Contract No: 044089 (SSPI)

MODELS

MOdel **D**evelopment for the **E**valuation of **L**isbon **S**trategies

Instrument:	Specific Targeted Research Project (STREP)
Thematic Priority:	SSP - 5A Scientific Support to Policies 3.4. Forecasting and developing innovative policies for sustainability in the medium and long term

FINAL PUBLISHABLE ACTIVITY REPORT

Reporting Period:	from February 2007	to January 2010
Project Start Date:	1 February 2007	Duration: 36 months

Project Coordinator: **Institute of Communication and Computer Systems (ICCS) – E3MLab**

Date of Preparation: April 2010

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1 INTRODUCTION

MODELS is a specific targeted research project running from 2007 to 2010, co-funded by the European Commission and co-ordinated by E3MLab of Institute of Communication and Computer Systems (ICCS) at National Technical University of Athens, Greece.

The consortium of the MODELS project consists of 5 institutes (Table 1) established in 4 European countries.

Table 1: List of Participants.

Participant Role*	Participant No	Participant Name	Participant Short Name	Country
CO	1	Institute of Communication and Computer Systems of National Technical University of Athens	ICCS/NTUA	**Greece**
CR	2	Netherlands Bureau for Economic Policy Analysis	CPB	**Netherlands**
CR	3	Centre d'Etudes Prospectives et d'Informations Internationales	CEPII	**France**
CR	4	Équipe de Recherche en Analyse des Systèmes et Modélisation Économiques, University of Paris	ERASME	**France**
CR	5	Institute for Prospective Technological Studies	IPTS	**Spain**

***CO=Coordinator, CR=Contractor**

The scientific objective of the MODELS project is to develop advanced economic modeling methodologies and to support the European Commission services to operate the suite of macroeconomic models in their premises in order to carry out policy simulations related to climate change mitigation policies and to the policy agenda set for the Lisbon strategy.

The project started from the existing operational versions of four major general equilibrium and macroeconometric models developed in Europe namely GEM-E3 (E3MLab), WorldScan (CPB), MIRAGE (CEPII) and NEMESIS (ERASME). These model versions have further developed in the course of the research project aiming at incorporating in their specifications state-of-the-art modeling techniques that are relevant to the policy questions addressed.

The required model improvements are scientifically challenging just because they had to address complex issues arising in the impact assessment of GHG mitigation policies and of the Lisbon strategy, as for example issues regarding the labour market, the technological progress and the recycling in the economy of revenues from carbon mitigation tools (as the ETS auctioning).

The scientific work for the model improvements has included the development of new mathematical specifications for certain components of the models, the development of new model codes, the testing of these codes by running several model versions and the policy applications, which have been carried out and presented to the Commission services (from various Directorate Generals). Also, in the course of the project, all models were fully updated and re-estimated (or re-calibrated) using the latest available statistics from Eurostat, GTAP and other sources.

The research objective of the project has been successfully fulfilled and the installation of the models at the European Commission premises has been accomplished, according to the instructions from the Commission services.

Four major workshops were organised by the MODELS project - in June 2007 on labour market issues, in July 2009 on energy and environment policy impacts, in November 2009 on climate change mitigation and in March 2010 on climate policy and revenue recycling. In these workshops, attended by several European Commission officials, the modelling teams participating in the project presented policy applications using the models on policy case specifications defined by the Commission.

The modelling teams also developed user friendly interfaces to the models and training materials and courses for supporting operation of the models at the European Commission premises.

1.1 RESEARCH WITH GEM-E3 MODEL

Work has been carried out by E3MLab/ICCS

1.1.1 OBJECTIVES AND WORK PERFORMED

The GEM-E3 (World and Europe versions) model is an applied general equilibrium model, simultaneously representing 21 World regions/24 European countries. The model projects to the future in detail the macroeconomic and sectoral figures according to a computable general equilibrium methodology which takes into account the interaction between the economy, the environment and the energy systems. The projections cover all production sectors (aggregated to 26) and institutional agents of the economy. The model user can define different aggregation schemes for countries and/or sectors, depending on data availability. The model computes the equilibrium prices of goods, services, labor and capital that simultaneously clear all markets under the Walras law and determines the optimum balance for energy demand/supply and emission versus abatement effort.

The objective within the MODELS project was to improve the GEM-E3 model and to install new operational versions on the computer system of the European Commission for in house use. The new versions of the model were designed for supporting a series of policy applications on issues related to the Lisbon agenda, climate change mitigation policies and the assessment of impacts from regulation and legislative initiatives of the Commission.

The improvements of the GEM-E3 model have regarded the following areas:

1. Incorporation of frictions in the labour market module and representation of imperfect equilibrium in the labour market allowing endogenous equilibrium unemployment.
2. Development of a world version of GEM-E3 with endogenous R&D and innovation investment.
3. Update of the model database for both the EU and the World model versions (including an update of the process related greenhouse gas emissions and calibration for the year 2004).
4. Development of reference (baseline) scenarios for both the European and World version of GEM-E3.
5. Improvement of the dynamic properties of the model by introducing econometrically estimated investment functions by sector.
6. Establishment of a new detailed model linkage between the PRIMES energy system model projections and the macroeconomic projections with GEM-E3, that can handle various energy policy issues.
7. Development of a graphical user interface that facilitates the use of the GEM-E3 model.
8. Development of a goal programming software assisting development of baseline and targeted scenarios with the GEM-E3 model.

Labour Market

In the standard version of the GEM-E3 model labour market is perfect in the sense that wages adjust until there is no excess labour supply and hence unemployment. Labour demand is derived from the optimization behavior of producers, and labour supply is a result of utility maximization by the households regarding consumption, leisure and savings. In this initial version, the model's result corresponds to the notion of voluntary unemployment. In order to improve the realism of the model a new specification of the labour market was designed and implemented, following the methodology of the efficiency wages approach by Shapiro and Stiglitz (1984). The union bargaining approach specified by Bohringer and Boeters (2005) was also introduced into the model but it is not included as a default option.

The new model version keeps the same equilibrium approach as the initial model version, in which wages adjust until labour supply equals labour demand; hence the approach is characterized as equilibrium unemployment. The new methodology consists in introducing labour market imperfections which drive a different labour supply function that the one derived from households' utility maximization. Hence unemployment cannot be interpreted only as a voluntary choice of households for leisure, but also as a result of labour market imperfections.

Several modelling approaches exist that adopt similar approaches and introduce, at least for the short/medium term, frictions and other market imperfections, which induce shifting of the labour supply curve giving rise to involuntary unemployment. In this case, wages balancing labour demand with the shifted labour supply lead to unemployment that is higher than the voluntary unemployment.

A widely used approach for modelling such frictions in the labour market is for example the Philips curve (1958). Blanchflower and Oswald (1990) estimated such a relationship for the USA and UK labour markets. Blanchflower and Oswald (1994) extended these estimations for 12 EU countries.

According to a literature survey, published by MaCurdy (1999) and Barros et al. (2001a), the labour market imperfections leading to involuntary unemployment can be interpreted by the existence of one or more of the following imperfections:

- Minimum wages, as set by legislation. The existence of minimum wages mainly affects the employment levels of new and unskilled workers, and not the overall unemployment level, as shown by Abowd (2004)[1].
- Mismatch of job vacancies and labour supply due to lack of information. See Mortensen - Pissarides (1999) for searching and mismatching issues.

[1] Brown, Gilroy & Kronen (1982) showed that minimum wages affect only marginally overall unemployment levels while Kaufman (1989) estimated that the minimum wage elasticity of unemployment in the UK is close to 0.06. The Kaufman results were verified by Seltzer (1997) who studied the effect of minimum wages in the UK, Canada, and USA. Similar studies for France, as in Abowd & Kramarz (1999), did not establish any significant relationship between minimum wages and overall unemployment. An OECD (1998) study covering a large number of countries concluded that minimum wages affect unemployment of workers at an age between 15 and 18, marginally affecting workers of age between 18-29 and not affecting older workers.

- Trade union with strong negotiating power, as in De Menil (1971). Unions exploit their negotiation power to achieve wages that are higher than the equilibrium wages.
- Existence of efficiency wages, see for example Shapiro & Stiglitz (1984). Employers have the incentive to set wages higher than the equilibrium wages because they anticipate an increase in the effort and productivity of their employees. In addition efficiency wages attract high quality workers and they reduce the probability of someone quitting his job.

In the GEM-E3 model the efficiency wage approach was finally selected to be the default option for representing involuntary (equilibrium) unemployment. This modelling approach was preferred because of its empirical validation, by using for example the Blanchflower and Oswald (1994) results, its simplicity, and the fact that it is parsimonious in parameters. The specification of efficiency wages in GEM-E3 is based on Shapiro & Stiglitz and Annabi (2003) approaches.

The efficiency wage approach for simulating involuntary unemployment relates to the assumption that there is a negative correlation between wages and unemployment. This approach states that productivity/quality of labour has a positive correlation with wages. In periods with high unemployment firms are not motivated to offer high wages to attract higher quality labour or to increase productivity of existing workers. On the contrary at low unemployment rates it is efficient for firms to offer wages above their equilibrium level, because they seek for increases in labour productivity and for reducing the probability of someone quitting the job and hence reducing costs from the recruitment of new personnel; see Phelps (1994), Campbell and Orszag (1998).

An alternative approach is incorporated in GEM-E3 as an optional variant. This follows the version of the wage bargaining model of Bohringer and Boeters (2005). This relies on results published in the labour market literature (i.e. Lingens (2007)[2]), the CESifoDICE[3] database statistics and OECD surveys. According to this information, the primary factor of wage determination in the EU27 member states is the union wage bargaining (the 90% of the wage contracts is derived through union bargaining).

The implementation of involuntary unemployment in the GEM-E3 model required additional data (i.e. unemployment levels, minimum wages etc.) that were extracted mainly from the CESifoDICE and EUROSTAT databases.

Endogenous R&D

Technical progress in the standard version of GEM-E3 is modelled through exogenous parameters, following the concept of autonomous technical progress. These parameters express either technical progress embodied in the production factors (KLEM approach) or total factor productivity, and are projected to the future for building a baseline scenario.

There are many reasons suggesting abolishing the exogeneity of the technical progress parameters and deriving them as a result of the market equilibrium. Firstly, there is overwhelming evidence that technological change is not totally autonomous but a great part can be attributed to drivers stemming from the rest

[2] Jorg Lingens, "Unions wage setting and economic growth", Journal of economic modeling, 2007.
[3] www.cesifo.de

of the economic system. Secondly, altering technical progress with economic projections reflecting policy-oriented scenarios is important for policy making. For example, if technological innovation is among the tools of policy making, then the economic assessment of environmental and energy policies would be enriched and would be certainly different from approaches that consider only autonomous technical progress. Thirdly, if investment in innovation is introduced among the options for decision by the economic agents, trade-offs arise between productive and innovation investment which have consequences on the model results and the long term projections.

For climate change studies it is important to endogenise technical progress. Models incorporating technological change as induced by climate policy targets find substantially lower total abatement costs than models representing exogenous technical change. Therefore, ignoring induced technological progress in the modelling of economy-energy-environment interactions, may lead to biased policy recommendations.

Only recently the applied modelling literature has begun to include technological process as an endogenous process. The delay is partly due to the complexity of implementing numerically the theoretical formulations. The first attempt to make the technical change endogenous in GEM-E3 has been performed by Erasme in the TECH-GEM Project for European Commission (2002). In that version, the technical progress rate is embedded in the production function as a total productivity factor. In policy applications with the modified model it was shown that there are consequences on policy recommendations, as for example for results regarding the replacement of the existing capital stock with more energy efficient technologies. However, that version of the model failed addressing embodied technical progress, thus differentiating innovation decisions between different production factors.

The methodology of the modelling approach adopted for the GEM-E3 model specification about induced technical progress was based on the literature such as Lucas (1988), Romer (1990) and Grossman and Helpman (1994), Fougeurolas et al (2002). These authors treat innovation as a result of explicit investment in R&D. The new growth theory recognizes that technological innovation is an economic activity arising from the profit maximizing efforts of agents. The induced innovation hypothesis is presented in some aggregate climate change models, notably by Nordhaus (1999), Goulder and Schneider (1999), Buonanno et al. (2000) and Goulder and Mathai (2000).

The research work performed within the MODELS project aimed at refining and extending the previous research on representing endogenous technical progress in GEM-E3. The new research specified six different types of technical change in the model: product quality (total factor productivity) and embodied technical progress for each production factor (capital, labour, fuels, materials and electricity). In addition, the research aimed at improving the representation of inter-sectoral and international diffusion of knowledge, as the diffusion of technical innovations has important effects in terms of positive externalities but also consequences on trade and competitiveness. These improvements were incorporated to the world version of the GEM-E3 model.

Dynamic Properties

GEM-E3 is a recursive dynamic general equilibrium model. The projection is for several years but the agents' anticipations are modelled as adaptive expectations, hence the expectations are not rational. The implied myopia,

contrasting perfect foresight approaches, has consequences on the long term simulation properties of the model, not only in cases of shocks (the model simulates as if the shocks are not anticipated) but also in case of policy targets varying over time. For the latter case, the use of the model has to take care to manually modify the values of the anticipation parameters, form scenario to scenario, in order to fully reflect the consequences of policy targets that very over time.

A fully intertemporal, hence simulating perfect foresight, version of the GEM-E3 model has been developed, but the computer solution is uncertain (because of algorithm limitations) beyond a certain model size; hence a significantly more aggregated version of the model can run in an intertemporal way. This model version can evidently address any dynamic policy issue or shock, but lacks the full model detail.

The major dynamic equations of the model regard sectoral investment and the purchasing of durable goods. There could be also other dynamic functions, for example regarding investment and borrowing-debt relations, but these are modelled statically in the current model version.

Apart the aggregated intertemporal model version, the aim of the research within the MODELS project, was to improve the dynamic adjustment mechanism of the sectoral investment functions. The approach consisted in specifying a new dynamic mechanism for the investment functions that is estimated econometrically. This allows for providing a validation basis regarding the adaptive expectation parameters, which play an important role for the simulation properties of the model. According to the methodology adopted, future expectations are derived from an independent simple dynamic growth model which produces steady state projections serving as expectations entering the new adaptive expectations mechanism of the investment function in the GEM-E3 model. The econometric estimations (thee stage least squares) were made by using combined time series and cross-section data. The basic assumption of the investment function is that the actual value of the share of the capital stock which is invested differs from the desired share because the adjustment to its optimal level corresponding to domestic production change is not immediate.

Update of the model database

Within the MODELS project the regional coverage of the GEM-E3-World model has been extended so as to incorporate all key international players concerning climate change mitigation policies. In addition its database has been updated to the latest input output tables available (2004). 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 and be consistent within the National Accounts framework.

The database of the model consists of Input-Output tables, Consumption Matrix, Investment Matrix, Bilateral Trade Matrix, National Accounts (by institutional sector), Energy Balances and Emission Statistics. The Input-Output tables are combined with the National Accounts to form the Social Accounting Matrix (SAM). The most recent year for which available and complete data could be obtained was 2004 for the world version of GEM-E3

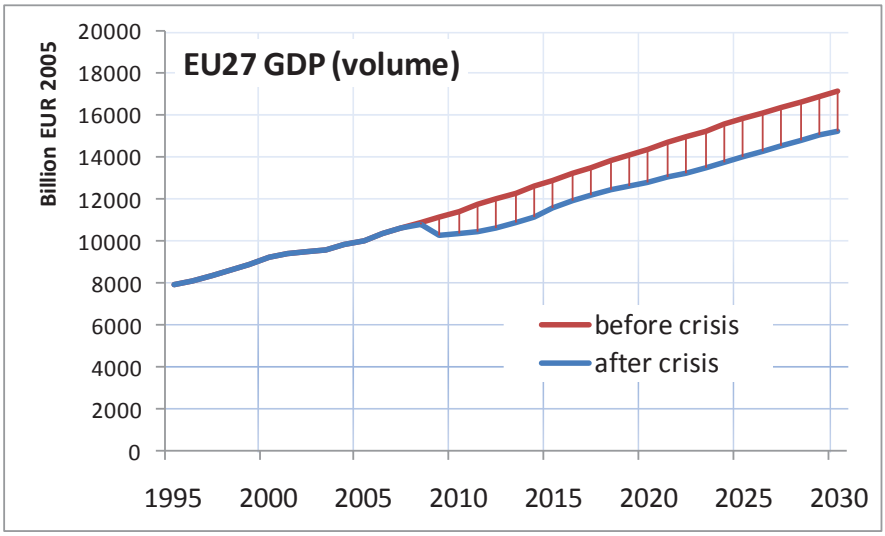
and 2001 for the European version. The main data sources used for this purpose were EUROSTAT and GTAP-V7[4]. Additional data required, which are not available from the GTAP database, concern the consumption matrices, the labour market, bottom up data for the power generation sector, interest rates and marginal abatement cost curves. These were extracted from various sources including the ILO, US-EPA, EU-KLEMS, IEA and the OECD.

Reference Scenario

For the preparation of the new GEM-E3 reference case E3M-Lab has used the latest short term forecasts published[5] by DG ECFIN (May 2009) and the DG ECFIN Ageing 2009 report (April 2009)[6] which includes long term GDP, population and labour force projections. The reference case projection shows a considerable downturn of the European economy which started after the financial crisis that emerged in autumn of 2008. The economic prospects for the EU can be divided in three periods: the recession (2008-2014), the recovery (2015-2022) and the low but stable growth period (beyond 2022).

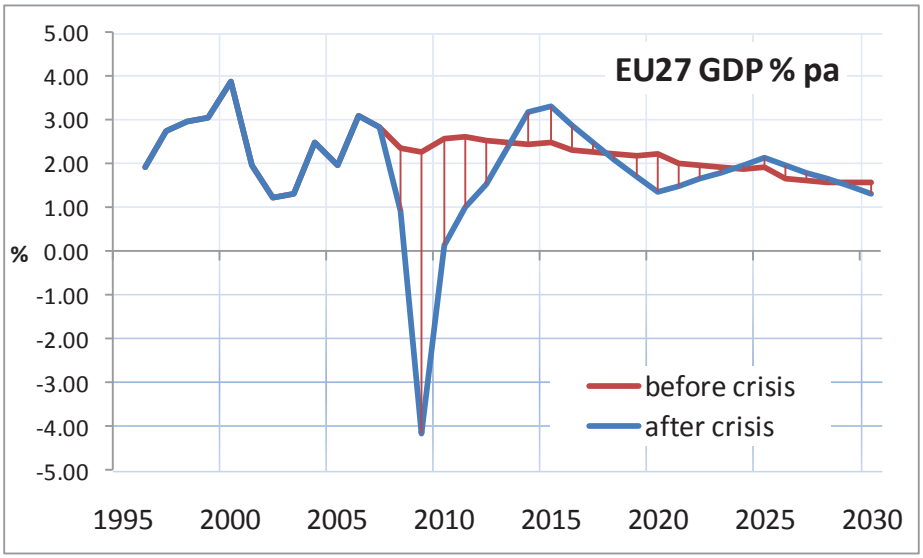
The model was successfully used to simulate both the crisis period and the post-crisis economic developments. To simulate the crisis, three parameters were introduced: a risk premium which simulates a shadow interest rate reflecting credit rationing during the crisis; a barrier to international trade reflecting the retention in credit facilitation of trade transactions; a loss of capital assets. The recovery period was simulated by assuming accelerated technical progress reflecting the restructuring during the crisis and by increased positive anticipations which affect investment behaviour. The slowdown in the long term was mainly due to demographic assumptions and to a slowdown in labour productivity progress.

Figure 1: Post crisis GEM-E3 reference cases.



[4] GTAP provides input output and bilateral trade data for 113 regions and 57 sector for the year 2004 (all data expressed in 2004$).
[5] http://ec.europa.eu/economy_finance/publications/publication_summary15046_en.htm
6 http://ec.europa.eu/economy_finance/publications/publication_summary14911_en.htm

Figure 2: Post crisis GEM-E3 reference cases (annual growth rates).



The graphics above, show results for the EU27 and illustrate that the recovery cannot compensate for the loss of GDP encountered during the recession period and thus permanent loss of GDP takes place over the time period until 2030 compared to pre-crisis projections with GEM-E3. Loss of GDP involved in the 2009 projection compared to the 2007 has downward consequences on energy demand, hence on GHG emissions. The growth rates of the EU GDP in volume are projected to be lower in the long term compared to the recovery period. The annual growth rate is projected to be on average 2% per year between 2020 and 2025 and 1.7% per year between 2025 and 2030. The growth patterns differ by EU member-state: the northern and centre old members of the EU suffer more than other from the recession and recover more slowly, however stay on a significant and positive growth pace over the long term; the new member-states suffer also an important depression compared to the high growth experienced over the last few years, but their recovery is more pronounced than the EU average, followed by a slowdown in growth rates as they are progressively getting into maturity; southern economies display a similar growth pattern but their long term prospects are slightly lower than the new member-states. Total population and active population are assumed to grow at low but positive rates over the entire projection period.

The construction of a reference case which involves targets (or pathways) for certain aggregate figures, such as GDP, emissions, etc., is carried out by calibrating the exogenous parameters. A manual calibration is extremely cumbersome, since the model involves multiple sectors and countries and so the exogenous parameters are numerous. The exogenous parameters to calibrate concern: demographics, the labour market, anticipation parameters in the investment functions, technical progress embodied in capital, labour, energy and material, and public consumption and investment.

Instead of manual calibration, a computer-based procedure was developed by the E3M-Lab of the ICCS. The aim is to calibrating GEM-E3 (both EU and World versions) so as to simulate closely enough exogenously given values and

trajectories, by ensuring that shifts in model's exogenous parameters are relatively small and within set bounds.

The methodology of constructing the GEM-E3 baseline respects the logic and structure as well as the dynamic properties of the GEM-E3 model and therefore maintains consistency while allowing for great flexibility on target choices and their hierarchy, as well as calibration instruments. It involves the use of three distinct tools which are encoded in GAMS: the GEM-E3 model itself, a linearization facility and a Parameter Calibration Model (PCM). The linearization facility is used to express all equations of the GEM-E3 model in linear relationships involving rates of growth and shares. Then the linearized GEM-E3 model is inserted into a goal programming framework so as to incorporate the user defined targets (related to GDP, emissions, sectoral activity etc.). The PCM module is used to solve the linearized goal programming model in a stepwise manner in order to ensure that the targets are reached and the shifts in the model exogenous variables are relatively small compared to exogenous assumptions and bounds. In the stepwise process, the linearization is updated so as to better approximate the non linear relationships of the GEM-E3 model. At the end, the full scale model is used for projection in order to validate the closeness to the required trajectory.

Linkage between energy system model PRIMES and GEM-E3

The energy sector of GEM-E3, as is the case of all CGE models, is rather aggregated and the energy volumes and prices are measured as economic indices (as in National Accounts). Energy is disaggregated following the definitions of Input-Output tables and not as in Energy Balances. Consequently, although the energy system is included in the general equilibrium model, GEM-E3 cannot produce energy system simulations as accurately as for example the PRIMES model, lacking details and engineering evidence.

Therefore, it was judged better to link the two models by calibrating the GEM-E3 energy-related projections to those obtained by the PRIMES model. The latter model takes as inputs the economic and sectoral projections of GEM-E3.

This is not a trivial task because there is no one-to-one matching between energy balances and input-output tables and also because there exist significant overlapping in system coverage by the two models: for example despite their methodological differences both models incorporate energy demand and supply.

To tackle these difficulties, E3MLab established a correspondence between the models allowing using them in an iterative sequence, as follows: Firstly an economic scenario is produced by using the GEM-E3 model. Secondly, PRIMES is used to produce an energy projection by using as exogenous parameters the economic activity projections of GEM-E3. Within the logic of partial equilibrium analysis, PRIMES is used to produce counter-factual energy system projections, for example reflecting energy policy target. The energy system projection implies changes in energy consumption by sector and changes of fuel-mix in supply and demand sectors, compared to baseline. It implies also changes in energy system costs and prices. Subsequently, several parameters used in the GEM-E3 models are changed to reflect the change of energy structure produced by the PRIMES model. In addition, the

policy changes reflected in the energy counter-factual scenario of PRIMES are also introduced in GEM-E3. Finally, other macroeconomic adjustments, as for example the choice of closure rule for the current account or the public finance, are also introduced. So, GEM-E3 is used to quantify the counter-factual scenario within the logic of general equilibrium analysis. As a result, economic activity and GDP projections are altered compared to the baseline scenario. Finally, these altered economic activity projections are introduced in the PRIMES model and a new energy system scenario is produced. This iterative process may continue until convergence is reached, i.e. until no changes are produced in the data exchanged by the two models. However, because of the high complexity of the models and the long computer time required to run them for all the EU member-states, the iteration stops after the second run of the PRIMES model. At this stage, the energy and economic system results are reported and compared to those of the baseline scenario: the results are used in impact assessment studies.

For the linked model usage in energy policy applications, a bottom-up representation of the electricity sector was introduced in the GEM-E3 model, which is designed to project generation costs, selection of power technologies and the cost of transmission and distribution of electricity. The technologies represented are: coal generation, gas generation, oil generation, nuclear, biomass for power production, hydro, wind and solar PV. Electricity producing technologies are characterised by different cost structures and conversion efficiencies. The shares of each technology in power generation in the base year are introduced from energy balance statistics. Some of the potential technologies that may develop in the future are not used in the base year.

The Input-Output tables represent the electricity sector as an aggregate of two activities, namely the power generation and the transmission and distribution of electricity. This is not convenient for the bottom up model, and so it was necessary to split the Input-Output column and row in different activities, some corresponding to power generation by technology and the rest corresponding to transmission and distribution of electricity. The split was performed by combining data from energy balances and company-related economic data about generation and transmission and distribution activities by country. In order to disaggregate the power sector a mapping was specified between the entries of the input output table and the cost and energy balance information retrieved from the energy databases. The engineering estimated costs are associated with the corresponding cost elements of the Input-Output statistics and so the SAM are adjusted and expanded. Toward this end a cross entropy method was applied. The nesting of the electricity sector production functions were revised and extended in order to allow for endogenous choice of power technologies.

Graphical user interface

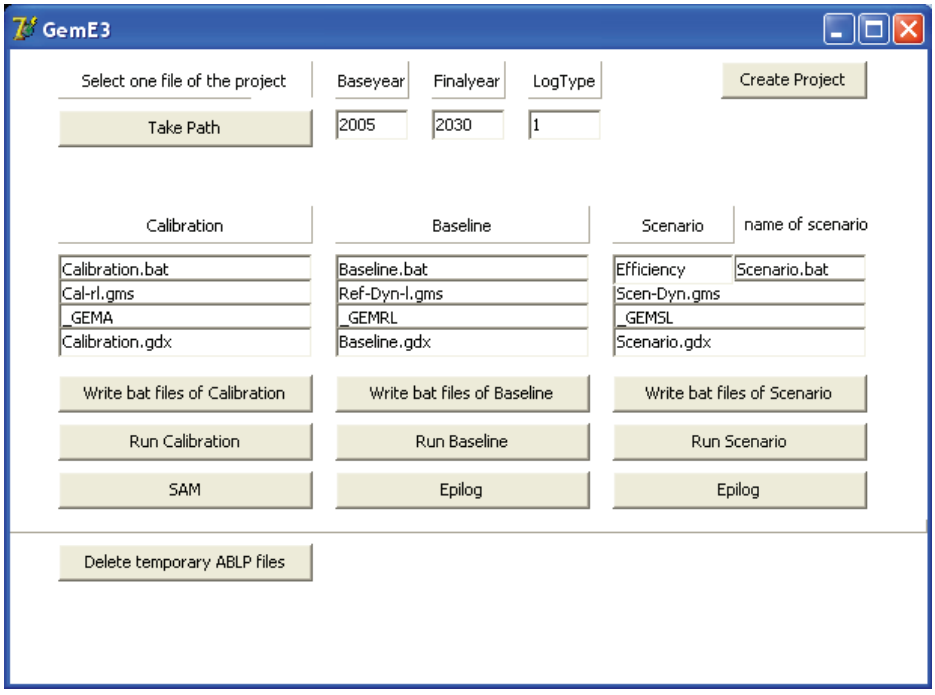
The GEM-E3 model is formulated as an MCP problem with equal number of equations and equal number of variables. The MCP problem is solved for each year following a time-forward path. The model uses the GAMS software and solved by using the PATH (MCP) algorithm.

All data of the model (i.e. social accounting matrices, bilateral trade etc) are stored in Excel files and are read at the calibration stage of the model through GAMS utilities. Once the calibration of the model is done a file is generated with the definitions and values of all sets, parameters and variables of the model. These files together with the assumptions on the exogenous variables of the model are inserted as inputs to the main GEM-E3 model. The model runs up to 2030 (or 2050) with a 5 year time step and the output is exported to Excel files. The model has several built-in options to run counterfactual scenarios and the user needs only to specify in an excel sheet the policy scenario that he wants to simulate and the values for the corresponding options. However the options provided to the user cannot cover all possible simulation cases. In case of more complex policy simulation requirements the user has to specify a GAMS code which manipulates the input data.

Within the MODELS project E3MLAB developed a graphical user interface that allows the user to run the calibration of the model, run the reference case of the model and perform certain counterfactual scenarios. The program was written in Delphi and its user interface is depicted in a picture below.

Through this interface the user can specify the time period of the simulation (maximum up to 2030) and define the names and the location on the hard disc of the assumptions of the different policy simulations that she wishes to perform.

Picture 1: GEM-E3 Graphical user interface v1



1.1.2 ENVIRONMENTAL POLICY MODELLING AND SCENARIOS

The objective of this work package was to enhance the environmental and energy part of the GEM-E3 that will enable a better representation of the energy, technology, environment, economy nexus; the new model is installed

at the Commission premises for supporting analysis of policy scenarios regarding the economic impacts of a wide range of energy and environmental issues. The model developments carried out included the incorporation of a bottom up power generation module in the world version of GEM-E3, the update of the marginal abatement cost curves for process related greenhouse gas emissions and the update of the non-CO2 GHG emissions database. The new GEM-E3 model version was used in a study about the costs of achieving the EU27 20-20-20 climate change and energy policy targets (decided in December 2008), the employment effects of a steady increase in energy-efficiency and the employment effects from a steady rise in renewable energy sectors.

The new GEM-E3 bottom-up model extension for power generation is shortly described in section 2.1.1.

Process related marginal abatement cost curves and emissions

Emission abatement is modelled in GEM-E3 by associating a cost to the production or consumption input which is responsible for the emission. The increased input cost influences the decision process of the firms or the households. The price of energy, inclusive of carbon charges or energy taxes, enables energy related CO2 emission abatement. In case emissions relate to production (process emissions), the cost of production increases by means of a non linear cost function, which expresses the marginal abatement cost. This is applied for process related emissions and non CO2 GHGs. In this case the model establishes a correspondence between abatement expenditures and additional demand for goods and services for implementing the abatement technologies. It is clarified that the marginal abatement cost curves do not apply for the energy-related CO2 emissions, hence abatement and the corresponding additional costs and demand for goods and services results from substitutions among energy forms or between energy and non energy inputs and from changes in production and consumption levels.

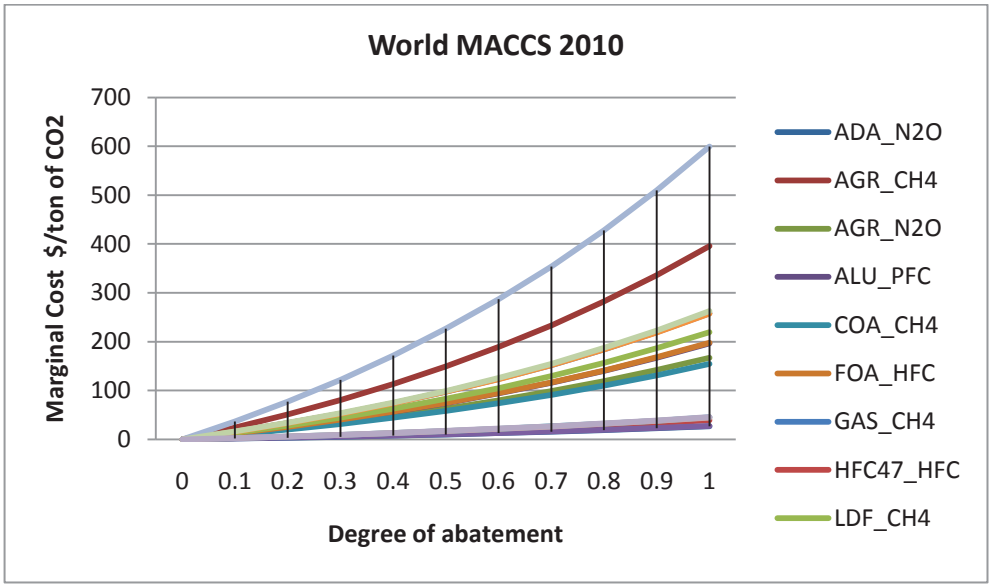
Table 2: Estimation of GEM-E3 World MACC based on EPA information (2010) c1*(eaa-1)

Activities	GHG	Estimation (C1)
Agriculture (AGR_ CH_4)	CH_4	230.14
Agriculture(AGR_ N_2O)	N_2O	97.20
Solvents (SOL_ HFC)	HFC	152.71
Semiconductors (SCD_PFC)	PFC	26.00
Refrigeration (REF_HFC)	HFC	349.00
Oil (OIL_ CH_4)	CH_4	180.79
Gas (GAS_ CH_4)	CH_4	150.16
Nitric Acid (NAC_ N_2O)	N_2O	26.13
Magnesium (MAG_ SF_6)	SF_6	16.06
Landfills (LDF_ CH_4)	CH_4	127.75
HCFC (HCF47_HFC)	HFC	22.86
Foams (FOA_HFC)	HFC	115.09
Electric T&D (ELE_HFC)	SF6	26.62
Coal (COA_ CH_4)	CH_4	89.87
Aluminium (ALU_ PFC)	PFC	114.37
Adipic Acid (ADA_ N_2O)	N_2O	15.48

The coefficients of the marginal abatement cost curves were estimated for each non CO2 greenhouse gas, type of activity and sector, as available in the

"Global mitigation of non CO2 greenhouse gasses", US EPA, 2006. The following table presents the estimations of the world MACCs of GEM-E3 based on the EPA data. The EPA report provided data for the following countries/regions: Africa, Annex I, Australia and New Zealand, Brazil, Canada, China, CIS, Eastern Europe, EU-15, India ,Japan, Latin America/Caribbean, Mexico, Middle East, Non-EU Europe, Non-OECD Annex I, OECD, OPEC, Russian Federation, South & SE Asia, South Korea, Turkey, Ukraine, United States, World. Marginal abatement costs were available for the years 2010 and 2020.

Figure 3: Illustrated MACC curves for GEM-E3



For the update of the process related greenhouse gas emissions of GEM-E3 the GTAP non CO_2 and UNFCCC databases were used.

Study on the difference in the costs of achieving the climate change targets between a moderate and a severe / prolonged recession at the start.

The economic slowdown following the financial markets turmoil affects the effort needed for the EU economy to meet the Climate Action and RES targets set by the EC decision 3738/08, the directive 2003/87/EC and the directive 3736/08. E3MLab used the computable general equilibrium model GEM-E3 to evaluate "what would be the difference in the costs of achieving the climate targets between a moderate and a severe/prolonged recession at the start?" For this purpose two reference cases were used, namely Baseline '2007[7] and the Baseline'2009[8] scenario. Two Climate Action and RES scenarios were simulated, assuming implementation of the 20-20-20 package in the absence of the crisis and implementation of the package after the crisis. Conclusions were drawn by comparing each policy scenario against the corresponding Baseline.

[7] Macroeconomic and sectoral growth scenario as projected for DG TREN Baseline scenario end 2007
[8] Post crisis scenario prepared in 2009 and used by DG TREN

Table 3: Aggregate GEM-E3 results

Macroeconomic Aggregates (EU) (% changes from corresponding baseline)	Before crisis		Crisis	
	2020	2030	2020	2030
Gross Domestic Product	*-0.38*	*-1.04*	*-0.09*	*-0.51*
Investment	*-0.26*	*-0.70*	*-0.04*	*-0.26*
Private Consumption	*0.20*	*-0.26*	*0.24*	*-0.03*
Exports to RoW	*-1.94*	*-3.12*	*-0.86*	*-1.74*
Imports from RoW	*0.02*	*0.11*	*0.14*	*0.21*
Terms of Trade	*1.31*	*2.16*	*0.68*	*1.31*
Employment	*-0.08*	*-0.50*	*0.07*	*-0.23*

Source: GEM-E3

Table 4: Sectoral GEM-E3 results

Domestic Production (EU) (% changes from corresponding baseline)	Before crisis		Crisis	
	2020	2030	2020	2030
Agriculture	*4.1*	*6.3*	*4.4*	*6.7*
Coal	*-32.6*	*-39.0*	*-18.5*	*-27.4*
Oil	*-7.9*	*-11.6*	*-4.7*	*-7.5*
Gas	*-13.4*	*-22.6*	*-8.0*	*-13.3*
Electricity	*-3.3*	*-4.0*	*-2.1*	*-2.0*
Ferrous and non ferrous metals	*-1.7*	*-2.6*	*-0.4*	*-1.1*
Chemical Products	*-1.2*	*-2.0*	*-0.2*	*-0.8*
Other energy intensive	*-1.2*	*-1.9*	*-0.3*	*-0.8*
Electric Goods	*-1.0*	*-1.9*	*-0.5*	*-1.1*
Transport equipment	*-1.3*	*-2.5*	*-0.5*	*-1.4*
Other Equipment Goods	*-0.6*	*-1.3*	*0.0*	*-0.5*
Consumer Goods Industries	*-0.7*	*-1.6*	*-0.1*	*-0.7*
Construction	*-0.2*	*-0.7*	*0.0*	*-0.3*
Telecommunication Services	*0.0*	*-0.3*	*0.1*	*-0.1*
Transport services.	*-1.3*	*-2.7*	*-0.1*	*-1.2*
Services of credit and insurances	*0.0*	*-0.4*	*0.1*	*-0.2*
Other Market Services	*-0.2*	*-0.8*	*0.1*	*-0.4*
Non Market Services	*0.1*	*0.0*	*0.1*	*0.0*

Source: GEM-E3

The consideration of the economic growth slowdown post crisis leads to smaller negative effects on economic activity (-0.5 as opposed to -1.04 in the before crisis scenario). Carbon prices estimated for meet the targets are lower in the context of the post crisis scenario (30.64 €/t. of CO_2 in 2030 as compared to 51.39 €/t. of CO_2 in the before crisis scenario). Thus the increase in domestic prices is lower and so the effects on competitiveness are smaller.

For both scenarios energy and carbon intensive sectors are negatively affected at a larger degree than for other sectors. However in the context of the Crisis scenario, the effects are smaller in magnitude. Agricultural production is positively affected driven by higher production of biomass and biofuels. Sectors supplying goods and services to RES and other low carbon footprint equipment

are less affected than other sectors and in some cases the effects are positive in both scenarios.

The economic crisis is found to facilitate transition towards meeting the Climate Action and RES targets, because of lower energy needs. However a possible increase in interest rates (risk premium reflecting lower credit availability) which may prolong in the post crisis period will increase compliance costs, as shown in a sensitivity analysis.

Study of the employment effects of a steady increase in energy-efficiency and/or a steady rise in renewable energy sources

E3MLab used the computable general equilibrium model GEM-E3 to evaluate: "*the employment effects from: i) a steady increase in energy efficiency ii) a steady rise in renewable energy sources*", iii) "*the long term GDP and employment effects in 2020 and beyond of reaching 20% RES, with a 15% reduction of energy consumption and climate change policy*". The new version of the GEM-E3 model that incorporates labour market imperfections according to the efficiency wages methodology was employed. These exercises assumed a baseline scenario that does not include the financial crisis, as simulated for DG TREN in 2007. The *energy efficiency* scenario simulates a reduction of primary energy consumption of 15% in 2020 and 20% in 2030 relative to Baseline, driven by structural bottom-up policies (insulation, more efficient appliances, etc.) in many sectors. The *renewable energy scenario* simulates a 20% of total gross final energy consumption in 2020 supplied by RES and a 25% in 2030, driven by RES promoting policies (no carbon price). The combined Efficiency, RES and Climate Action (ERC) scenario was based on the respective PRIMES scenario for DG TREN.

Regarding the labour market flexibility sensitivity analysis was performed: three cases considered, corresponding to a rigid, moderate or flexible labour market. The effects on domestic activity are very sensitive on the degree of flexibility of the labour market. User costs of energy increases, because energy saving investment is financed through taxes on energy consumption. The resulting higher energy productivity relaxes revenue constraints and drives higher demand for other factors. However higher production costs induce competitiveness losses; their magnitude depends on the labour market flexibility.

Higher RES induce more domestic activity for producing the RES equipment, hence more labour. However cost of energy services increase, driving higher production costs in all sectors. In addition, wage rates and unit cost of capital tend to increase as a result of higher domestic activity induced by RES. Hence, part of the benefits on domestic activity is offset by the loss in competitiveness inducing higher imports and lower exports. The net effect on economic activity is ambiguous depending on the flexibility in the primary factor markets. In case of moderate and rigid labour market flexibility the effects from loss of competitiveness dominate over direct effects, hence net effects on employment are found negative. The GEM-E3 model results have showed that the employment effects from a steady increase in energy-efficiency are more likely to be positive because of a higher multiplier effect on the domestic economy, compared to other carbon friendly deployments.

Table 5: Macroeconomic effects of the energy efficiency scenario

	flexible		moderate		rigid	
Macroeconomic Aggregates (EU) (% change from reference)	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
Gross Domestic Product	*0.49*	*0.78*	*-0.19*	*0.17*	*-1.12*	*-0.74*
Investment	*0.67*	*0.73*	*0.34*	*0.32*	*-0.11*	*-0.28*
Private Consumption	*1.09*	*1.57*	*0.08*	*0.74*	*-1.28*	*-0.51*
Exports to RoW	*-0.51*	*-0.58*	*-0.97*	*-1.06*	*-1.62*	*-1.77*
Imports from RoW	*0.72*	*0.52*	*0.50*	*0.31*	*0.19*	*-0.02*
Terms of Trade	*1.13*	*1.30*	*1.23*	*1.43*	*1.38*	*1.65*
Employment	*1.27*	*0.83*	*0.18*	*0.06*	*-1.28*	*-1.12*
Real Wage	*-0.93*	*-0.05*	*0.34*	*0.66*	*2.12*	*1.81*
Consumer Price Index	*0.75*	*1.04*	*0.92*	*1.27*	*1.17*	*1.61*

Source:GEM-E3

Table 6: Macroeconomic effects of the RES scenario

	flexible		moderate		rigid	
Macroeconomic Aggregates (EU) (% change from reference)	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
Gross Domestic Product	*0.46*	*0.21*	*-0.21*	*-0.39*	*-1.11*	*-1.30*
Investment	*0.08*	*0.04*	*-0.25*	*-0.37*	*-0.69*	*-0.96*
Private Consumption	*1.19*	*0.97*	*0.21*	*0.16*	*-1.13*	*-1.07*
Exports to RoW	*-0.63*	*-1.03*	*-1.10*	*-1.51*	*-1.74*	*-2.24*
Imports from RoW	*0.33*	*0.45*	*0.10*	*0.23*	*-0.22*	*-0.09*
Terms of Trade	*0.74*	*1.08*	*0.85*	*1.23*	*1.01*	*1.46*
Employment	*1.06*	*0.72*	*-0.02*	*-0.05*	*-1.47*	*-1.24*
Real Wage	*-1.16*	*-0.65*	*0.14*	*0.08*	*1.94*	*1.27*
Consumer Price Index	*0.42*	*0.62*	*0.57*	*0.84*	*0.80*	*1.17*

Source:GEM-E3

1.1.3 SUMMARY OF RESULTS AND CONCLUSIONS

The GEM-E3 model as developed within the MODELS project identifies 37 regions of the world (each EU27 member state separately), 25 economic sectors (of which 9 power producing technologies). It covers the period 2005-2030 with a five year time step and its reference scenario is based on the DG ECFIN Ageing 2009 report for the EU27 countries while for the rest of the world regions the reference case is made consistent with the GDP assumptions used by the partial equilibrium world energy model POLES. The models' database includes data from GTAP, EUROSTAT, ILO, UNFCCC and IEA. Involuntary unemployment is represented in the model through the efficiency wages approach and a detailed bottom-up module has been incorporated so as to discretely identify nine power producing technologies. There is a soft-link created between the partial equilibrium energy model PRIMES and GEM-E3 so as to include in a more consistent way the adjustment of the energy system induced by a policy shock. The world version with endogenous R&D is operational but it was not consolidated with the new version of the GEM-E3 model. The final versions of the GEM-E3 model were delivered and installed to IPTS premises during scheduled training sessions.

1.2 RESEARCH WITH WORLDSCAN MODEL

Work has been carried out by CPB

1.2.1 OBJECTIVES AND WORK PERFORMED

WorldScan is a recursively dynamic general equilibrium model for the world economy, developed for the analysis of long-term issues in international economics. The model has both been used as a tool to construct long-term scenarios and as an instrument for policy impact assessments, e.g. in the fields of climate change, economic integration and trade. In scenario development, WorldScan acts as an organising device to explore and discuss the potential impacts of current trends such as ageing, the rise of emerging countries, the depletion of fossil energy resources or the rise of greenhouse gas emissions. In assessing specific policy issues the model is frequently adapted in order to better reflect the policy question. Being a CGE model WorldScan can be used to perform welfare analyses of policy proposals.

The objectives of the workpackage are to adapt the WorldScan model in several directions and to deliver the adapted model versions to the European Commission, together with documentation that fully reflects the model changes made. Thus, the aim is to improve the usefulness of the model in evaluating and assessing several targets on the Lisbon-agenda. In particular, the usefulness of the model is improved in the fields of employment, human capital and growth, and competition, innovation and productivity.

The first task implemented by the CPB team related to the improvement of the WorldScan labour market. In particular, the labour supply by skill type at the intensive and extensive margins were endogenized and involuntary unemployment within a wage bargaining setting was incorporated into the model. Moreover, the database was expanded with country specific data on income taxation and social security benefits. These have been documented in detail in (Boeters et al., 2008). In addition, an econometric study into the interactions between employment and productivity has been undertaken. The purpose of this study was to provide impact estimates that could be adopted in WorldScan. However, the results of the study (see Bettendorf et al., 2008) are not robust enough to be included in the model.

The second task related to the human capital formation and growth. The focus was a) to improve the parameterization of the human capital satellite model (Jacobs, 2005), b) to integrate the human capital satellite model with the WorldScan version with endogenous labour participation and endogenous unemployment in the sense that policy measures adopted in the satellite will automatically be transferred to the WordScan model and c) to extend the labour split in WorldScan from two to three skill levels. A paper on the work done was presented at the GTAP-conference in Chile, June 2009 (Rojas-Romagosa and van Leeuwen, 2009).

New modelling options in WorldScan were introduced so as to address policy questions related to human capital and skill formation. The new features introduced in WorldScan to deal with human capital policies are: i) new production structure ii) constrained supply of high-skilled workers in the R&D sector and iii) a higher dependency on information from the satellite model. The new model is used to evaluate current EU human capital policies. The results have a similar pattern of macroeconomic outcomes, but with larger effects than using previous WorldScan versions.

The climate change version of WorldScan was extended with the endogenous labour market component (as shown in the Models' Workshop of July 2009). Thus, this model version became more suitable for simulating permit revenue recycling options, as was illustrated with simulation outcomes at the Models' Workshops of November 2009 and March 2010.

The third objective to extend WorldScan in the direction of innovation and competition was also addressed (Hopman and Rojas-Romagosa, 2010). They analyse the theoretical and empirical relation between changes in competition levels and innovation efforts. Using OECD panel data they find a positive and significant elasticity of 1.8 between competition (measured as one minus the Lerner index) and innovation (measured as R&D intensity). This result is similar to other studies that find a monotonic relation between both variables. However, it was not found an inverted-U relationship as in the influential paper by Aghion et al. (2005). Using theoretical insights and own empirical results we included this relationship in WorldScan. Although the sectoral impacts of competition changes on R&D expenditures can be significant, our simulations using WorldScan do not result in significant macroeconomic changes when the link between competition and innovation is present.

Finally, a full model version including all the improvements made in the Models project (endogenous labour market, upgraded human capital representations and the relationship between innovation and competition) has been shipped to DG ENTR with a user guide that explains the mechanisms of the policy simulations that were presented in the papers (see Boeters and Rojas-Romagosa, 2010).

Labour market

In the labour market module of WorldScan, labour supply and unemployment are endogenous variables, not exogenous parameters, which they were in the previous set-up. Labour supply at the intensive margin (hours of work) results from the optimising consumption-leisure choice of a representative household. Labour supply at the extensive margin (participation) is modelled as the comparison of the expected utility of participation with a fixed cost of taking up work, which varies between households. Wages and unemployment are determined through collective bargaining between firms and a trade union in a representative sector of each economy. These modelling choices produce interaction effects, which are integrated in the model as far as possible. Labour supply at the two margins has different consequences for unemployment: Without labour demand reactions, an additional participating worker increases unemployment, whereas an additional hour of an already participating worker does not. Unemployment, in turn, affects labour supply

at the extensive margin, because the households consider the expected value of participation in their decision and high unemployment rates have a discouraging effect. Finally, bargained wages feed back to the individual hours-of-work decision, which then co-determines employment in persons. Interaction effects turn out to be intricate and are not always resolved in a completely consistent way in WorldScan. Most prominently, the empirical parameters of the Linear Expenditure System are not in all cases compatible with empirical wage differentials and replacement rates. Second, there remains a ambiguity between personal and functional income distribution in the disaggregated household accounting. Finally, the wage bargaining equation is not calibrated to empirical wage curve elasticities. However, these weak points of the current set-up are not dominant as drivers of the model's basic reactions to policy shocks. Nevertheless, they must be kept in mind when interpreting the simulation results.

Human Capital

The main goal of this study was to update and revise the satellite human capital model by Jacobs (2005) and the way it is linked to the WorldScan model. The updating procedure included a literature review that checked for new empirical estimates of key parameters in the satellite model and new insights into economy-wide skill formation processes. Furthermore, we also updated some features of the WorldScan model itself. For instance, we change the production structure and we impose an empirically based constraint on the supply of high-skill workers in the R&D sector. These new features of WorldScan and the new human capital satellite model (NHK-SM) are used to address policy questions related to human capital and skill formation in the European Union. The data and modelling updating process can be divided in several steps: In the first step, we build on the human capital satellite model developed by Jacobs (2005). This satellite model provides time-trend changes in labor efficiency associated with increases in different types of human capital levels. The model has a stylized cohort model that maps the target completion to changes in the skill structure of the labour force. To achieve higher skills, however, there are associated indirect costs. Workers must bear the opportunity cost of staying longer in school and devoting time to on-the-job training, and this affects negatively the labour supply in the short run. The resulting human capital version of WorldScan, however, has distinct features from the original satellite model.

First, a different skill classification was used and three different skill types were included in WorldScan. In particular, the skill definitions from the QUEST III model of the European Commission (Roeger et al., 2008) were followed, where low-skill workers are those that did not completed secondary education, medium-skill workers have a secondary education or higher and high-skill workers have a tertiary degree in science or engineering or a second stage of tertiary education (PhD). It was assumed that these high-skill workers are perfect substitutes for medium-skill workers, but are a specific factor to the R&D sector. Secondly some of the key exogenous parameters were updated and revised. This updating process has brought the NHK-SM in line with the recent literature. For instance, the elasticities of substitution between different skill groups have been changed based on recent econometric estimates and the new skill classification we use. One key change is the larger

impact of cognitive skills measured as standard deviations in test scores on labour productivity. The low and high skill split from the GTAP database was retained, but we incorporate high-skill workers that are specific to the R&D sector. This particular update is based on the recent survey by Hanushek and Woessman (2008) who present micro and macro evidence of the link between cognitive skills and labour productivity. The second step consists in changing how the satellite model is linked to WorldScan. Instead of including only changes in aggregate labour efficiency, the new human capital version of WorldScan directly incorporates supply and efficiency changes for low and high-skill workers. The human capital version also integrates the WorldScan version that includes an endogenous labour market and R&D activities.

The third step is to update the core WorldScan model to allow for a production structure where capital and high-skill labour are complements. In addition, following Goolsbee (1998) we add labour supply constraints to account for the empirical observation that the supply of specialized R&D workers is inelastic in the short run.

Fourth, direct schooling costs were introduced. Even when the opportunity costs already accounted for in the satellite model, are by far the most important costs, including direct costs improves the accuracy of the impact assessments. The OECD data on expenditure by student and current enrolment rate from EuroStat were used to estimate the education expenditure as a percentage of GDP for our baseline case and when the Lisbon skill targets are implemented. The last step is to conduct sensitivity analysis on some of the key parameters of the NHK-SM.

Once the model has been set, an analysis was made on which country-specific policy instruments could be employed to quantitatively assess EU policies. There are many empirical studies that analyze the impact of educational policy on human capital formation and its relation with macroeconomic outcomes. However, the link between policy instruments and actual human capital outcomes is weak (cf. Webbink, 2005; Checchi, 2006). Thus, there are no robust and reliable empirical results that can be readily adapted to a CGE framework. With this limitation in mind, we use an approach based on what-if scenarios where the policy goals are reached with no clear distinction of the precise policy instruments (as in Gelauff and Lejour, 2006). Therefore, the macroeconomic impact of current EU human capital policies was analyzed.

In particular, first the general equilibrium effects of Lisbon Agenda human capital goals for each EU country are analyzed. Later on the impact of increasing the cognitive skill levels of the EU countries were estimated.

The results from the Lisbon Agenda evaluation using this new human capital version of WorldScan present the same pattern as previous studies (Gelau§ and Lejour, 2006; Lejour and Rojas-Romagosa, 2008). Particularly, there is a significant positive impact on consumption and production, but this is only achieved after 2025, when the negative short-run effects (due to the initial indirect costs of a reduced labor supply) are absorbed and higher skill levels are finally attained. However, CPB results present higher positive impacts. This is due to the higher impact of cognitive skills, and the compounded effect of increased labour productivity on labour supply and employment through the endogenous labour market module. It was also found that increases in the general level of cognitive skills by country have a significantly high positive impact on the macroeconomic aggregates.

Finally, the R&D workers supply constraint yields very different results from previous WorldScan estimations of the effects of R&D expansion policies. When the expansion of the R&D sector is constrained by an inelastic supply of R&D workers, we still obtain an increase in the total expenditure in R&D, but this is reflected in higher wages for R&D workers at lower activity levels. This follows the findings of Goolsbee (1998) that R&D subsidies stimulate R&D wages but not necessarily activity levels. Therefore, this new version of WorldScan results in much smaller increases in R&D activity volumes -as a result of R&D subsidies- than in the previous WorldScan version.

Innovation

Competition can have important effects on productivity and economic growth trough different channels. One of these channels is the effect that increased competition has on the incentives to innovate. The relation between competition and innovation, however, can be complex. Innovation may allow firms to escape increased competition from rival firms, but at the same time, firms need rents to finance costly R&D expenditures, and these rents in turn are associated with current competition levels. The relation is also influenced by market-specific characteristics and strategic interactions between competing firms. In this respect, the existing theoretical papers point to different and sometimes contradictory influences of competition on innovation (c.f. Aghion et al., 2001, 2005; Boone, 2001).

Following Aghion et al. (2005) it can be concluded that there are reasons to believe that the influence of competition on innovation efforts can have both a positive and a negative dependence. Whether such arguments remain valid or relevant in real-life economies, and if so, in which regime (high or low competition) most firms are, is then an empirical question. The policy implications are most relevant. If innovation efforts depend positively on competition, then it appears to be straightforward that the usual thought of "the more competition the better" is correct. However, if more competition leads to less innovation and hence less growth, there is a trade-off between growth and the allocation of resources, and it is not a priori clear what economic policy is preferable: a focus on the near future and aim through increased competition for a better allocation of resources, or a focus on long term growth through innovation, for which a somewhat lower level of competition could be conducive.

The research on innovation with WorldScan was twofold: firstly the empirical relation between competition and innovation in European Union countries was identified. For this, the theoretical and empirical relation between competition and innovation were surveyed and CPB conducted its own panel-data estimations using OECD data to assess the effect of competition on innovation, secondly using these empirical results, WorldScan CGE model was upgraded to include this link between competition and innovation. Previous versions of WorldScan did not account for interactions between competition levels and innovation. Using this upgraded version of WorldScan we can assess the effects of changes in competition given by EU policies. For example, through the Lisbon strategy, which contains a range of measures to improve the functioning of the EU internal market and enhance competition.

The panel data from the OECD STAN database were used to define competition and innovation measures for 52 4-digit industries in 23 OECD countries for the period 1987-2007. A positive and significant elasticity of 1.8 between competition (measured as one minus the Lerner index) and innovation (measured as R&D intensity) was found. This result is similar to other studies that find a monotonic relation between both variables. However, we do not find and inverted-U relationship as in the influential paper by Aghion et al. (2005).

Using the theoretical insights of the literature, together with CPB estimations of the elasticity between competition and R&D intensity, a new version of WorldScan was created that incorporates this relationship into the core CGE model. Using different counterfactual simulations, it was found that the sectoral impact of competition changes has a significant change in R&D expenditures, but at the aggregated macroeconomic level the changes are not big, with respect to simulations where the competition-innovation link is not present.

1.2.2 SUMMARY OF RESULTS AND CONCLUSIONS

The final version of WorldScan includes an improved labor supply representation where labour supply by skill type at the intensive and extensive margins were endogenized and involuntary unemployment within a wage bargaining setting was incorporated. In addition the model was developed so as to strengthen its link with the human capital satellite model of (Jacobs, 2005). Finally, the new model versions have been delivered and installed to DG ENTR. A brief user guide for the aggregation facility is available (see van Leeuwen and Verweij, 2008). In addition up to the completion of the project several model versions reflecting new WorldScan modelling improvements have been shipped to DG ECFIN for joint policy analyses (Hayden et al., 2010).

1.3 RESEARCH WITH MIRAGE MODEL

Work has been carried out by CEPII

1.3.1 OBJECTIVES AND WORK PERFORMED

MIRAGE is a multi-sector, multi-country Computable General Equilibrium model describing imperfect competition in an oligopolistic framework à la Cournot. It accounts for horizontal product differentiation linked to varieties, but also to geographical origin (nested Armington – Dixit-Stiglitz utility function). The modelling is performed in a sequential dynamic set-up, where the number of firms by sector adjusts progressively, and where installed capital is assumed to be immobile, even across sectors. Capital reallocation therefore only results from the combined effect of depreciation and investment. It makes it possible to describe the adjustment lags of capital stock, and the associated costs. Foreign direct investment (FDI) is explicitly modelled.

The goal of this workpackage is to adapt MIRAGE model for an "in-house" use by the European Commission and to develop several modules that will become useful for policy analysis in a near future.

As regards the adaption of the MIRAGE model as an "in-house" facility for the Commission", CEPII provided a MIRAGE EC version to DG Enterprise.

The development of the EC version model was done by upgrading the most recent version of the MIRAGE model including the following tasks:

- Model code translation for labels, structure and comments from French to English
- Simplification of file structure
- Development of the integrated labour market for skilled and unskilled labour and development of capital integrated market
- Incorporation of the model in the GSE interface in cooperation with LEI (Wageningen)
- Development of an online manual accessible through the World Wide Web. This manual incorporates a complete description of the model structure and all the associated equations. It also provides practical advices on the use of the model through GAMS and GSE. It is maintained by the MIRAGE team at CEPII.

Installation of the definitive version of the model was done during February 2008 in coordination with DG Enterprise.

Regarding the MIRAGE manual it was convened to build it and deliver it in a web form in order to benefit from all the features that allow such a tool. A wiki-base website has been developed explaining the model structure and

providing information on its handling. It is an open contribution tool for members of the MIRAGE consortium. This website will be continuously updated as new developments of the model occur. It will contribute to the dissemination of public policy reports and research papers, and be a forum for MIRAGE users.

The manual is available at the following address:www.cepii.fr/miragewiki.htm

Finally under the MODELS project, CEPII has also done the following developments of the MIRAGE model.

Transport breakdown

The transport sector plays a specific role: it covers both regular transport activities, which are demanded and can be traded like any other service, and international transport of goods. The latter accounts for the difference between FOB and CIF values of traded goods. Thus, the market clearing equation for a transport sector presents two terms: the demand for transport activities other than freight, and freight.

The transport sector is now divided into its three classical modes: by air, by sea and other transports.

For each trade flow, we define the corresponding demand for transport through a constant multiplier whereas the freight demand is then broken down by mode through a Cobb-Douglas specification. Regarding the supply side, each region contributes to the world supply of freight. The choice between the various freight providers is made according to a Cobb-Douglas demand function. This supply is finally aggregated in a world supply of freight per mode.

Mobility for factor market in MIRAGE: the case of Labour and Capital

Reforming the labour market and improving the business environment are two important pillars of the Lisbon Strategy. When considering trade policy shocks with a CGE model such as MIRAGE, the impact of such reforms needs to be taken in consideration to assess the sensitivity of results to the completion of the Lisbon Agenda. That is why the modelling of MIRAGE was improved in order to take into account different assumptions on the level of integration of European labour and capital markets.

1. Skilled labour market can be considered in the model in two different situations.
    a. Separated regional markets with different prices and no mobility between regions
    b. Single EU27 labour market with a single price and perfect mobility across regions
2. Unskilled labour market can be considered in the model in two similar designs. The main difference is that the unskilled labour market is segmented: urban and rural areas (rural corresponding to primary

agriculture products), and these two labour markets are considered linked with imperfect mobility. The design for integrated market can follow one of the two options:

a. Separated regional segmented markets. There is imperfect mobility across rural and urban markets but not across countries.

b. Single European segmented market: there is one urban and one rural labour market for the whole EU. Rural unskilled workers are fully mobile across the EU27 with a unique wage and urban unskilled workers follow the same pattern. There is imperfect mobility between rural and urban markets.

3. Capital market can be also considered integrated; however, rates of return on capital remain sector-specific in order to respect the theoretical consistency of the investment function, relying on different dynamics across sectors.

    a. Capital rate of return can be sector and region-specific.

    b. Capital rate of return can be the same for all regions of Europe inside a country

    Considering the capital as fully mobile across the EU27 and across sector is also possible but would correspond to a static shock, which MIRAGE can produce. This design is, however, not possible in the dynamic mode.

The different types of design can be selected through the GSE interface when selecting the configuration of the model.

More details on these modelling features are available in the documentation at www.cepii.fr/miragewiki.htm.

Simulations with this modelling have been made under MODELS project. Changing assumptions on mobility of factors can lead to different magnitudes of results. CEPII's study illustrates the differences in results from two extremely diverging assumptions. Looking at trade liberalisation of main regions of the world, we observe increased heterogeneity between regions when assuming more mobile factors. The combination of scenarios with mobile factors even leads to multiplicative effects in some countries.

This work also shows that, although the same for each Member States, the European Union trade policy can have very uneven effects on EU countries. This heterogeneity is masked when the EU is modelled as a single region but is also underestimated when trade is the only linkage between Member states. Under this assumption, we observed that most advanced economies benefit more from trade liberalisation with increased mobility of factors, although causes behind this can be multiple (level of perceived protection and/or structure of production costs).

Protection in services

Services account for around 70% of GDP in developed economies and around 40% of GDP in developing countries. Due to technological progress, this sector has become more tradable during last twenty years. Thus, in applied economics and especially in international trade, protection in services is an important issue, both in terms of data and modelling.

Under MODELS project, two different types of barriers[9] to trade in services for mode 1 or 2 (as defined by the GATS) have been modelled in MIRAGE. The default modelling is a trade cost. Indeed, we consider that the initial objective of protection in services is only to protect a given market. The opening of the latter leads to new entrance of foreign producers.

Another possible modelling takes the form of an export tax. In that case, one considers the barrier as rent-creating. This rent is thus given to the exporter that succeeds to enter the foreign market.

FDI modelling

Under MODELS project, CEPII has undertaken a new modelling of FDI. The specification is similar to Petri (1997): products are now differentiated by the country of the origin of the capital, and then by the country of production. We call this new release the "MNF" version because consumers identify the brand of the multinational firm, which is assimilated here to the nationality of the parent company.

The modification of the supply side in the "MNF" model adds, in each country, some foreign firms that differ from local businesses. This reflects the fact that production is divided between production of local firms and production by foreign companies. We identified their ownership by adding an index r_k indicating the origin of capital. Production functions are identical among local and foreign firms and they compete in a perfect competition framework, regarding production factors other than capital. Production is distributed in the base year between local and foreign firms proportionately to capital stock within each sector. Local and foreign productions will then evolve independently only depending on the demand they are addressed.

To test the impact of this new modelling of FDI in MIRAGE, we compared the results of an identical shock on FDI in both versions of the model. The Mirage set-up is dynamic and the competition is considered as perfect, with an aggregation of 8 countries and 13 sectors. The simulated scenario is a tax exemption on foreign capital in Europe (corporate taxes come from the GTAP database).

This new modelling of FDI in MIRAGE is interesting from several points of view. It models explicitly multinational firms and uses a global FDI dataset in three dimensions (country-country-sectors). It also allows to better represent the effects of MNF's investment on the demand of, in this case, industrial goods. In particular, production coming from FDI not directly competes with local production because these two productions correspond to two different

[9] Data on protection comes from CEPII which has built a specific dataset on that topic.

branches in the nested demand. This model also shows substitution effects between FDI and international trade. The simulation shows positive results in terms of welfare whereas those were negative when using the original MIRAGE modelling of FDI. This result deserves to be clarified using more detailed data and, as results crucially depend on key parameters α (the elasticity of investment to capital return) and σ_{var} (demand elasticity between goods produced by a given MNF in different regions), efforts will have to be made to obtain good-quality estimates of these parameters or run sensitivity analysis.

1.3.2 SUMMARY OF RESULTS AND CONCLUSIONS

The MIRAGE model has been installed at DG Enterprise and its manual can be accessed online through www.cepii.fr/miragewiki.htm. This manual incorporates a complete description of the model structure and all the associated equations. It also provides practical advices on the use of the model through GAMS and GSE. It is maintained by the MIRAGE team at CEPII.

1.4 RESEARCH WITH NEMESIS MODEL

Work has been carried out by ERASME

1.4.1 OBJECTIVES AND WORK PERFORMED

The aim was to further develop the comprehensive econometric sectoral model NEMESIS and install its operational version at the Commission premises. The NEMESIS model developments concerned: i) human capital ii) the incorporation of skilled and unskilled labour, iii) the econometric specification of the wage bargaining function and iv) to make the model available for assessment of Lisbon related policies, or other policies and structural reforms, proposed by the European Commission services.

NEMESIS is a comprehensive macro-econometric model estimated for each European country with coverage of 30 sectors. For non European regions, the model is less detailed except for the USA and Japan for which the level of detail is close to the European model. Despite the well-known criticism by Smith and Lucas, the macro-econometric modelling nowadays is still advantageous: for example NEMESIS, estimated over long time series, has a solid back-casting validation, so as to justify its relevance for constructing reliable forecasting scenarios. Such scenarios can assess short and medium term consequences of policies. In addition, the NEMESIS model, with its detailed representation of 30 activity sectors, emphasizes supply side economic mechanisms and incorporates endogenous technical change.

The model complements the econometric production functions with five conversion matrices which handle the interdependencies of activity sectors with final consumption, investment goods, intermediate consumption, energy/environment and technological transfers. The supply side block is based on modern approaches to endogenous technical change: product and process innovations, economically driven technology improvement and knowledge "spillovers" between sectors and countries. The model also includes an energy-environment module that transforms activity indicators at a sectoral level into energy indexes with information on price effects and emissions of pollutants (CO_2, SO_2, NOx, HFC, PFC and CF_6 are covered).

Human capital

Before incorporating human capital in Nemesis Model's some issues were tackled on its role on productivity and growth. Last studies on human capital concern distance to technological frontier. As first show by Nelson & Phelps and by Cohen and Levinthal 1989, the source of technological progress is dual, it results from: innovation and imitation activities (called Innovating and learning in Cohen and Levinthal works'). Vandenbussche, Aghion and Meghir (VAM-2004) show that far from the technological frontier, the potential for catching up is very large and so imitation contributes significantly to technological improvement. Close to the frontier, the potential for catching up is very small; innovation and tertiary education are needed for technological

progress. There is a proximity threshold above which tertiary education has a growth-enhancing effect.

ERASME (2007) extends VAM sample to 44 countries (OCDE and emergent countries). Heterogeneity of sample allows observation both on developed country (closed to the frontier with major activities of innovating) and country in development (far from frontier with major activities of imitating). The authors proceed with two methods of estimation. First they study impact of human capital in level on growth (human capital is defined as the fraction of population with high degree of education). The second method analyses the effect of human capital accumulation on TFP growth (human capital is split in low and high level of education function of year spend in education).

Data on human capital for the demand side is issued from EUKLEMS' work which provides data for 3 kinds of skill: low, medium and high. Definition of skill is based on educational attainment and could differ across country. They therefore assume comparability only across the bachelor degrees educational level (high), but not at the other levels. For this reason we aggregate low and medium skill of Euklems classification into Unskilled Labour and High skill into Skilled Labour.

The results of the first method highlight a positive impact of human capital (Fraction) on TFP growth. Proximity (proximité) presents a negative impact, traducing the decrease of imitation opportunity near the frontier. Most interesting is the interaction term. It traduces the effect of human capital in innovation and imitation process i.e. human capital productivity on TFP growth in regard of the distance to technological frontier. Positives values show that human capital is more productive when country in closed to the frontier. If we consider that countries close to the frontier are more intensive in capital, we can interpret interaction term as a complementarity effect between human capital and physical capital. **Error! Reference source not found.** and **Error! Reference source not found.** present estimations results for different country in regard of distance to the frontier.

In the light of these results it was found that the relationship of complementarity between proximity and skilled human capital is not as obvious as assuming in VAM model (linear relation). ERASME estimates highlight that the stock of human capital is more determinant for country far from the frontier than the other. This goes against the results of VAM, for whom the skilled labour force has a strong effect on economic growth when the country is close to the technological frontier. Based on the data of Domènech De la Fuente (2002), they concluded that for 13 countries (on 16), the tertiary education have a negatively effect on growth.

In summary principals results highlight that the stock of skilled human capital has a positive and significant impact on the TFP growth in emerging countries. Moreover, this impact is stronger for emerging countries than for OECD economies which are closer to the frontier.

Estimates of the second formalization support our first finding, the complementary relationship between the skilled human capital, and proximity to the technological frontier is not evident than implied by the model VAM. We find a positive relationship between the skilled labour force and productivity growth for developed countries but beyond a certain level of

development, this relationship tends to weaken as the country moves closer to frontier; with an elasticity of the term YearsT (Number of years of schooling completed in higher education) "higher" for developing countries than for OCDE's ones. The primary and secondary education (YearPS), even if they have only a negligible effect on productivity growth in developed countries, are nonetheless indispensable for countries who have built their growth on the work of imitation, and for emerging country. The proximity to the technological frontier can have opposing effects on the productivity growth depending on its level of development. We observe here that the countries farthest from the frontier tend to have a catch up to the technological level of leading countries. They increase the potential of physical capital that lead to a development of their adaptation capacity to technologies (already developed by the advanced countries).

By contrast, the countries closest to the frontier show a productivity growth to decline when these countries move closer to the leader. Inclined to reallocate their workforce to innovative activity in order to increase their productivity, these countries cannot expect anything but an incremental growth of their productivity given the random nature of the occurrence of innovations.

Data on human capital for the demand side were extracted from EUKLEMS' database which provides data for 3 kinds of skill: low, medium and high. Definition of skill is based on educational attainment and could differ across country. They therefore assume comparability only across the bachelor degrees educational level (high), but not at the other levels. For this reason we aggregate low and medium skill of EU-KLEMS classification into Unskilled Labour and High skill into Skilled Labour. Regarding the labour supply side data comes from the EUROSTAT database.

Labour Market

Nemesis bloc of production is extended to allow two kinds of human capital: Unskilled and Skilled. Nemesis's supply side is defined by 30 sectors and 5 factors of production: material, high skill labour, low skill labour, stock of capital and energy. Sectorial productions functions are represented by a four level nested CES (constant elasticity of substitution function). CES framework is the same for each sector (same factor bundle) but allow distinct sector parameters (elasticity of substitution, scale parameter…).

The NEMESIS model considers five factors (if we except intermediate energy demand which is considered as a fixed part of the production) M, Lu, Ls, K and E represents respectively Materials, Low skill labour, High skill Labour, Capital, and Final Energy. The production function is a nested four-level CES function. The choice for grouping factor had been tested using a translog cost function. Data sample include eleven countries and 12 years for each of the 30 nemesis' sectors. In reason of lag value, data sample is restricted to 11 years that give 121 values by sector. As indicated below, we use pool panel method's estimation with FIML estimator. Estimation is made sector by sector. Restricted sample imposes common estimating parameters for all country (but differ by sector) at the exception of scale parameters. We estimate four elasticities of substitutions, five delays, one technological trend and 11x5

scales parameters for each sector (65 parameters estimated by sector that correspond to 1950 parameters estimated for all sectors).

Concretely the sector parameters were estimated in three steps. First ERASME estimated only scale parameters and technological trends with imposed value for other parameter. In second step elasticities parameters were relaxed and at last all parameters were relaxed without any constraints.

If some estimated value gave unrealistic result that doesn't allow reaching convergence, it was constrained to its extreme value. For example chemical sector during estimation presents a value for sigma 1 closed to zero. This was constrained to 0.05 that correspond to ours limit value to allow some substitution between parameters. Most constraints parameters appear for capital delay parameter. In this case delay appeared to be infinite. Constraint values correspond to a median delay of 20 year (detailed results related to Nemesis estimated parameters are already available and will be published in a forthcoming working paper).

Concerning labour supply, ERASME focused on the choice of econometric specification for the wage bargain function. This choice was directed by recent developments of the literature (Reynes F. 2006) and the availability of data (The main data used are from the database EUKLEMS). The selected specification follows from a WS-PS model where the reservation wage is assumed to be equal to the previous wage. In practical terms we retain the specification developed by Chagny and al. (2002) and Reynes (2006) to estimates the wage formation according to the Nemesis nomenclature.

1.4.2 SUMMARY OF RESULTS AND CONCLUSIONS

MODELS project allowed making important improvement to the NEMESIS model: a new production block, with two skills for labour, endogenous technical change, the possibility of biased technical progress, endogenised on R&D or other channels, as education expenditures for labour. The developments on labour market proved to be difficult, especially for the estimation of labour supply and wage formation. This may be the consequences of the important structural changes that occurred in European economies during the last 20 years that impacted deeply the functioning of labour markets in Europe. There is thus room for improving again this work but NEMESIS is now armed to deal with new policy assessment in the area of R&D, innovation, employment and education. The model will also be able to produce many new socio-indicators as employment per skill, gender and age group categories. Unemployment rate for the same categories could be also provided with the required improvement in the calculation of labour supply. The NEMESIS model was installed at IPTS premises.

1.5 SUPPORT OF COMMON MODEL DEVELOPMENTS AND DEFINITION OF APPLICATIONS

Work has been carried out by E3MLab/ICCS, CPB, CRSA/ERASME and IPTS

1.5.1 OBJECTIVES AND WORK PERFORMED

The work in this work package concerned the organisation of exchange of information between the project partners in order to perform policy applications with common assumptions and design. The exchange of information was carried out through two types of action:

i) the development and activation of a website which is accessible to partners and to EC services only (www.ecmodels.eu); the project website has served as a repository of scientific papers, policy reports, statistical data and presentations made during the meetings and workshops.

ii) the organisation of a series of project workshops on policy applications. Each workshop had a specific topic of research and policy application and its objective was to facilitate the understanding between the modellers and the Commission officers. The MODELS project organized four workshops as follows: a) Labour market and human capital, b) Energy and Environment Policy Applications, c) Alternative recycling options from auctioned GHG permits and d) EU Alone and International concerted action in GHG mitigation.

The specification of the scenarios implemented was based on suggestions made from the Commission officers (DG-ECFIN, DG-Enterprise, DG-EMPL, DG-ENV and DG-TREN).

Workshop on "Labour market and human capital"

This workshop focused on the different approaches adopted by the modelling teams regarding the enhanced representation of the labour market and human capital aspects in the four models. The different market imperfections leading to involuntary unemployment were discussed and each team presented in detail the adopted methodology. The GEM-E3 model adopted the efficiency wages approach in representing equilibrium unemployment while WorldScan incorporated a labour market where wages are set through collective bargaining between trade unions and employers associations using the right to manage approach. In NEMESIS, a wage/price setting framework involving a modified Phillips curve and a price setting equation in level was adopted.

Workshop on "Energy and Environment policy applications"

This workshop focused on the impact of the economic slowdown for the cost of the EU climate action and RES targets. The analysis combined simulations focusing on employment effects with climate action and RES targets being

met. Another focus was on the impacts from moving from an EU stand-alone 20% reduction of GHG effort to an internationally concerted action with 30% GHG emission reduction. The policy applications simulated by each team are further listed below:

Policy applications performed by ICCS (GEM-E3):

- Analysis regarding the difference in the costs of achieving the climate change targets between a moderate and a severe / prolonged recession at the start.
- Analysis of the employment effects of a steady increase in energy-efficiency and/or a steady rise in renewable energy sources.
- Long term GDP, employment and GHG effects in 2020 and beyond of reaching 20% RES with 20% reduction in energy consumption by 2020 compared to a reference scenario close to the Baseline scenario published in the "Trends to 2030 - update 2007" EC publication
- Analysis of the economic impacts of moving from an EU stand-alone 20% reduction position to an internationally concerted action with 30% reduction.

Policy applications performed by CPB (WORLDSCAN):

- Difference in the costs of achieving the climate change targets between a moderate and a severe/prolonged recession at the start.
- Economic impacts of moving from an EU stand-alone 20% reduction position to an internationally concerted action with 30% reduction.

Policy applications performed by ERASME (NEMESIS):

- Simulation of the employment effects of energy-efficiency progress and of high deployment of renewable energy sources.
- Long term GDP, employment and GHG effects in 2020 and beyond of reaching 20% RES with a 20% reduction of energy consumption in 2020 compared to a reference scenario.
- Economic impacts of moving from a 20% reduction position to 30% reduction in the EU.

Workshop on "Alternative recycling options from auctioned GHG permits"

The GEM-E3, WorldScan and NEMESIS models were used to assess the economic impact of alternative uses of the revenues arising from auctioning of GHG emission allowances. Two mitigation scenarios were considered:

- EU-Alone: EU performs a mitigation policy while the rest of the world is not involved.

- Grand-Coalition: All regions of the world perform a mitigation policy.

The different recycling options simulated are as follows: i) promotion of carbon free technologies ii) support of households' income iii) general tax reduction iv) lowering labour cost through the reduction of social security contributions v) R&D financing of carbon free technologies.

Workshop on "EU Alone and International concerted action in GHG mitigation"

This workshop was a follow-up of the previous workshop aiming at analysing the impacts of pursuing GHG emission reduction unilaterally by the EU against a global concerted action and at comparing the impacts among different options for recycling carbon revenues (from auctioning) within the economy. In this workshop new GHG emission targets compared to November of 2009 workshop were used, based on the pledges submitted after the Copenhagen summit. The GEM-E3, WorldScan and NEMESIS models simulated the policy cases presented in the table below.

GHG mitigation scenario	Recycling options
EU-Alone: EU performs a GHG mitigation policy while the rest of the world is not involved.	1. Labour Cost 2. Households' income 3. Promotion of energy from renewable sources 4. Reduced taxation
Grand Coalition: International concerted action for reducing GHG emissions according to the pledges announced after the Copenhagen summit	

Scenario definition

According to the 2003/87/EC directive and its amendments[10] the GHG emission reductions of the ETS sectors (in the case where there is no international concerted action to reduce GHG emissions) is -21% for 2020 compared to 2005 levels. For the non ETS sectors the reduction is roughly 10% from 2005 emission levels. After 2020 the ETS allowances will decrease yearly in a linear manner by 1.74% (the decrease applies to the level of ETS allowances in year 2020).

The allocation of emission allowances to the ETS sectors followed the 2003/87/EC directive which provides for full auctioning applicable to the power sector and a gradual decrease of the free allowances allocation applicable to the rest of the ETS sectors. It is assumed that for these latter sectors, the allowances to be allocated free of charge in 2013 shall be 80 % of the total allowances, 30 % by 2020 and zero (hence full auctioning) by 2030.

Trading of allowances is possible only within the ETS sectors. The Directive mentions that some flexibility within the non ETS part is allowed, however since there is no exact indication of degree of flexibility, the modelling exercise did not assume any flexibility in the non ETS. The 20% renewable target, by 2020, is imposed in volume terms. As mentioned above, the GHG emission reduction

[10] M1,M2,M3,M4

simulated in the Grand Coalition scenario follows the pledges announced during the Copenhagen summit of both ANNEX I and non ANNEX- I countries.

Regarding the proceedings from auctioning allowances the 2009/29/EC Directive states that at least half of the proceedings should be directed to the following activities: i) reduce GHG emissions, ii) to take adaptation measures, iii) to fund R&D projects oriented towards GHG emission reduction and adaptation to climate change, iv) promote energy from renewable sources, v) increase energy efficiency, vi) provide measures to avoid deforestation and vii) protect the low income households from a possible increase in electricity prices. The recycling options considered by the models are: Promotion of renewable sources in the form of subsidies (iv-option), Support of Households' Income thorugh lump-sum transfers (vii-option), Reduction in Labour Cost by reducing the employers' social security contributions, Indirect Tax Reduction on Products, and R&D promotion by increasing the budget of R&D policies (iii option).

1.5.2 SUMMARY OF RESULTS AND CONCLUSIONS

The objective of the modelling exercises for the different policy issues was twofold: i) to provide a thorough and consistent analysis of the policy questions raised, involving inter-model comparisons, ii) to allow the evaluation of the new modelling techniques adopted by the different models and illustrate their use to the Commission officers. Two of the models used have comparable methodologies and scope, (the general equilibrium models GEM-E3 and World Scan) while NEMESIS complements the analysis by providing insights by means of a macro-econometric modelling approach. The summarized policy briefs bundled in this report reflect the consensus found over different policy cases. Although all models confirm these messages, there are sometimes differences among individual model results, reflecting the different methodologies adopted.

As a background to the description of the model results, **Table 7** gives an overview of the models involved.

Table 7: Overview of the models participating in the MODELS policy applications

Model (Type)	Regional Coverage	Sectoral Coverage	Production function	Consumption function
GEM-E3 (CGE - Recursively dynamic)	37 regions (EU27 each member state separately)	25 sectors (9 of which are power producing technologies).	Nested CES	LES (13 consumption categories) Identification of durable and non durable goods
WORLDSCAN (CGE - Recursively dynamic)	14 regions	25 sectors	Nested CES	CES-LES: CES in goods and leisure, LES in 9 consumption goods; for four different types of households
NEMESIS (ECONOMETRIC - Recursively dynamic)	EU27 (each member state separately	30 production sectors	Nested CES	AIDS system Identification of durable and non durable goods

Table 8 presents the impact on EU27 GDP from the different recycling options of the auctioned GHG allowances in the case where EU alone performs the GHG emission reduction policy. The effects from loss in competitiveness constitute the dominant mechanism in all recycling cases thus GDP falls (as compared to the 2020 reference case) in all cases examined (apart from the macro-econometric NEMESIS model results which will be discussed in detail further below). The two general equilibrium models GEM-E3 and WorldScan display similar results, as for example for the case of recycling revenues for reducing the labour costs, which for both models figures out as the least cost option (in terms of GDP). This is because reducing employers' social security contributions lowers unit production costs which partly offsets the loss in competitiveness induces by the GHG emission reduction. The implied factor substitution favours employment which is positively affected in this recycling options, contrasting all other options that imply more unemployment. Real wages increase as there is an increased demand for labour.

Table 8: Impact on EU27 GDP of the alternative recycling options (% change from 2020 reference)

	GEM-E3	WorldScan	NEMESIS
Labour Cost	-0.09	-0.41	-0.03
Tax reduction	-0.13	-0.47	-0.13
Renewables	-0.14	-	0.18
Income	-0.2	-0.51	0.02

The worst case, in terms of GDP loss, among the recycling options considered is the lump-sum transfer of revenues to households. In this option private consumption and hence welfare are less decreased than in any other recycling option considered. However increased private consumption adds to increased domestic activity which substitutes for energy imports and so the pressure on primary production factors markets increases. This aggravates the negative effect of the GHG constraints on the competitiveness of the EU, hence the implied change in exports and imports cancels the effects on private consumption and on domestic activity. As a result, both investment and employment decline.

It is worth pointing out that both GEM-E3 and NEMESIS display attractive results for the case of recycling revenues for promoting the RES deployment. However, NEMESIS displays that this recycling option is likely to exert positive effects on GDP, whereas GEM-E3 shows small but negative effects. According to NEMESIS, the RES option figures out at the top of all recycling options as it presents a 0.18 increase of GDP (as compared to the reference case). The different results between the two models can be attributed to the different methodological foundations on which the two models are built. In particular the GEM-E3 model takes into account both the price effect[11] and the crowding out effect[12]. In

[11] The additional RES deployment entails higher costs for electricity and other energy services. These additional costs are reflected onto prices of domestic commodities and induce loss of competitiveness of the EU economy.

[12] Substituting imported commodities (oil, gas, coal) by domestically produced commodities (the RES equipments) imply higher use of capital and labour resources per unit of GDP.

previous simulations of GEM-E3 where the crowding out effect was neglected, the RES deployment had a positive effect on GDP (similar to NEMESIS model result). However in the absence of the crowding out effect, the price effect alone is not sufficient to render negative the effects of RES deployment on GDP. Thus the crowding out effect and in particular the pressure on the unit cost of capital mainly explains the negative GEM-E3 result on GDP.

The NEMESIS model also simulated a case in which auctioning revenues are used to increase the R&D policy budget. The resulting technical progress has positive effects on the economy and on competitiveness, which offset at a great extent the implications from GHG emission reduction effort. Nevertheless, the results are very sensitive on the spillover effects. Further research is needed to conclude on this issue.

However, because of market constraints the relative unit costs of labour and capital tend to increase as a result of the substitutions in favour of domestic activity.

2 PLAN FOR USING AND DISSEMINATING THE KNOWLEDGE

A.1 Dissemination of knowledge

During the course of the project the largest part of dissemination effort was intentionally limited only within the Commission services, following instructions.

Overview Table

Planned/actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
February 2008	Website	Public, scientific community	All	Web	CEPII
April 2007	Website	Public, scientific community	All	Web	ICCS
May 2008	Draft CPB paper on "The Labour Market in WorldScan; revisions in the "MODELS" project".	Public, scientific community	All	scientific community	*CPB*
Feb 2009	CPB paper on "Does employment affect productivity?"	Public, scientific community	All	scientific community	*CPB*
June 2009	"Modelling Human Capital in WorldScan" Paper to be presented at the 12th GTAP Conference, Santiago.	Public, scientific community	All	scientific community	*CPB*
July 2009	Workshop on "Energy and Environment Policy Applications"	Commission staff	All	10-15	ICCS
November 2009	Alternative recycling options from auctioned GHG permits	Commission staff	All	10-15	ICCS
March 2010	EU Alone and International concerted action in GHG mitigation	Commission staff	All	10-15	ICCS

A.2 Publishable results

CPB intends to publish a policy document in autumn 2010 on the 'New Lisbon Agenda' making full use of the model improvements of the Models project and is open to take up joint work in this field with DG ENTR and/or DG ECFIN

ICCS intends to publish a policy document on the 'Alternative recycling options from auctioned GHG permits' using the MODELS project results.