent now lies closer to the value at which it is optimal to stop research than before. Making patents last longer increases the incentives for starting research but decreases the length of research projects.

Stimulate competition in the energy market - it reduces the value of a patent as quasi-rents diminish. Less research projects will be feasible and it will generally take longer for research projects to reach their optimal value.

Public research - Public research can stimulate private research in three ways, first by improving the knowledge base that is available before a private research project is started, making more research projects become feasible and by shortening the length of private research projects as the starting value of projects is closer to the value at which it is optimal to stop research. Second, collaboration between private and public research groups increases the probability of success for a given amount of private research expenditure. It will raise the number of feasible projects as well as lengthen them. Third, private firms may benefit from public research through the labour market. If researchers are trained in the public sector before being hired by a firm, research will be less costly for firms. Lower costs increase both the number of feasible projects and their expected duration.

Prohibition of technologies - A radical policy instrument would be the prohibition of some of the currently used technologies. This would change the expectations about the growth of capacity. In a relatively competitive energy market, a decrease in the growth rate of capacity has a positive effect on the value of research projects. The average duration of a research project will decline.

5. Energy/environmental policy design and the choice of policy instruments (CES and ZEW)

The cost of GHG abatement policies has been highly debated in the economic literature, both with theoretical and applied general equilibrium. The extensive literature on double dividend with general equilibrium models have shown the importance of different elements for the cost of GHG reduction policies, such as tax interactions, tax shifting and taxbase effects, economic structure, hence the importance of evaluating policy instruments with a large scale multi-country general equilibrium model as GEM-E3. The GEM-E3 model allows the modelling of different types of policy instruments (taxes, standards, permits), different modalities of implementation of these instruments (national or EU, differentiated by sector, by country etc.) and different distribution schemes for the policy-generated rents. The existing taxes are implemented in the model and the links between countries through trade are explicitly modelled, country by country and sector by sector. Moreover the environmental benefits can be evaluated, including those resulting from transboundary effect and inclusive their feedback on the economy. This renders the model a very appropriate tool for empirically evaluating the (welfare) differences of energy and environmental policies. As imperfect competition on the goods market and transaction cost in permit market can influence the effectiveness of environmental policies, the model was further developed by CES and ZEW respectively to allow for these possibilities.

a) Policy instruments in a perfect competition framework (CES)

The policy instruments considered by CES are grandfathered permits, taxes/charges and standards. Voluntary agreement are not considered because they are rather difficult to implement in a modelling framework and their environmental effectiveness are often questioned, though they are certainly the most favoured by industry. The evaluation of the policy instruments occurred through running policy scenarios in which the EU Kyoto target for 2008-2012 was imposed, the country domestic target being given by the EU burden sharing agreement. Moreover in all scenarios, the relative current account deficit/surplus of the EU with the Rest of the World is imposed to remain at the same relative level as in the reference scenario. Five scenarios were thus explored:

1. an EU CO2 permit system with grandfathering of the permits
2. domestic CO2 permit systems with grandfathering of the permits
3. domestic CO2 tax with recycling through employers' social security contributions
4. domestic CO2 tax with recycling through a lump sum transfer to households
5. domestic energy efficiency standard

The policy, whatever instrument is used, induces a direct effect on the price of goods and services through the increase in the cost of energy and this has a direct impact on the competitiveness of the EU countries. The price increase leads to a loss of competitiveness of the European economies compared to the Rest of the World, the level of the loss will depend on the share of exports in GDP, the share of non EU exports in total exports and the level of the price increase. On the EU market, the loss is lower as all EU countries apply the same policy. Given the implicit export/import price elasticities (through the Armington substitution elasticities assumed in the model), part of the price increase can be passed over to the export partners and make the foreign sector pay some of the cost of the policy, but this is not always enough to relax the trade balance constraint, even with decrease in imports induced by the decrease in economic activity and in energy consumption (energy is imported in most EU countries). However terms of trade effect compensate partly for the loss in activity and its is beneficial for the domestic consumers.

The price increase can be tempered, depending on the recycling strategy or the assumption regarding the distribution of the rents. The recycling strategy can also limit the tax interaction and reduce existing tax distorsion. Depending on the strategy, the distribution between economic agents of this benefit will vary. When recycling through SS, the cost decrease benefits both domestic and foreign consumers. This is also the case with grandfathered permits with the rents implicitly distributed to all consumers, though the sectoral impact will not be the same. The first strategy will more benefit the labour intensive sectors, whereas the second one is more favourable towards energy intensive sectors. Strategies which do not imply any recycling with a direct impact on the price (as with transfer recycling) will induce a greater loss. However, the recycling strategy through transfer benefits entirely to the domestic consumers.

As in GEM-E3 the capital stock is fixed within the period, the burden is partly shifted on capital income and therefore on firms which retain part of the capital income. This has a positive effect on the welfare cost.

Table 2 summarises the welfare impact of the different policies evaluated. The overall impact of the Kyoto policies remains rather low, the welfare changes being nearly for all countries less than one percent compared to the reference scenario. The environmental welfare change is approximately the same for all scenarios as the same CO2 target is imposed and the substitution effect between energy vectors is also relatively the same (it is the decrease in the total energy consumption which is the driving factor). Only in the EU permit case is the environmental welfare per country changed because the decrease in energy consumption changes with the selling or buying of permits.

Table 2: Welfare impact of alternative policy instruments
(% change compared to reference)

	EU CO2 market	Domestic CO2 market	CO2 tax with SS recycling	CO2 tax with transfer recycling	Energy efficiency standard
Austria	-0.58%	-0.57%	-0.71%	-0.68%	-1.37%
Belgium	-0.40%	-0.31%	-0.17%	+0.29%	-0.82%
Germany	-0.19%	-0.22%	+0.20%	-0.22%	-0.55%
Denmark	-0.31%	-0.32%	+0.37%	+0.12%	-0.68%
Finland	-0.21%	-0.20%	+0.29%	+0.19%	-0.67%
France	-0.41%	-0.51%	-0.74%	-0.77%	-0.68%
Greece	+1.84%	-0.19%	+0.51%	-0.04%	-0.32%
Ireland	-0.55%	-0.44%	+0.44%	+1.23%	-0.64%
Italy	-0.44%	-0.45%	-0.89%	-0.97%	-0.77%
The Netherlands	-0.39%	-0.37%	-0.77%	-0.38%	-0.78%
Portugal	+0.43%	-0.14%	+0.61%	+0.25%	-0.33%
Spain	-0.22%	-0.15%	-0.03%	+0.00%	-0.36%
Sweden	+0.06%	-0.15%	+0.50%	+0.14%	-0.32%
UK	-0.17%	-0.22%	+0.69%	+0.45%	-0.36%

Given the assumptions, the ranking of the policy instruments is on the whole conform to what the economic literature foresees: policy instruments generating revenues and allowing to reduce distortive taxes and which are cost efficient are preferred. However this is not verified for all countries mostly because of the trade interactions and terms of trade effects. When the constraint on the trade balance is relaxed, allowing a positive or negative financial contribution of the ROW to the EU saving constraint, a domestic permit becomes more favourable than a domestic tax, because in the last case the countries do not receive all the potential benefits of the tax instruments, part of it going to the foreign sector when the trade balance constraint is not imposed; on the contrary with a permit system, the foreign sector pays more of the cost of the policy. However this raises the question of the sustainability of such a policy.

When the rents generated through the grandfathered permits are included in the capital income and not used to reduce the price as in the results above, the overall economic activity reduces in both permit scenarios as the loss in competitiveness is greater (the price increase is higher). However this does not necessarily have a negative impact on welfare in most countries as the abatement cost is reduced and the foreign sector pays also for the price increase, relaxing the current account constraint, while the domestic consumer benefits from the rent.

The overall sectoral effect is dominated by the decrease in general activity, which is the highest in the tax scenario with transfer recycling. The highest decrease are observed in the coal and oil sector which are the primary target of the policy, gas benefits from the energy substitution. The permit scenarios as implemented are, as expected, more favourable to the energy intensive sectors than the tax scenarios. This might indicate that the carbon leakage outside the EU is more limited in these cases, also the cost of restructuring the economy towards less carbon intensive sectors in terms of employment displacement and capital destruction can be less.

When the feedback effects of pollution reduction on consumption and production (through the health impact related to morbidity) are taken into account using an extended version of GEM-E3 developed by CES, the welfare losses are smaller but the ranking of the instruments remains the same. This is mainly explained by the smaller loss in competitiveness and by the labour market effect. The main impact of modelling the feedback of the change in the environment goes through the labour market and it is the feedback on the production sectors which is dominant. The improvement of the local environment by the CO_2 policy has a positive effect on public health and decreases the number of working hours lost because of health problems. The final impact on employment is negative compared to the result without feedback. This induces a decrease in the real wage rate w.r.t. the standard model. However, this impact on the real wage rate has a positive effect on the competitiveness of the economy, boosting the exports and improving the current account.

b) Policy instruments in a imperfect competition framework (CES)

As imperfect competition can remain important in some sectors, even with the internal market, it was important to look at the impact this can have on the choice of policy instruments. At this stage, the study remains at an exploratory level and examines what it implies for environmental policy evaluation at the macroeconomic level of GEM-E3. It does not yet try to examine the different strategic behaviour of firms and countries in reaction of environmental policies at EU and country level.

The modelling framework implemented in GEM-E3 consider the Nash-Cournot assumption for the functioning of the oligopolistic markets. The firm's optimal mark-ups depend on the perceived price elasticities of demand for its output, which can change endogenously with the changes of the competitive environment through changes in the number of firms or through changes in the share of domestic and imported goods in final demand or across imported goods. The number of firms within imperfect competitive branches can endogenously vary to represent entry and exit/merging of firms. If profits are positive, then new firms may decide to enter into the market while negative profits will induce a higher industrial concentration to exploit economies of scale potential and reduce fixed costs. On the demand side (both from consumers and from firms), the desirability of variety was implemented by considering an additional lower level in the demand function, representing the choice between different varieties of the same good. On the production side, scale economies are modelled by assuming a fixed cost element, which generates decreasing unit cost functions. For instance, certain fixed output-independent amounts of labour and capital are required per firm to maintain the capacity to produce any output, the variable output-dependent input requirement being determined by a 'classic' production function. A complete new version of GEM-E3 and of its calibration with this specification was developed. At this stage the data are still those collected in a previous project and will need an update and extension. and tested with alternative scenarios.

The same scenarios as for perfect competition were examined. Under imperfect competition, the policies are more costly than in the perfect competition case, whatever policy instruments is used. The welfare loss is however smaller when a permit market is used, though the ranking does not change. For the IC model the overall effect, besides the general equilibrium effect present in both models, depends on the specific factors as the exploitation of the economies of scale and the endogenous price elasticities determining the mark-ups which both in the simulation presented push the cost/price upwards. Depending on the sector and the country, the production per firm, i.e. the size of the firm decreases or increases. Overall, the economies of scale are less exploited because of the decrease of total production and a rather stable number of firms and this pushes the unit production cost higher, which explains the higher welfare loss. As the permit market is favouring the energy intensive branches, this effect is less pronounced in that case. The endogenous price elasticities determine the mark-ups and these are slightly decreasing compared to the reference inducing higher mark-up and hence higher cost for the economic agents. The table hereafter gives the welfare impact of alternative policy instruments when imperfect competition is present.

Table 3: Welfare impact of alternative policy instruments with imperfect competition
(% change compared to reference)

	EU CO2 market	Domestic CO2 market	Domestic CO2 tax with SS recycling	Domestic CO2 tax with transfer recycling
Austria	-0.79%	-0.82%	-1.03%	-1.09%
Belgium	-0.61%	-0.56%	-0.52%	-0.15%
Germany	-0.39%	-0.44%	-0.07%	-0.55%
Denmark	-0.49%	-0.52%	0.13%	-0.19%
Finland	-0.43%	-0.44%	0.02%	-0.15%
France	-0.58%	-0.71%	-1.02%	-1.12%
Greece	1.68%	-0.40%	0.22%	-0.40%
Ireland	-0.82%	-0.78%	0.06%	0.74%
Italy	-0.62%	-0.65%	-1.14%	-1.29%
The Netherlands	-0.60%	-0.62%	-1.05%	-0.73%
Portugal	0.18%	-0.43%	0.27%	-0.19%
Spain	-0.41%	-0.38%	-0.32%	-0.37%
Sweden	-0.14%	-0.35%	0.25%	-0.16%
UK	-0.44%	-0.51%	0.31%	-0.03%
EU	-0.42%	-0.55%	-0.43%	-0.64%

These are still very preliminary results, however imperfect competition seems more important than expected from the work done with GEM-E3 for the evaluation of the impact of the internal market. As the impact on economies of scale and mark-ups can be positive or negative depending on the sector, the data calibration is certainly a crucial element to be examined further.

c) The role of transaction costs in the choice of policy instruments (ZEW)

For the implementation of transaction costs in GEM-E3, a literature survey on transaction cost was done by ZEW. For the different instruments considered, the transaction costs can be divided into nonrecurring costs in the pre-implementation phase and ongoing costs in the implementation phase. Transaction costs occurring during the pre-implementation phase are likely to be lower for taxes and standards than for permits, as these instruments are already used in other economic fields and the existing institutions may be used. On the other hand, it is expected that comparable costs in permit markets will decline quickly, due to learning effects. The transaction cost advantage of taxes and standards over permits in the pre-implementation phase may be offset by the advantages of a permit trading system in the implementation phase. It is not possible with respect to transaction costs to favour one of the instruments over the others, a detailed case-to-case analysis will be necessary, though some estimates were derived for international emission trading and joint implementation.

Transaction cost were implemented in GEM-E3 and their impact on the cost of a climate policy was evaluated, using an EU permit system as policy instrument and different assumptions for the level of the transaction costs. The presence of transaction costs reduce the magnitude of efficiency gains from emissions trading. The higher the transaction costs, the higher the permit price and the lower the overall level of permit trading. The incorporation of transaction costs into the modelling framework changes the optimal choice between domestic abatement and permit trade: with higher permit price, companies will abate more themselves.

6. Policy studies at European level (BUES, CES, PSI and ZEW)

Some specific themes related to energy/environmental policies within Europe were analysed with the model GEM-E3 integrating, sometimes partly, the model developments and extension described above. More specifically, the following policies were evaluated:

1. The phasing out of nuclear power in five EU countries, Belgium, Germany, the Netherlands, Spain and Sweden
2. Analysis of the impact of Eastern enlargement on the EU and Accession countries growth and trade
3. CO2 policies for Switzerland to comply with its CO2 Law
4. The combination of an EU policy and national policies to reach Kyoto target and implications for the EU policy of the Eastern enlargement.

The different scenarios are evaluated in relation to a common baseline scenario for the EU, Switzerland and the Accession countries. The baseline simulates the dynamic path of the EU economy until 2010 based on exogenous assumptions about the technical progress associated with production factors and about world growth and prices and about the national public policies. In view of consistency of the studies with GEM-E3 on different EU research project, the baseline for this exercise is based on the general growth assumptions developed by CEPII for POLES in another research project. The baseline is rather important because it conditions the efforts necessary to reach the Kyoto target, therefore there is certainly more research to be made in the comparison with other projections. However two remarks have to be made:

1. this baseline assumes that no policy measures regarding the Kyoto target are already implemented while some countries have already done so and firms have also anticipated future measures;
2. in this exercise the baseline is used for the comparison between policy measures and must not be considered as a forecast. In spite of the sectoral detail and the multiperiod nature of the CGE model, it is not designed for forecasting purposes.

The macroeconomic growth and emission profile for the EU is given in the table below.

Table 4: EU Macroeconomic growth (annual growth rate)

Macroeconomic Aggregates	2000/2005	2005/2010	2010/2015	2015/2020	2020/2025	2025/2030
Gross Domestic Product	1.74%	1.68%	1.31%	1.19%	0.93%	0.72%
Employment	0.27%	0.24%	0.04%	-0.02%	-0.23%	-0.28%
Private Consumption	1.67%	1.66%	1.49%	1.47%	1.44%	1.45%
Investment	1.68%	1.58%	1.42%	1.34%	1.20%	1.10%
Energy Consumption	1.91%	1.82%	1.30%	1.25%	1.15%	1.16%
Exports	1.83%	1.69%	0.89%	0.59%	-0.11%	-0.61%
Imports	1.49%	1.47%	1.32%	1.31%	1.29%	1.50%
Real Wage Rate	2.27%	2.18%	2.36%	2.35%	2.63%	2.74%
Relative Consumer Price	1.01%	1.28%	1.64%	2.04%	2.56%	3.58%
Terms of Trade	0.77%	0.74%	1.41%	1.64%	2.10%	2.42%
Current Account (% of GDP)	1.45%	0.76%	-0.12%	-0.39%	-0.93%	-1.14%
Total Atmospheric Emissions						
CO2 Emissions	1.43%	1.50%	0.93%	0.87%	0.78%	0.80%
NOX Emissions	-5.99%	1.69%	1.01%	0.93%	0.80%	0.80%
SO2 Emissions	0.29%	0.99%	0.60%	0.57%	0.46%	0.51%
VOC Emissions	-3.37%	1.83%	1.14%	1.06%	0.96%	0.96%
PM Emissions	0.81%	1.12%	0.72%	0.69%	0.60%	0.65%

The baseline for the Accession countries is based on the same assumptions for the key exogenous variables as for the EU baseline, with somewhat higher expected growth for the coming periods.

a) The phasing out of nuclear power (ZEW)

Several governments of EU member states have recently started initiatives for a premature phase-out of nuclear power. Central issues surrounding the controversial policy debate of phase-out initiatives are the induced economic and environmental impacts that depend on the concrete shutdown schedule of power plants, the availability and costs of replacing technologies, etc. With this scenario some quantitative insights into these issues are provided. The model version with the bottom up description of technologies in the electricity sector is used. It is an extreme phase-out scenario in which five EU member states do not consider nuclear power as a long-run supply option (i.e. Belgium, Germany, the Netherlands, Spain and Sweden) and impose a linear decline of nuclear power from business-as-usual levels in 2000 to zero production in 2020. The shares of nuclear power generation in domestic electricity production for these countries range from 4 % in the Netherlands, 31% in Germany, 52% in Belgium up to 90% in France.

The administration of this premature phase-out of nuclear power as compared to *BAU* induces a supply-side gap that is reduced or closed using three options: decrease in electricity demand, increase in electricity imports and the construction and operation of new non-nuclear power plants. A fourth possible option could be the increased utilisation of existing power plants, but would cover only a small fraction of the base-load gap caused by a nuclear phase-out, because this measure is rather costly and limited in overall scope. The premature investment in replacement technologies raises power production costs which in turn increases electricity prices as compared to *BAU*. The variation in cost changes across these countries reflect country-specific differences in the opportunity costs of a premature phase-out as captured by the magnitude of “lost” nuclear generation, the cost-potentials of replacement technologies (i.e. relative profitability of existing nuclear power plants vis-à-vis the back-up options) and the ease of economy-wide electricity savings. Not surprisingly, the increase in electricity prices has a negative impact on electricity demand. The higher the transitional increase in electricity prices the larger the decline in electricity demand.

Welfare losses for the phase-out regions are non-negligible ranging from –0.2 percent in 2020 for Germany up to –1.2 percent in 2020 for Belgium. The magnitude of welfare losses is closely related to the increase of electricity production costs associated with the premature nuclear phase-out. A premature nuclear phase-out will increase carbon emissions in the respective countries as compared to *BAU* since carbon free nuclear power will be in part replaced by electricity from fossil fuel based technologies. Obviously, the costs of carbon abatement constraints will be increased when nuclear power, as a carbon-free energy option, is abandoned.

b) Analysis of the impact of Eastern enlargement on the EU and Accession countries growth and trade (BUES)

It is generally assumed that the accession will further open-up and liberalise trade between the present and new EU member states, and will thus expand intra-EU-trade. Most the trade barriers have already been abolished due to the association and preparatory accession agreements made before 2000. In 1995, however, there were certain import duties still in effect, and their abolition can be expected to create further trade diversion and trade creation effect. It was assumed that from 2005 all remaining imports tariffs were abolished. Further we have assumed that the product and technology patterns of the accession countries will become more similar to those of the present EU countries. This development will result in higher substitutability, and consequently, higher competition between the commodities produced in different European countries, in particular in the two (EU and not EU) areas. This phenomenon has been captured by introducing a further nesting in the CES functions for the determination of the regional composition of imports[3] and the value of the elasticity of substitution between imports coming from the two areas within Europe will increase (by 30 per cent on average) after the accession. The accession would also reduce the risk associated with investment in those countries, decreasing the cost of investment and an increase in labour efficiency.

The initial effect of the accession is significantly higher than its postponed effects. The removal of import tariffs has, on the whole, a one shot effect. this move has a trade redirection effect in export and to a lesser extent, in import. About 50 per cent of the increase in GDP and exports within Europe, and two thirds of the increase imports within Europe can be attributed in the short run to the removal of the remaining tariffs. As far as the increased substitutability between commodities produced in the old and the new EU member countries is concerned, it has minor effect on most of the macroeconomic variables, but does significantly redirect the EU import demand towards the new accession countries and has a cumulative effect on the long run. The disappearance of the (by assumption) relatively high risk premium on investments has surprisingly slight effect on both the short and long run. That may be partly a critique of the formulation of the investment function. But it may also be the consequence of the fact that the model did not allow for the reallocation of capital between countries. It will be of special interest in the future to get a better estimate of the capital stock and of the return on capital, and try to recalculate the possibility and the effect of the movement of factors of production across countries. Finally, increase in labour efficiency does the expected effect. Almost 50 per cent of the increase in GDP can be attributed to this factor on the long run.

The combined impact of the individual factors induces on the whole a rather positive development from the point of view of the accession countries. Since their economies are relatively small compared to the total of the EU economy and by assumption they were directly affected by the above changes, it is no wonder the changes affect primarily their growth prospects and they benefit the most from the increased efficiency. The whole analysis is somewhat asymmetric not only because of the above aspect (no scenario assumptions formulated for the EU countries), but also for the fact, that the three accession candidate countries can not represent the size effect that the accession of all the candidate countries might have on the EU economies. Also this stylised analysis can capture only some partial effects of the enlargement.

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[3] In GEM-E3 Europe, the total imports are allocated between the different countries and the ROW in one nest.

c) Environmental policy scenarios (CES)

The environmental scenarios considered in this study cover two objective: the evaluation of the cost of reaching the EU Kyoto target and the implications for the EU policy of the Eastern enlargement. For the EU Kyoto target, the focus lied on the combination of the EU proposal of an EU permit scheme for the energy intensive sectors starting in 2005 with different EU or domestic policies to reach the Kyoto target in 2010: a domestic CO2 tax, a domestic permit system for the other sectors for the period 2008-2012 or extending the EU permit scheme to all sectors.

For the accession countries, three scenarios were considered: the accession countries participate in the EU bubble, the accession countries organise a bubble for them and finally the accession countries follow a domestic policy. In the three scenarios, the reference to which they are compared is the scenario which includes the impact of the accession on the economies.

The scenarios presented here are still at a research level and meant to explore the different mechanism at work in the model and their implications. Further sensitivity studies are needed for their use at policy level.

(1) Combining EU and national policies for the Kyoto target

The targets for emission reduction imposed to the EU by the Kyoto protocol have been allocated among the EU countries through the burden sharing agreement, leaving to each country the choice of how to reach their respective target. However, because of the differences in abatement cost between EU countries and of the importance of transboundary pollution linked to energy consumption, it might be beneficial to implement some policies at the EU level. The EU has taken a first step in defining a coordinated policy by proposing the implementation of an EU CO2 permit market for energy intensive sectors starting from 2005 onwards. The amount of permits allocated to those sectors within a country is left to the country in the proposal. Here it is assumed that the country relies on a cost efficiency criteria: the sectors included in the ET scheme are imposed a reduction target for 2005 corresponding to a % of the emission reduction they would do if a domestic permit system was implemented. The permits are distributed free of charge to the selected sectors, following the grandfathering approach. In these simulations the percentage has been fixed to 50%, the permit scheme being seen more as a learning process than as a real reduction strategy.

For 2010, the Kyoto period, three policies are evaluated:

1. extending the EU permit scheme to all sectors in 2008-2012, with the EU target and the allocation of permit to countries following the burdensharing agreement, within the country the permits are grandfathered to all sectors and household.
2. combining the EU permit scheme for the energy intensive sectors with a domestic permit for the other sectors for the period 2008-2012, the energy intensive sectors receiving their cost efficient share of the country target.
3. combining the EU permit scheme for the energy intensive sectors with a domestic CO2 tax for the other sectors for the period 2008-2012, with social security recycling to all sectors.

The different simulations were done with the model integrating the depletable resource module. Moreover in all scenarios the EU current account is constrained in relative terms to the reference level.

Combining the EU permit system with a domestic tax with social security recycling is less welfare decreasing nearly for all countries compared to the other scenarios. In fact in this scenario the cost efficiency gain through the EU permit system are taken where they are the most important (the energy intensive sectors) and all sectors, inclusive the energy intensive sectors, are benefiting from the social security recycling. The sectoral impact remain very close in the different scenarios.

Table 5: Welfare cost of the policies in 2010
(% change from reference)

	CO2 EU	CO2 EU	CO2 EU

	market for all	market for EI, domestic market for other	market for EI, domestic tax with SS recycling
Austria	-0.44%	-0.47%	-0.59%
Belgium	-0.10%	0.00%	-0.04%
Germany	0.00%	-0.02%	0.39%
Denmark	-0.23%	-0.23%	0.36%
Finland	-0.06%	-0.06%	0.33%
France	-0.25%	-0.33%	-0.60%
Greece	2.24%	0.94%	1.58%
Ireland	-0.35%	-0.20%	0.45%
Italy	-0.23%	-0.23%	-0.80%
The Netherlands	-0.20%	-0.18%	-0.52%
Portugal	0.66%	0.18%	0.96%
Spain	-0.04%	0.02%	0.16%
Sweden	0.24%	0.07%	0.72%
UK	-0.05%	-0.11%	0.71%
EU	-0.04%	-0.11%	0.03%

(2) Implications for the EU global warming policy of the Eastern enlargement

According to the Kyoto protocol, the Eastern countries have their own emission reduction targets for greenhouse gases. Their accession to the EU raises new issues for the protocol and the EU burden sharing agreement. The objective here is to evaluate the possible benefits from a cooperation between the EU and the Accession countries regarding climate policy. In particular the following policies are analysed, all reaching the Kyoto target for the EU and the Accession countries:

- the implementation of an EU permit market for the EU countries and a domestic permit market in each accession country
- the implementation of an EU permit market and an Accession countries permit market
- the implementation of a joint EU-Accession countries permit system.

In each scenario the permits are grandfathered according the burden sharing agreement or the Kyoto target for the Accession countries and the rent generated from this allocation are redistributed in the price of the goods[4]. These scenarios are only indicative because at this stage only three Accession countries are included in GEM-E3 and only CO2 is considered.

The scenarios show that the potential for emission trading with the Accession countries can be quite large as their abatement cost are lower than the EU cost (except for Slovenia). Participating in an EU enlarged permit market is favourable towards the Accession countries having low abatement cost because they benefit from the demand for permits coming from the EU countries. High abatement cost Accession countries on the contrary would prefer to keep the low cost supply of permits for themselves and see a permit market between Accession countries. These results are very preliminary given the limited number of Accession countries modelled until now.

Table 6 Welfare impact of the policy scenarios
(% change compared to reference)

	CO2 EU+	CO2 EU	CO2 EU

[4] Another possibility in GEM-E3 is to redistribute the rent in the capital income, a comparison between these two options has been made in the section regarding the ranking of policy instruments.

	AC domestic market	market and AC market	+AC market
Hungary	-0.40%	-0.46%	-0.13%
Poland	-1.14%	-1.08%	-0.15%
Slovenia	-0.63%	-0.61%	-0.86%
Austria	-0.61%	-0.60%	-0.57%
Belgium	-0.42%	-0.42%	-0.39%
Germany	-0.22%	-0.22%	-0.23%
Denmark	-0.33%	-0.33%	-0.34%
Finland	-0.23%	-0.23%	-0.24%
France	-0.43%	-0.43%	-0.40%
Greece	1.81%	1.81%	1.53%
Ireland	-0.58%	-0.58%	-0.54%
Italy	-0.46%	-0.46%	-0.44%
The Netherlands	-0.40%	-0.40%	-0.39%
Portugal	0.39%	0.39%	0.30%
Spain	-0.24%	-0.24%	-0.25%
Sweden	0.04%	0.04%	0.01%
UK	-0.20%	-0.20%	-0.22%

d) CO2 policies for Switzerland to comply with its CO2 Law (PSI)

One has evaluated economic consequences for Switzerland of two policies to reduce its CO_2 emissions by 10% from the 1990 level by 2010, so as to comply with its CO_2 Law: a domestic tax policy with recycling through the SS contribution ("tax only" policy); and a policy combining a domestic tax with the buying of permits on an international market at a fix price ("permits & tax" policy), where either a limited amount of permits corresponding to a maximum of 50% of the reduction target ("ceiling" case) or an unlimited amount of permits ("no-ceiling" case) can be bought.

All reduction policies yield a double dividend in terms of CO_2 emission reduction and employment increase, but the latter is higher in the *tax only* approach. However, the *permits & tax* policy yields a better situation in terms of GDP and sectoral impacts, especially in its *no-ceiling* variant. From this point of view, this report advocates for Switzerland the combining of a "low" carbon tax with the use of the Kyoto flexibility mechanisms. The consideration of direct economic benefits supports the choice of the *no-ceiling* variant over the *ceiling* one. However, one should also consider "secondary benefits" of reducing emissions in Switzerland instead of buying permits on an international market. Among these benefits is the fostering of domestic technological innovation. By supporting innovation, one helps Swiss industries get a competitive advantage ("first mover" advantage) in export markets.

C. Exploitation plan and anticipated benefits

The main outcome of this project is an extended and further developed version of the general equilibrium model GEM-E3 with respect to its database, its model specification and its regional scope. Moreover the extended version has been tested with a set of policy scenarios covering the issues related to the model development. With these extensions the project has significantly contributed to the scientific research in the field of CGE modelling. The developments also widen the range of possible applications of such a large scale macroeconomic model and can contribute to a consistent quantification of efficiency effects and distributional impacts of policy measures.

The exploitation of the project results are mainly in two directions: in the academic field and in the political field. In the academic field, the exploitation goes mainly through the publication of papers under various forms (discussion papers, journal articles, book publications) and through presentation in conferences and workshops. Several papers with results from the newly developed model have already been presented at international conferences. GEM-E3 can also be applied in other research projects.

In the political field, the exploitation concerns policy studies with the GEM-E3 model for national or international ministries and organisations. All partners have already been involved in this type of studies in the past and will continue to do so.

III. FINAL MANAGEMENT REPORT

A. List of Deliverables

The deliverables foreseen in the planning of the project are 18. The deliverable 6 and 8 have been integrated and the deliverable 14 has not been done because it has been decided not to do the scenarios foreseen. The reports corresponding to these deliverables have been integrated in the report 'detailed technical final report', either in the full report or in the annex to the report. Moreover, all partners have received an update version of the model database, the model calibration, the model and the report writer, one of the most important result of the project, though not classified as a deliverable. A full description of the model and of its simulation possibilities has been written and is given as an annex to the final report.

Table 7: Deliverables for the project

Deliverable N°	Deliverable title	Delivery date in the technical annex	Delivery date revised
D1	Model Development of GEM-E3: engineering representation of electricity sector and modelling of energy supply	Month 12	Month 18
D2	Model Development of GEM-E3: imperfect market structure	Month 12	Month 18
D3	Extension of GEM-E3 to Eastern European countries	Month 12	Month 18
D4	Full integration of Switzerland	Month 12	Month 18
D5	The database update for GEM-E3	Month 12	Month 18
D6/D8	Implementation in GEM-E3 of prototype with endogenous technical change and new features	Month 12	Month 22
D7	Model development regarding technical change: the role of risk in R&D, basic and public R&D,	Month 18	Month 18
D9	Case studies regarding new features of endogenous technical change	Month 24	Month 24
D10	Analysis of the choice of policy instruments within a perfect competition framework with GEM-E3	Month 18	Month 22
D11	The role of transaction costs in the choice of policy instruments, an analysis with GEM-E3	Month 18	Month 24
D12	Analysis of the choice of policy instruments within an imperfect competition framework with GEM-E3	Month 18	Month 24
D13	Energy policy scenario : nuclear phase-out	Month 24	Month 24
D15	Environmental policy scenario for Europe	Month 24	Month 24
D16	Impact of Eastern enlargement	Month 24	Month 24
D17	Policy Scenario for Switzerland	Month 24	Month 24
D18	Final report	Month 24	Month 24

B. Comparison of initially planned activities and work actually accomplished

The tasks foreseen in the planning of the project have, on the whole, been accomplished. There has been a delay in the database update because of the difficulty encountered in building a consistent database for GEM-E3 for 1995 because of the change in nomenclature for national accounts and the lack of consistent new IO tables from EUROSTAT. However a procedure has been written to ease the integration of new IO tables when they will be available. Moreover the data collection for the bottom-up model of the electricity sector and for the R&D extension has taken more work than foreseen to arrive at the quality of data needed for the model, which has led to a delay for the policy simulations with the extended model. It has however been possible to accomplish all the tasks foreseen and arrive at a fully developed GEM-E3, though still some data work will have to be done.

C. Management and Coordination

The coordination was ensured through meetings (full meetings and bilateral meetings) and frequent e-mail contacts and information exchange. The collaboration between partners has been very fluent continuing the past experience of collaboration and the integration of the new partners was successful.

The coordinator has been in charge of the development of the fully integrated version of GEM-E3 to be used by all partners. This was mainly done through the bilateral meetings: the full integration of the Swiss model into GEM-E3 (between PSI and CES), the running of the model for the associated countries (between BUES, NTUA and CES), the integration of the bottom-up and top-down module (ZEW and CES) and the integration of the endogenous growth module in GEM-E3 (ERASME and CES). This has allowed to develop a common version of the model in which the different modules for the new development are easily integrated.

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