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Foreword

With a view to providing input for the policy debate on climate change, UNICE asked COWI to use its GTAP-ECAT model (Global Trade Analysis Project - European Carbon Allowance Trading) to calculate the economic effects in 2010 of EU climate-change-linked policies under various sets of assumptions.

UNICE hopes that these analyses will make a useful contribution for developing the internal and external dimensions of Community climate change policy up to and beyond 2010.

Mr Philippe de Buck,

Secretary General of UNICE

Preface

This report presents an economic modelling of EU climate change policies and calculates the economic effects of these policies for the year 2010 under different assumptions. This analysis uses a Computable General Equilibrium model (CGE) of the world economy with a special emphasis on energy use and emissions of CO_2 .

By nature, such calculations are indicative and all results should be interpreted with care. The calculations are sensitive to a number of central assumptions, and the results should be seen in the light of these assumptions.

This report is an interim report, presenting *preliminary* analyses on a dataset (the GTAP dataset) which is expected to be updated significantly in the very near future. Furthermore, the time frame for completing this analysis has been very short. For these reasons, a number of simplifying assumptions have been made throughout the analysis. It is expected that a final analysis will follow the present analysis. In the final analysis, it is expected that the updated dataset can be used, and that especially the projection of economic development in the absence of Climate Change policies can be offered more attention. Still, a large effort has been made to ensure that projections and simulations in the present analysis are comparable with those of other models for Climate Change policies.

The analyses have been carried out by COWI, but the assumptions behind the calculations have been selected in cooperation with the UNICE Task Force on Climate Change. Some of these assumptions are realistic best estimates, whereas others are of a more illustrative nature. Also, some assumptions have been selected in order to ensure comparability with other work in the field of Climate Change policies.

It is the intention that the present analysis can form a sound starting point for UNICE's discussions on the implementation of the EU Climate Change Policy.

COWI, Copenhagen, 31 October, 2004

Executive Summary

The EU Climate Change Policy, including the scheme for a greenhouse gas (GHG) Emission Trading System (ETS) is currently being finalised in the European Commission and in September 2004 the Commission launched a consultation on how the future global climate change regime should be shaped and what the EU's contribution to this should be. The aim of this consultation is to assist the Commission in identifying important issues for consideration in preparing its report for the spring 2005 European Council.

The aim of this report is to provide insight into the overall economic effects of the planned reductions of European GHG emissions compared with other economically important world regions. In the report, the net cost of different implementations of EU Climate Change policies for one year, 2010, is analysed and compared. Thus the figures reported for net costs can be interpreted as the net total yearly costs in that year.

What is analysed?

EU25 Climate Change mitigation net costs analysed

This report analyses the so-called *internalised net costs* of EU25 Climate Change mitigation policies. Although external benefits (such as avoided potential damage from climate change, reduced non-GHG air pollution) from reduced GHG emissions also exist, this report does not include these benefits but only the benefits from the re-allocation or reemployment of resources in more carbon-friendly activities.

Internal net costs is gross cost minus gross benefit

To reduce GHG emissions, some economic activity must be scaled down or altered in a way that would not be economically sensible if no cost was assigned to GHG emissions. The cost of these *GHG-related changes* is called the gross reduction costs. However, some of the resources (i.e. money, goods, labour, or capital) that are taken out of use can be reused for other purposes that emit less GHG, although typically at a lower productivity. This reuse causes gross benefits, and the difference between the gross cost and benefit is thus the net cost of the Climate Change policy. This report analyses these net costs only.

Long term loss analysed

GHG related-changes have been carried out since it was realised that GHG emissions may cause significant damages in the future. This report assesses the cost of the changes that have happened since 1997 since the model utilised in this analysis is based on 1997 data. Therefore the model

does not start from the latest figures on actual emission of CO_2 in 2001 from EU25 as reported by the European Environment Agency. However, costs incurred in the period 1997 to 2001 will be reflected in the figures reported. Furthermore, costs already incurred are just as relevant as costs from further actions to mitigate GHG emissions, as the costs already incurred will be felt just as much as costs to come. The main insight is that costs already incurred are not only costs in the year they appear but will add to cost of climate change actions in the years to come. Thus starting from emissions in 2001 would to some extent miss this point.

The estimated costs can be interpreted as the minimum costs of the Kyoto policy for bringing emissions into line with the Kyoto reduction requirements. If actual reduction measures undertaken since 1997 have not been cost-effective, the extra costs of these can be added to the lowest costs estimated here.

Financial burdens are not analysed

It is also important to note that this report does not investigate allocation of the *financial burden* of the reductions, i.e. which companies and sectors should be given grandfathered allowances, but only where the *real reductions* will take place if they are carried out in a cost-effective way, given the implemented Emission Trading policy. Whether or how much the firms undertaking the cost-effective real reductions should be compensated is outside the analytical scope of the model used.

World economy model gives overall picture

This report utilises a comprehensive Computable General Equilibrium model of the world economy to investigate the effects of the planned reductions of CO_2 emissions from fossil fuel combustion. The advantage of using this type of model is that spill-over effects from the reduction in one sector to any otherwise unaffected sector are also captured. Thus this model type in many respects provides a more complete picture of the economic effects of EU Climate Change policy than models analysing only the costs of the new technologies needed to transform the European industrial structure towards less CO_2-intensive production. However the model utilised will not describe the costs of transition e.g. unemployment through sticky wages. Thus it is assume that all resources without costs can be reallocated to be used in less productive sectors. From historical experiences transmission from e.g. the labour force to other activities is not an easy task. The experiences from e.g. Germany reveal that it is very hard in the short term to find alternative employment in sectors affected by structural changes. This is not reflected in the model applied here.

Technology adaptation takes time

Two variants of technology adaptation assumption have been used in the simulations. In the one, the original GTAP-E assumptions on technology change have been retained. However, these assumptions relate to mid- to long-term changes, whereas some of the needed technology changes to adapt to a low emission situation still need to be undertaken. This is especially true in the heat and electricity sector, where lead times for new generation capacity can be up to 10 years. Therefore, a second variant assumes that this technological adaptation will be rather difficult in this sector up to 2010, and that it is difficult to replace production of electricity in the EU with electricity produced in countries outside the EU, e.g. Russia.

The economic effects of GHG mitigation

Emission gap determines costs

A very clear result of the present analysis is that, given the models structure, the primary determinant of the mitigation costs is the size of the *emission gap*, defined as estimated future emissions without any climate change policy and the Kyoto emission target. In this study, the central scenario for the emission gap is 689 Mt for EU25, which is based on emissions growth of 0.89% p.a. since 1997. This growth should be perceived as the emissions growth assuming GHGs are harmless and thus not abated at all.

Production is reallocated

The first consequence of GHG mitigation is that productive resources are reallocated from emission intensive inputs and sectors towards less emission intensive inputs and sectors. This will mean lower productivity, and the impact on EU25 economic activity in terms of production value is minus 0.48% with sluggish technology adaptation in the electricity sector, whereas easier adaptation leaves an activity reduction of minus 0.36%. This activity reduction amounts to the equivalent of EUR 52 billion in 2010 with sluggish adaptation in the electricity sector and EUR 36 billion with long-term technology.

Re-allocation costs not assessed

The calculations depart from the assumption that the reallocation of productive resources takes place seamlessly and without extra costs, such as temporary unemployment or scrapping of capital goods like buildings and machinery. Experiences from German reunification, which led to major changes in East-German industrial structures, suggest that unemployment in particular can be a significant problem.

Consumption is reduced

The reallocation of resources is also costly, as their productivity was higher in their original use. Thus, real wages and interest rates fall, as does the (gross national) income of the consumers owning the resources. With emissions trading, the carbon emission allowance is a new productive resource. This means that net sellers of this resource will benefit from the revenue. In particular, this concerns the EU10 countries, which experience increased incomes, and thus increased consumption. In this respect, the net buyers of allowances compensate the net sellers for their reduction in productive activity. On an overall scale however, total EU25 income is reduced. Of course, the gain of EU10 depends heavily on the realised allowance price.

Competitiveness is affected

The GHG mitigation efforts also reduce the competitiveness of the EU25 countries compared with countries where there is no emission target. The reason is that the price of allowances and increased final energy prices will increase the costs of EU25 output. This will reduce the demand for EU25 goods and services. Most of the reduction is, however, caused by the falling income and economic activity in the emission-reducing countries, so the fall in trade follows the fall in activity quite closely. However, for energy-intensive goods exports to outside EU25 experience a much sharper change of minus 3.8% with long-term technology adaptation. Similarly, the imports of such goods from outside EU25 increase by 4.3% (as opposed to imports of other goods which also fall because of falling income). These figures are minus 5.1% and plus 3.1% with sluggish technology adaptation.

CO_2 leakage from altered trade flows

Because of the diversion in international economic activity towards countries without reduction commitments, the reduction efforts of the EU25 countries are counteracted and diminished. Extra EU25 demand for goods and services from these countries causes extra emissions there. Especially if the production in these countries is more CO_2-intensive than European production, this will cause CO_2 leakage. The model simulations show that the reduction efforts of EU25 and the Annex 1 countries are reduced by 17.8% in a global context, because of diverted economic activity. The leakage with sluggish technology is 21.0%, as more diversion happens.

Successful Lisbon Strategy increases costs

The ambitious Lisbon strategy for improved European competitiveness and growth will cause problems for emission reduction efforts. Increased economic growth inevitably will increase the need for energy, which in turn will increase emissions and the emission gap. Cautious calculations have been made to illustrate the effects of increased economic growth through a successful Lisbon Strategy. In the case of 3.2% p.a. economic growth, the activity reduction caused by the Climate Change policies has been estimated at 0.7% of GDP with sluggish short-term technological adaptation, and 0.5% with long-term adaptation. For a 4% p.a. economic growth rate, these figures are estimated at 0.8% and 0.6%. These estimates are based on a relatively conservative assumption for emission growth rates.

Allowances prices

The estimated allowance prices are 17.0 Euros/tCO_2 with long-term adaptation and 26.5 Euro/tCO_2 with sluggish shorter-term adaptation. In the simulations this implies a significant increase in electricity prices.

The impact of policies and uncertainties

A number of policies may cause the reduction efforts to be more cost-effective. Although simulation results are not presented, the consequences of some of these policies have also been investigated.

Linking is limited, but cost-effective

The amount of flexible mechanism credits from JI and CDM projects that can be made available within the first Kyoto Commitment period of 2008-2012 is limited. Even though the number of potential projects is enormous, it takes time to implement these projects. Consequently, the possibilities for linking between the European allowance market and the market for flexible mechanism credits is limited. As the amount of credits that can be imported may be a considerable share of the needed reductions, linking is an important element in cost-effective EU25 reductions, and any effort capable of increasing the amount of credits that can be acquired by EU25 actors will bear significant economic benefits.

EU10 allowance surplus can reduce costs

With the projections used for the world economy, some of the new EU member states (EU10) with Kyoto limitations have emissions that are below the Kyoto target for this region. Within the Kyoto framework, it is legal to sell these excess allowances as Assigned Amount Units (AAU's). As excess allowances by some parties are seen as a controversial means of reduction, it is generally assumed that these will not be used widely in EU. Depending on the amount of excess allowances, significant reductions in the cost of the Climate Change policies may be achieved.

Risk of flawed reduction split

Only a part of the emissions within the EU25 countries are traded by the Emission Trading Sectors (ETSe), as the remaining emissions come from Non-Trading Sectors (NTSe). This leaves the risk that the split between ETSe reductions and NTSe reductions will not be optimal. A non-optimal split between ETSe and NTSe will thus increase the costs of the Climate Change policy. In the analyses, it has been conservatively assumed that the optimal split can be implemented.

1 Introduction

This report analyses and compares the net cost of EU Climate Change policies for the year 2010. The focus of the analyses is on the impacts on the European economy of reducing the emissions of Greenhouse Gases (GHG), either through the Europe-wide trading of emission allowances in the EU Emission Trading System (EU-ETS), or through cost-effective national reduction initiatives. For this purpose, a Computable General Equilibrium (CGE) model called GTAP-ECAT[1] is used.

In the logic of a CGE model, GHG emission reduction means a re-allocation of productive resources away from GHG intensive input, sectors and countries. Here, the gross costs can be said to be the resources no longer devoted to the emission-intensive activity. There is, however, also a gross benefit, namely the use of these resources for some other productive activity. Typically (and in the logic of the model: always), the reallocated resources are not as productive in their new activity. Therefore, the result of the re-allocation is a net cost: the net cost of reduction.

The net costs of reduction are all internalised, that is they are priced by model generated market prices. Only internalised costs are analysed. However, emission reduction may also carry so-called external costs and benefits. An external cost could be, say, unemployment caused by the re-allocation of resources. An external benefit could be reduced air pollution caused by the diminished economic activity, or avoided potential future damage from dramatic climate change caused by the present emissions. Also innovations rooted in the reduction efforts are external benefits to the model.

1.1 Why use a CGE model?

The main reason for using models is to better understand the consequences of proposed policies. As any model result is strongly dependent on the assumptions used, the model can be seen as a way to qualify and quantify the consequences of the chosen assumptions in a consistent way. Thus, the primary result of a model is seldom a forecast of

[1] GTAP-ECAT (GTAP European Carbon Allowance Trading) builds on the GTAP database and models and various extensions. GTAP-ECAT has been developed by COWI.

future consequences, but rather a systematised consequence calculation, illustrating the relative importance of the different input assumptions.

Partial equilibrium models like PRIMES and POLES illustrate mostly technological changes within emission-intensive sectors. When there is no model description of other parts of the economy, such models cannot say very much about the relative importance of effects outside the modelled sectors.

A global CGE model like GTAP-ECAT covers all sectors in the economy as well as induced consequences outside the reduction bubbles. Therefore global CGE models may be used to analyse the relative importance of effects outside the sectors where the bulk of the reductions happen. Especially, CGE models are well suited to analyse so-called effects of second and higher order, which are indirect effects of the reduction efforts (i.e. changes in income caused by changing relative prices, diversions in international economic activity, etc.).

As such CGE models are not likely to give higher or lower marginal or total costs of reduction than Partial Equilibrium models. This is because costs outside the sectors performing the reductions and the resulting welfare loss of the reduction efforts are captured by the demand elasticities of the partial equilibrium model. However, CGE models make these costs much more explicit because the effects of the reduction efforts can be traced through the entire world economy.

A benefit often not captured by CGE models is the level of detail regarding technological change. Typically, CGE models utilises generalised and smooth technology transformation functions, which are of a rather abstract nature. With such a model it is thus difficult to pinpoint benefits of specific reduction technologies.

1.2 Which effects are described?

GTAP-ECAT describes production, consumption and international trade in 22 goods in 28 regions of the world, demand for 4 primary factors of production, as well as emissions and trade in emission allowances and transfers of money between different so-called representative agents in the model. All these transactions happen in a large number of markets with which prices are associated.

The total number of transactions and prices is much too large to be meaningfully reported, so it is sensible to calculate some aggregate measures such as change in Gross Domestic Product (GDP) and Gross National Income (GNI), as well as different measures for emissions and international trade. These and other measures are very convenient when the consequences of different implementations of the EU Climate Change policy are described and compared.

A central aspect of Climate Change policy is the leakage rate. The leakage rate describes the increased emissions caused by international diversion of economic activity regarding to countries where there is no emission mitigation. Leakage can only be described in models incorporating regions with and without emission limitations where economic activity can be shifted between these regions. GTAP-ECAT does exactly that.

An effect that is not described is unemployment, as it is assumed that all primary factors of production are fully utilised. Also assumptions on economic growth and technological innovation are exogenous to the model. To this is added the fact that the changes in consumption, production and trade pattern are assumed to happen smoothly, and not abruptly.

Perfect competition and constant returns to scale are assumed throughout the model. For this reason, there is no profit in the model, and all produced goods are sold at their marginal cost. Therefore, the distribution of the financial burden of reduction between different firms and sectors cannot be analysed. All surplus of sale of goods and factors as well as tax revenue accrue to a representative agent of each modelled region.

1.3 What are the simulation results compared with?

To assess the cost of a specific policy with model calculations, two simulations must be produced: a Business-as-Usual (BaU) scenario where the policy is not implemented and a "counterfactual" experiment where the policy is implemented and the model response is measured. In the same way, the sensitivity of central model parameters upon the cost of the policy can be investigated by changing that parameter in an experiment and observing the change in the policy cost.

The most primary determinant of the total cost of a Climate Change policy is the reduction requirement, in this analysis called the **emission gap**. The emission gap for a region is the difference between the emissions in the specific BaU scenario and the region's Kyoto target. The future emissions depend heavily on the development in economic activity and in changes in energy use and fuel composition.

Unfortunately, the timeframe for this project has not allowed a detailed assessment of the future emission gap for the modelled regions. Instead appropriate assumptions for economic growth and emission intensity growth have been selected in order to calculate emissions gaps and these have been benchmarked against emission gaps of other studies.

To provide qualification of the importance of the emission gaps, five BaU scenarios with different emission gaps have been constructed. All policy experiments undertaken have been simulated in each scenario.

The BaU scenarios depart from the latest GTAP database, which forms the cornerstone of this analysis. The database consists of consumption, production, input/output matrices and international trade for a number of countries and goods. The database has its base year in 1997.

The composition of consumption and production input in the database is central to the costs of the analysed policies. Therefore, it is a natural choice to analyse the costs of climate change abatement since 1997. This is done by projecting the chosen economic growth rate and the rate for fall in emission intensity in the database to 2010. In this respect, the BaU scenario describes a situation where no climate change abatement policy has been conducted since 1997. Any change in emissions is caused by the natural development in economic activity and the associated emissions.

Thus, **applying a policy experiment where emissions are capped at the Kyoto limits in 2010 will illustrate the total yearly cost of the policy in that year.**

The model responds to the policy experiment by re-allocating resources until the emissions are no longer above the Kyoto targets. The re-allocation is either market-based (directed through the allowance market) or a cost-effective reduction response by the policy-makers of the modelled regions. As the model is static, the modelled costs describes the cost of the most cost-effective measures undertaken in the period 1997 to 2010 needed to bring the emissions into line with the Kyoto targets.

Therefore, **the estimated costs can be interpreted as the minimum costs of the Kyoto policy for bringing the emissions into line with the Kyoto reduction requirements.** If actual reduction measures undertaken since 1997 have not been cost-effective, the extra costs of these can be added to the least costs estimated here.

1.4 Which experiments are analysed?

Only two experiments are extensively reported here. These two experiments depict the influence of assumptions on the ease of technological adaptation assuming the same Climate Change policy implementation. A number of experiments depicting different implementation of EU Climate Change policy have also been simulated. The timeframe did unfortunately not allow extensive reporting, but qualitative results are provided. The two extensively reported experiments are:

1) **Long-Term Technology Adaptation:** In this experiment it has been assumed that the technological adaptation towards less carbon-intensive technology in the electricity and heat sector happens as a function of the easing of the long-term *substitution elasticities* of the GTAP-E model.

2) **Sluggish Short-Term Technology Adaptation:** In this experiment it is assumed that the primary factors of production in the electricity

sector almost perfectly complement[2] the fuel inputs, whereas the long-term adaptation experiment assumes that they are only imperfect complements. It is also assumed that changes in the pattern of international European electricity trade are very sluggish.[3]

Besides these experiments, simulations regarding the level of JI/CDM project credit imports as well as the use of EU10 excess allowances have also been undertaken. These experiments are reported only briefly and qualitatively.

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[2] All elasticities of substitution in the production of electricity and heat are reduced by 90%.

[3] The so-called Armington elasticity of substitution between foreign and domestically produced electricity is reduced with 90%.

2 Central assumptions

A number of assumptions are central to the results of the simulations. These include assumptions about economic and emission growth, as well as the expected future Climate Change policies of the EU and other countries. The most central and sensitive assumptions will be subjected to sensitivity and policy experiments.

The assumptions on the development in economic activity and emissions are relevant to the Business-as-Usual scenarios only, whereas the expected policies are applied in the basic policy experiment and are subjected to various alterations in the alternative policy experiments.

2.1 Emissions and economic activity in 2010

It is a well known fact that growth in productive activity is typically followed by a decline in both the energy intensity (i.e. kJ energy use per Euro of output) and the (economic) emission intensity (i.e. kg emissions per Euro of output). Insofar the use of primary energy sources is shifted away from very CO2-intensive inputs (measured in kg CO2 per energy unit, e.g. coal) towards less CO2-intensive inputs (e.g. natural gas). These developments are rooted in changes in relative prices and different developments in the productivity of the primary factors of production.

For these reason, an assessment of future emissions and economic activity is usually made using very elaborate descriptions of expected changes in productivity developments, relative prices, as well as demand and supply of energy caused by macro- and socio-economic developments for each of the assessed regions. Furthermore, it is necessary that the database used as input to the model must be in general equilibrium, which increases the time needed for projection of the BaU data.

The timeframe of the preliminary analysis has not allowed this detailed assessment of all these assumptions. Instead, two rather rough assumptions have been used to project the underlying database to a Business-as-Usual scenario for 2010: a uniform GDP growth rate applied to all modelled regions and a uniform emission intensity growth rate.

Taking into account historical growth rates since 1997 and expectations on economic growth based on Consensus Economics and Eurostat it is assumed that real GDP in EU25 will grow by an average of 2.3 % over the period 1997-2010. Thus the same growth rate is assumed for all EU25 countries even though it is expected that the new EU member countries will experience a higher growth rate than the old EU countries.

Based on information from the International Energy Agency, CO2 Emissions to GDP are assumed to grow by an average of -1.4 % over the period 1997-2010. It has to be stressed that this assumption reflects a situation where no further policies in the period 1997 to 2010 to comply with the Kyoto Commitment are in place. In this central historical reference scenario, the growth in emissions is 0.89% p.a.

A high and a low scenario are also provided. Here, the emission growth rates are 0.73 and 1.04% p.a. Also, two somewhat higher GDP growth rates are chosen to illustrate the ambitions of the Lisbon Strategy, and the likely effect that the Climate Change policies will have on the Lisbon ambitions. In these scenarios, the emission growth rates are 1.38% p.a. and 1.56% p.a. The growth rates, emissions and other relevant emission figures are shown in Table 2.1.

Table 2.1 Assumptions on growth and the resulting EU25 emission gaps

Reference scenario	Economic growth (% p.a.)	Emission intensity growth (% p.a.)	Emission growth (% p.a.)	BaU Emissions 2010 (Mt)	Gap, excl. surplus allowances (Mt)	Surplus allowances (Mt)
Historical-	2.10%	-1.36%	0.73%	4243	607	47
Historical	2.30%	-1.40%	0.89%	4330	689	43
Historical+	2.50%	-1.44%	1.04%	4419	773	38
Lisbon Strategy-	3.20%	-1.80%	1.38%	4610	963	36
Lisbon Strategy+	4.00%	-2.40%	1.56%	4722	1074	35

Source: Projections on the GTAP 5.4 database and calculations on data from Eurostat. Note: The GTAP database specifies firms' acquisitions of fossil fuels, which are converted to emissions with the relevant fuel emission factors (fuel input to Chemicals-Rubber-Plastics sector is deducted). These emissions thus also include emissions to international bunkers, and the national Kyoto targets are therefore adjusted upwards with bunker emissions (which amounted to 123 Mt in 1997). The feedstock corrected GTAP 1997 emissions for EU25[4] including bunkers are thus 3,860 Mt, whereas the Eurostat 1997 emissions of combustion plus bunkers is 3,869 Mt (external data for Luxembourg and Lithuania may explain the small 9 Mt discrepancy). The EU25 fuel combustion Kyoto target (including bunker emissions for 1997) is based on Eurostat data for 1990 and it is assumed that combustion related reductions are reduced proportional to the commitments from the Burden-Sharing Agreement. The EU25 Kyoto target is thus 3,683 Mt. In comparison in World Energy Outlook 2004 the International Energy Agency assumes a GDP growth for EU25 of 2.3% from 2002 to 2010 and a growth in emission intensity of minus 0.9%.

[4] When EU25 and EU10 are mentioned, Malta and Cyprus are generally excluded, as these countries have no Kyoto reduction obligations.

In the table, the emission gaps for EU25 have been calculated without surplus allowances (in the countries, which do not reach their emission limit by 2010 according to the stated assumptions), which are stated separately. In the simulations, it is assumed that surplus allowances cannot be sold in EU25.

The emission gap excl. surplus allowances may be compared with the gap for EU15 as reported by the European Environment Agency (EEA). In the report "Greenhouse gas emission trends and projections in Europe 2003" it is expected that with existing domestic policies and measures CO_2 emissions will grow by 4% from 2001 to 2010, resulting in a gap between projected emissions and the EU target (calculated as 92% of 1990 emissions) of 401 Mt.

This is somewhat below the "historical" scenario emission gap as reported in Table 2.1. However, this gap is calculated from 1997 to 2010 with no additional domestic policies and measures of the EU Member States in place. On the contrary, the gap reported by EEA does take account of new policies and measures in the period from 1997 to 2001 which most likely have resulted in relatively lower emissions than in a situation without new policies and measures. Furthermore, the figures reported by EEA also include official government decisions that have not been implemented but where there is a clear commitment to proceed with implementation.[5]

In Table 2.2 gaps from different studies are compared. The figures reported do not use the exactly same definitions of included gases and areas when reporting emissions, but nevertheless the emission gaps compared to the targets can be meaningfully compared. As can be seen, EEA expects (for the reasons mentioned above) a lower gap. The same is the case for the PRIMES projection. However, the gap of GTAP-ECAT is comparable to that of POLES.

Table 2.2 Inter-study comparison of EU15 emission gaps (Mt CO_2)

	Kyoto target	1990	2001	2010	Gap	% of target
EEA	3074	3341	3395	3475	401	13.0 %
PRIMES	2822	3068	-	3193	371	13.1 %
POLES	3010	-	-	3648	638	21.1 %
GTAP-ECAT	3007	-	-	3639	633	21.1 %

Note: The emissions presented here are not totally comparable, as the accounting definitions vary. Sources: Own projections of the GTAP 5.4 database (see Table 2.1); "Greenhouse gas emission trends and projections in Europe, 2003", European Environment Agency (EEA), and "Preliminary Analysis of the Implementation of an EU-Wide Permit Trading Scheme", IPTS 2000.

[5] Greenhouse gas emission trends and projections in Europe, 2003", European Environment Agency (EEA), p. 23, footnote 20.

2.2 Expected Climate Change policies

Linking is sluggish

In the spring 2004 the Linking directive was completed, and that directive did not put specific limits on the import of credits from JI and CDM projects. However, there is a lead time of 3-5 years of implementing such projects. Thus, the flow of credits does not adjust in line with the European allowance price. Only in a somewhat longer term will the real supply of JI and CDM adjust to the European and other emission bubble market prices.

The World Bank, IEA and IETA have made an assessment of the costs of potential JI and CDM projects.[6] The hard question to answer is how quickly the supply adjusts to the price signals from the different credit markets. A cautious approach has been selected, as the inflow of JI and CDM credits into EU25 is exogenously fixed in the model. In all experiments the inflow of credits into the ETS is set at 100 Mt. Furthermore, it is assumed that national governments will acquire 46 Mt of credits (as stated in the Allocation Plans for 2005-7 published hitherto). This inflow is in the same order of magnitude as the KPI/POLES inflows of credits.[7]

Externally estimated JI/CDM cost curve

The cost of these credits is also set exogenously using the cost curves from the above-mentioned assessments. In Figure 2.1 below, the derived cost curve is shown. The cost curve is based on an assessment of CDM potential and has been adjusted to include JI by enhancing the potential supply with 17.6 % corresponding to the Ukrainian supply potential.

Note that the curve is based on conservative estimates of realistic supply of CDM and JI credits. This reflects the assumption that the strict additionality criteria[8] will be applied to the approval of projects. Other factors that tend to limit the supply of JI and CDM compared to the theoretical potential include: considerable transaction costs in project development and approval; project development lead time; political risks; and uncertainty about the value of emission reductions post-2012.

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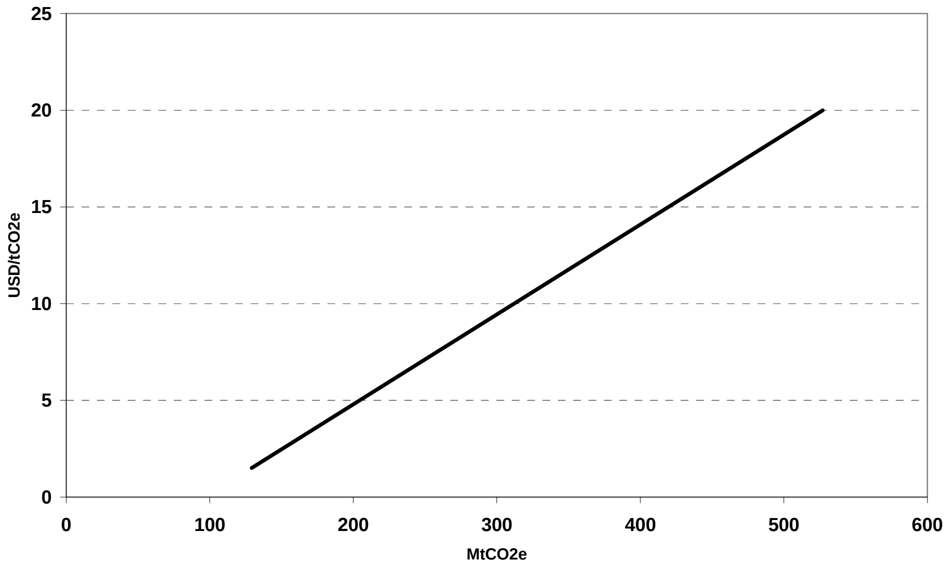
[6] See The World Bank Carbon Finance, IEA and IETA: "Estimating the Market Potential for the Clean Development Mechanism", June 2004.

[7] See the "KPI Technical Report" by Criqui and Kitous (2003).

[8] Referring to the requirement in the Kyoto Protocol that project proponents must provide evidence that the emission reduction would not have taken place in the absence of the JI/CDM project.

Figure 2.1 Assumed cost curve of JI and CDM that can be implemented in 2010.



Source: World Bank, IEA and IETA (see note 6).

The other Annex 1 countries demand JI and CDM as well. It has been assumed that they will cover a fixed part of their reduction commitment with JI and CDM reductions, namely 20%.

No "surplus allowance reductions" in EU

It is an assumption of the policy experiments that the EU member states will import only emission credits based on factual reductions. Thus neither Russian nor EU10 surplus allowances are used for the EU reduction efforts.

Other Annex 1 buys Russian AAU

It is assumed that the other Annex 1 countries will accept credits that are not based on factual reductions. For this reason, it is assumed that the group of remaining Annex 1 countries acquire Russian AAU's corresponding to 35% of their reduction requirements. This leaves the other Annex 1 countries with reductions within their own bubble of 45% of the reduction requirement.

Allowance allocation is cost-effective

A final assumption of the future EU Climate Change policy is that the national allocations of allowances are done in such a way that the marginal costs of reductions of each region's NTSe is equal to the allowance price. Such an allocation will result in a cost-effective split of the reductions between the ETSe and the NTSe. This assumption may be considered optimistic, but on the other hand it results in a conservative assessment of the total reduction cost, as any deviation from the cost-effective split will increase the total costs of reduction.

3 Analysis results

In this report, two experiments are analysed and extensively compared with each other. In the long term technological adaptation experiment, it is assumed that the ease of the technological adaptation to less carbon-intensive electricity production can happen with ease and costs of long-term adaptation as specified by the GTAP-E elasticities of production.

In the short-term sluggish technology adaptation experiment, the ease of technological adaptation is reduced, as is the possibility for import of electricity from other countries. This reflects the fact that changes in the electricity production system can happen only rather slowly, because installation of new capacity has significant lead times.

The consequence of the reduction efforts is re-allocation of the productive resources towards less CO_2-intensive production and consumption. This will mean that very emission-intensive outputs are reduced, and that consumers shift their consumption towards goods that are not affected as much by the emission allowance price. These goods are both less emission-intensive goods, as well as foreign goods from countries that have no emission cap or allowance price.

When more sluggish technology adaptation is assumed, activity in the electricity sector is even more reduced. This causes higher electricity prices, which again decreases other electricity using economic activities.

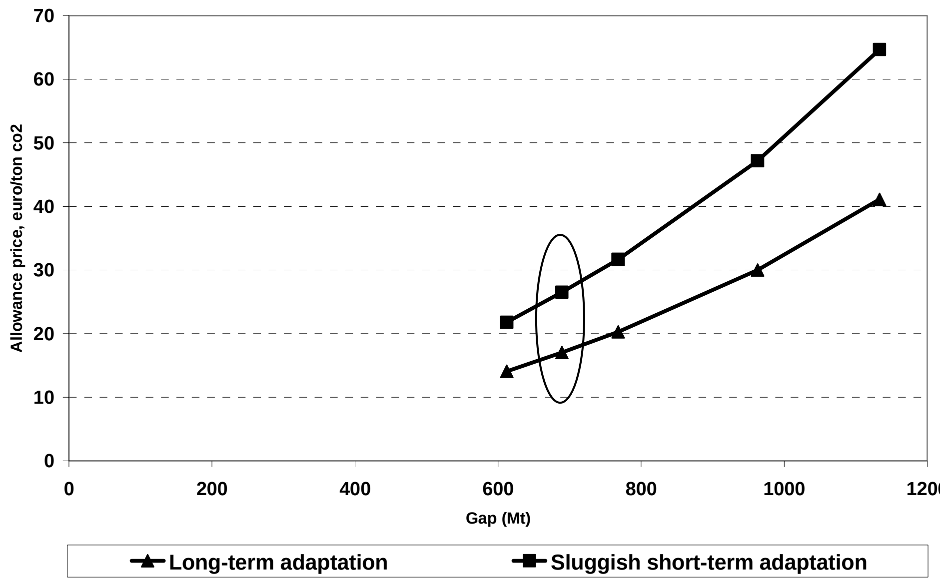
3.1 Changes in activity

In the reporting of the simulations, results for the five emission gaps are reported in most of the figures. The observations for the "historical" growth rates scenario are marked by an ellipse. A few graphs relate to one scenario only. In these cases the scenario is long-term technological change with "historical" growth rates.

3.1.1 The allowance price

For each of the scenarios, the allowance price has been calculated. Figure 3.1 shows an expected allowance price of 17 Euro/tonne with long-term adaptation and 26.5 Euro/tonne with sluggish adaptation. The range of estimated allowance prices given technology and emission gap is of 14 to 65 euros/tonne. In the simulations this implies a significant increase in electricity prices.

Figure 3.1 Allowance price in the EU25 in 2010



Source: Simulations with GTAP-ECAT.

3.1.2 Changes in production and consumption

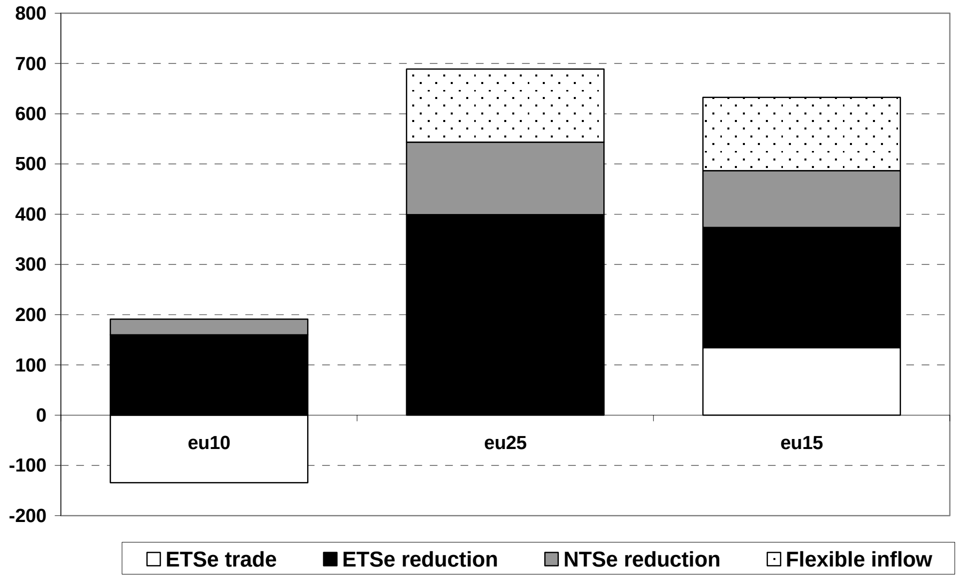
The allowance price illustrates the marginal cost of reducing one tonne of CO_2. This price signals to the economic actors whether they should increase or decrease their CO2 emitting activity, depending on their marginal costs of reduction.

The common EU allowance price thus ensures that productive resources are re-allocated efficiently from emission-intensive inputs and sectors towards less emission-intensive inputs and sectors. This response can be seen on both sector as well as national basis: reductions tend to happen in the most emission intensive-sectors as well as countries. This means that a relatively large share of the reductions will happen in EU10.

Typically, the cost-effective real reductions take place in emission-intensive sectors and countries, such as most of the ETSe. The tendency to make reductions in relatively emission-intensive sectors is valid on an international scale, as ETSe industries in the EU10 (which are even more emission-intensive than their EU15 counterparts) reduce relatively more than other ETSe.

For this reason, allowances flow from the EU10 ETSe towards the EU15 countries. This pattern can be observed in Figure 3.2, where the reduction effort of all EU10, EU15 and EU25 is split into ETSe and NTSe reductions, JI/CDM projects and EU-ETS allowance trade.

Figure 3.2 EU25 reduction efforts in 2010, historical scenario with long-term adaptation (Mt)



Source: Simulations with GTAP-ECAT. Note: Negative ETS trade is export of allowances.

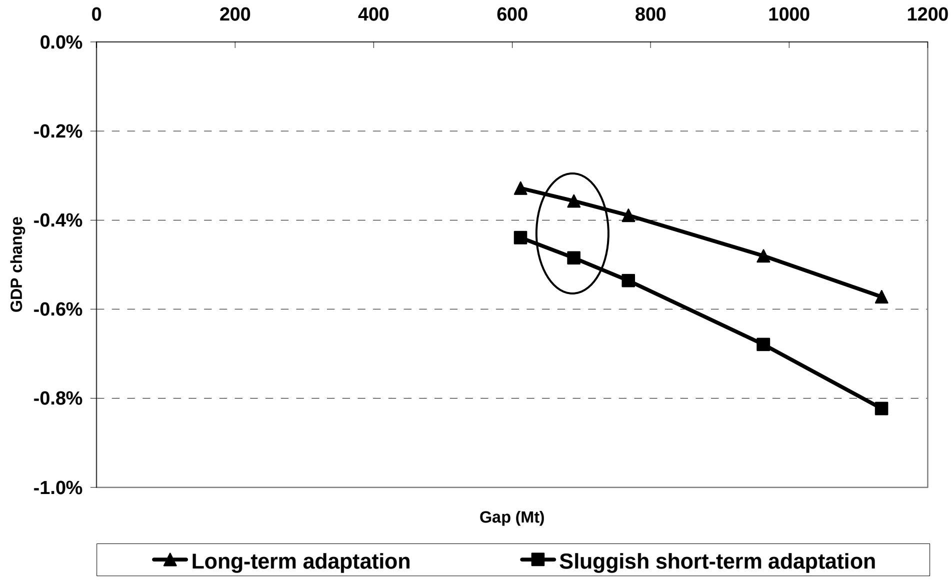
The results illustrated in Figure 3.2 are important to the overall economic activity measured by for example by GDP. As explained earlier, the most cost-efficient reductions can be found where the CO_2 intensity is high (because a 1 million Euro reduction of economic activity implies a larger reduction). Following this logic, the largest decline in economic activity should be found in countries with relatively high overall CO_2 intensities. This is especially prevalent in the EU10 countries.

While the EU10 reduce their economic activity, they are compensated for their reductions by the buyers of allowances, so even though their production falls, their consumption increases because they can pay for foreign goods with the revenue from allowance sales.

Figure 3.3 shows the loss of GDP compared to the five BaU scenarios for both long- and short-term adaptation. For both experiment, calculations are made based on five different assumptions regarding emission gaps (which in turn reflect different assumptions about economic growth and development in emission intensities). As can be seen from the Figure, there is a very direct correlation between the emission gaps and the change in GDP resulting from the closing of the gaps.

EU25 GDP is reduced by 0.36%, with long-term adaptation and with 0.48% with sluggish adaptation with the central growth scenario. The variability testifies to the strong dependency of the result on assumptions about the emission gap.

Figure 3.3 GDP change in 2010, all scenarios

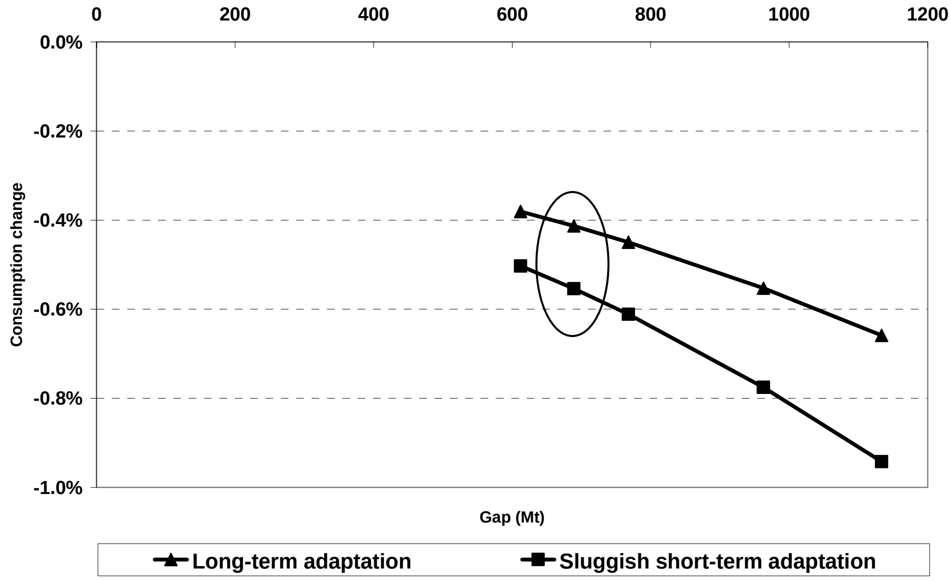


Source: Simulations with GTAP-ECAT. Note: The central scenario is marked on the figure.

The model simulations further show that, measured by production value in constant prices, almost all sectors (except EU10 services) contract their output as a consequence of the reduction efforts. This is partly a consequence of the income effects of the efforts.

Figure 3.4 shows the change in consumption. There is a rather close correlation between the GDP and the consumption change on an overall EU25 scale, whereas differences between regions exist depending on the region's reduction commitment and whether the region is a net seller or buyer of allowances.

Figure 3.4 Consumption change in 2010, all scenarios



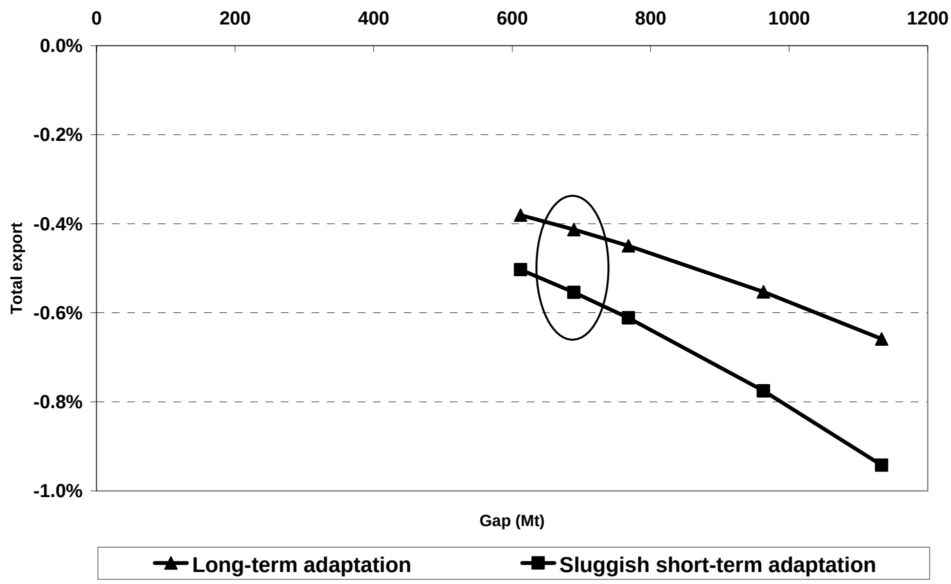
Source: Simulations with GTAP-ECAT. Note: The central scenario is marked on the figure.

3.2 Changes in international trade

3.2.1 Exports

The GHG mitigation efforts reduce the competitiveness of the EU25 countries compared with countries where there is no emission target. The reason is that the price of allowances and increased final energy prices will increase the costs of EU25 output. This will reduce the demand for EU25 goods and services. As can be seen from Figure 3.5, total exports from EU25 countries decline by between 0.41% and 0.55%, depending on technology adaptation.

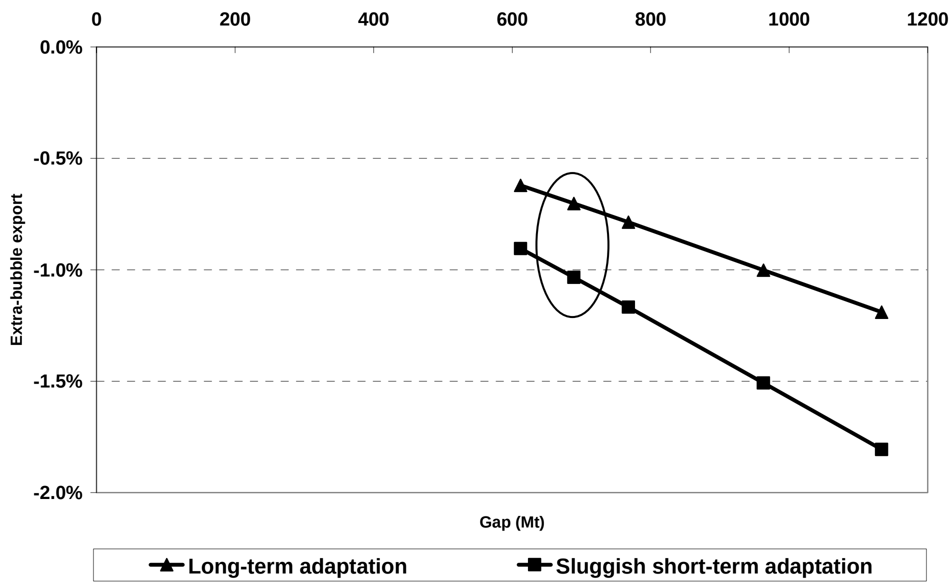
Figure 3.5 Change in EU25 countries' total exports inside and outside EU25 in 2010, all scenarios



Source: Simulations with GTAP-ECAT. Note: The central scenario is marked on the figure.

Figure 3.6 shows the export from EU25 regions to regions outside EU25 (so-called extra-bubble exports). Comparing this with Figure 3.5, it shows that extra-bubble exports fall more than total exports. This happens to compensate for the lower production inside EU25 caused by the reduction efforts.

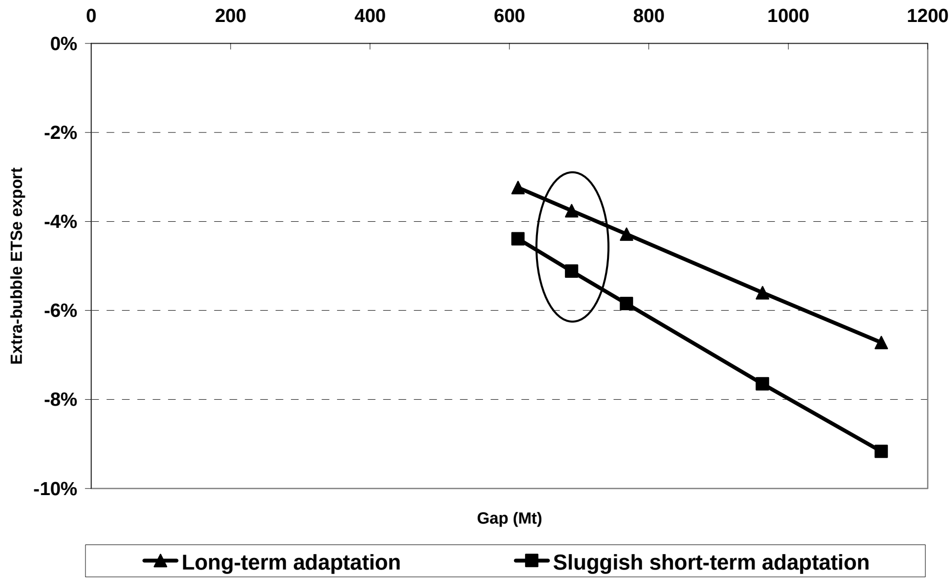
Figure 3.6 Change in EU25 countries' export outside EU25 in 2010, all scenarios



Source: Simulations with GTAP-ECAT. Note: The central scenario is marked on the figure.

Figure 3.7 below shows that exports outside of the EU25 bubble from the emission intensive ETSe sectors are likely to experience significant reductions, 3.8% to 5.1% in the historical growth rate scenario. Not surprisingly, changes in exports outside EU25 are affected much more severely for emission-intensive goods, as the price of allowances and the international competition hits harder here.

Figure 3.7 Change in EU25 countries' export of ETSe goods outside EU25 in 2010, all scenarios

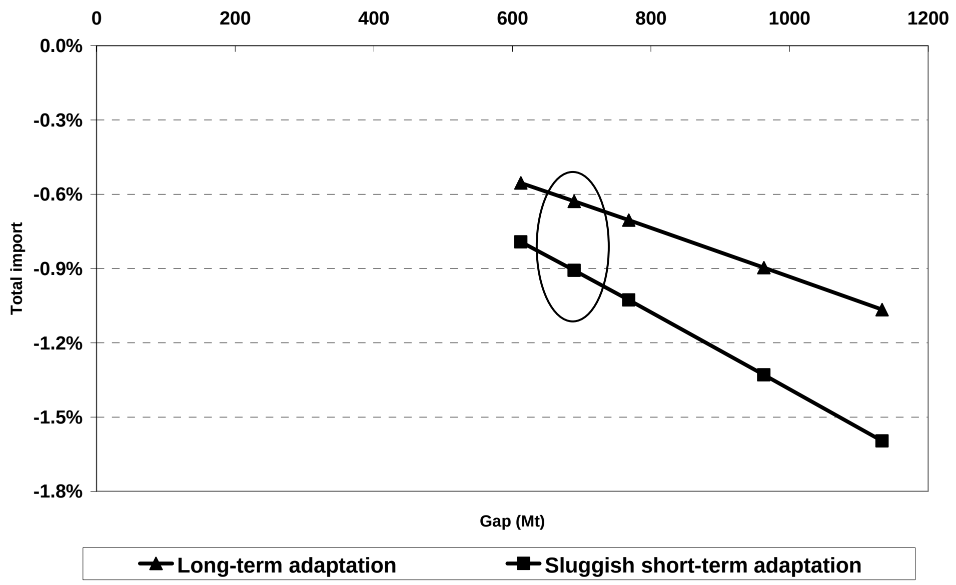


Source: Simulations with GTAP-ECAT. Note: The central scenario is marked on the figure.

3.2.2 Changes in imports

The decline in economic activity and income on the part of the EU25 countries result in reduced demand for imports between of 0.6% to 0.9% in the historical growth rate scenario, see Figure 3.8.

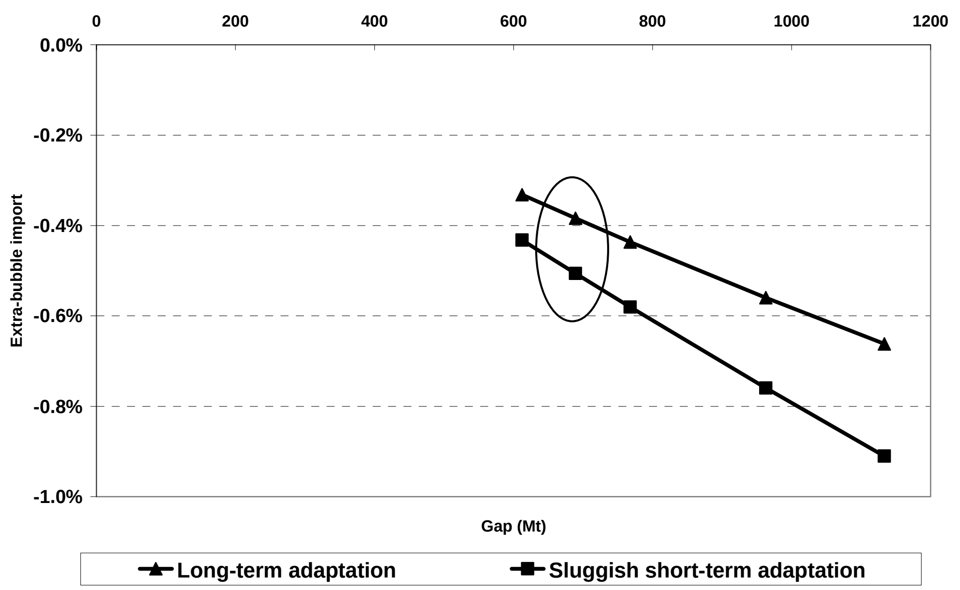
Figure 3.8 Change in total EU25 import within and outside EU25 in 2010, all scenarios



Source: Simulations with GTAP-ECAT. Note: The central scenario is marked on the figure.

Imports from extra-bubble countries, some of which do not have Kyoto commitments (which will thus experience an improvement in competitiveness), decline less than total imports, of between 0.4% and 0.5%, see Figure 3.9.

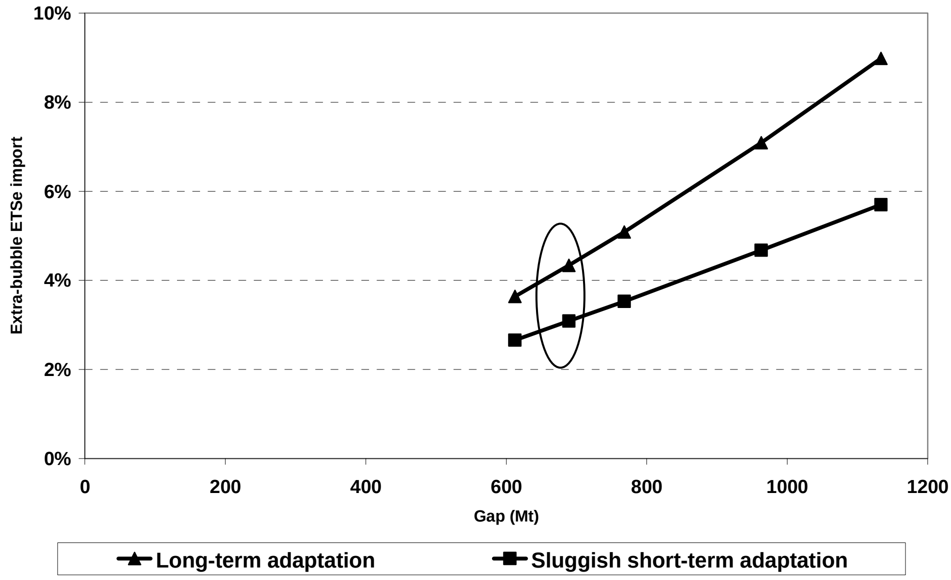
Figure 3.9 Change in imports from outside EU25 in 2010, all scenarios



Source: Simulations with GTAP-ECAT. Note: The central scenario is marked on the figure.

The strongest impact on import patterns will again take place in the emission-intensive ETSe sectors. Extra-bubble countries without Kyoto commitments experience improvements in competitiveness leading to extra-bubble ETSe imports increasing by around 4.3% with long term adaptation, and around 3.1% with sluggish adaptation, see Figure 3.10.

Figure 3.10 Change in ETSe good imports from outside EU25 in 2010, all scenarios

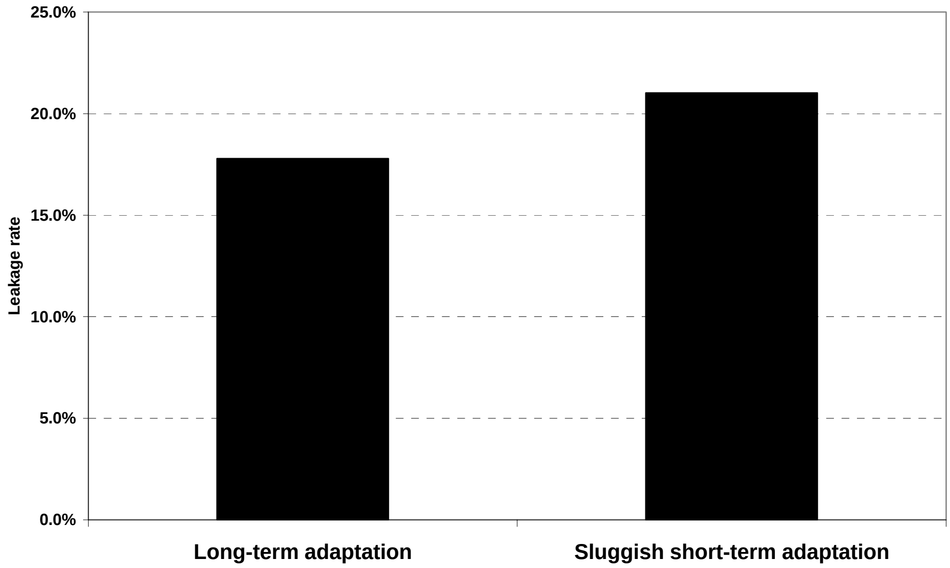


Source: Simulations with GTAP-ECAT. Note: The central scenario is marked on the figure.

3.3 Leakage

The changes in the international distribution of economic activities caused by diversion towards countries without reduction commitments is a source of *leakage*, counteracting and diminishing the reduction efforts of the EU25 and other Annex 1 countries. The displacement of emission-intensive production towards countries without Kyoto commitments tends to reduce the net effect of emission reductions in EU25 and other Annex 1 countries. The increased international trade lead to larger economic activity in the uncapped countries receiving the transfers, thereby causing emissions that partly offset the reduction from credit-generating projects. Figure 3.11 shows the expected levels of leakage, which are somewhat sensitive to the assumptions of technology adaptation. The leakage is 17.8 % with long-term adaptation and 21.0 % with sluggish adaptation.

Figure 3.11 EU25 and Annex 1 countries leakage rate in 2010



Source: Simulations with GTAP-ECAT.

It is also interesting to observe which sectors are most susceptible to leakage. In Table 3.1 below, the emission reductions and increases are shown together with a direct calculation of the leakage rate for five aggregated economic sectors.

Table 3.1 Reductions, leakages and leakage rates in 2010, all scenarios, historical scenario, long-term adaptation

	EU25	Other Annex 1	JI/CDM countries	USA	Leakage rate
	Reductions (Mt CO_2)		Leakages (Mt CO_2)		
Food	17.7	4.9	-2.8	-0.3	13.8 %
Energy	359.4	100.5	-64.0	-11.4	16.4 %
Energy-Intensive	87.6	39.5	-20.4	-4.4	19.5 %
Other Manufacturing	14.4	5.5	-1.8	-0.2	10.1 %
Services	55.4	29.9	-7.9	-3.3	13.1 %

Source: Calculations with GTAP-ECAT. Note: Positive figures denote emission reductions, whereas negative figures denote increasing emissions (leakages).

As can be seen from the table, the leakage is relatively larger within Energy- and Emission-Intensive sectors. This is as expected, as especially these sectors' competitiveness is reduced because of the reduction efforts, although Energy sector leakage arguably is of a more indirect character, caused by increased electricity demand outside EU25 and Other Annex 1 countries.

3.4 Qualifications

As in any model analysis, the results are driven by data and assumptions. Regarding models on the cost of Climate Change policies, the modelled cost crucially depends on the size of the emission gap (reduction requirement) that must be covered. This is as true for GTAP-ECAT as it is for POLES and PRIMES, which have also been used for the purpose of Climate Change policy cost estimation.

The gap analysed here is a "since 1997 Business-as-Usual" gap depicting the cost of EU Climate Change policy in 2010 compared with a situation where all emission reduction efforts were abandoned in 1997, resulting in a larger emission gap, than if for example the point of departure had been 2001. Principally, the "real" BaU emission gap will never be known, as reduction efforts have already been undertaken.

Obviously, the gap also depends on the assumed BaU developments, especially in the energy-intensive sectors. The reluctance towards nuclear power and the recent political developments in the regions supplying Europe with oil and natural gas might, in the absence of the ambitions of carbon emission reduction, have spurred a large increase in the use of coal for electricity production, which would add significantly to the emissions of CO2 in 2010 in a BaU scenario. Such a BaU scenario might leave a quite dramatic emission gap.

The construction of the BaU scenario in this analysis will be dealt with much more intensively in the final analysis. Especially, a clarification of the assumptions behind the emission gap will be emphasised.

Another point for further investigation is international capital mobility. In the experiments conducted here, some rough assumptions regarding the international flows of capital and equalising of changes in rates of return have been used. In the final analysis, capital mobility will be investigated using a detailed modelling of global capital flows, investment and savings.

Additionally, there is also some uncertainty around the level of emission credit imports stemming from JI and CDM projects. This uncertainty will be quantified in the final analysis, where experiments involving different amounts of JI and CDM credits will be performed. The same qualification goes for the amount of excess allowances bought in the form of AAU's. Also the price of AAU's can be affected significantly by the strategic considerations of major AAU suppliers. It is also planned that this topic will be addressed in the final analysis. Also, the potential participation of the USA in the Kyoto efforts can influence the results in a dramatic way, although this may not at present seem relevant to the first Kyoto commitment period.

Also the figures for changes in international trade should be viewed in the light that an Armington assumption of preferences between goods of different national origin is applied. Much more detailed in-depth partial equilibrium studies including imperfect competition are usually applied to assess the international trade consequences of altered competitiveness. Such modelling is not feasible here on the larger scale of all EU25 sectors exposed to international competition.

As the analysis will show, the assumptions on technology adaptation are also of major importance. The two experiments reported extensively deals with this uncertainty. A number of other assumptions on consumer and producer choice can also be subjected to sensitivity experiments in the final reporting.

A Detailed Model and Data Description

The GTAP-ECAT (EU Carbon Allowance Trade) model has been developed by COWI to perform analyses of the EU allowance system and its links to the Kyoto market. It is based on the so-called GTAP (Global Trade Analysis Project) model and especially two energy versions called GTAP-E and GTAP-EG.

GTAP was established in 1993 and has been widely developed since then. It comprises not only a Computable General Equilibrium (CGE) model, but more importantly also a detailed database covering the world economy. It is developed as an international project with participants from universities and research units from all over the world. Today, GTAP has become a common "language" for many of those conducting global economic analysis.

The GTAP database is frequently updated and improved. In the latest version (v5.4) used here, all base data are from 1997. The next version, which is expected to be released in late 2004, includes data from 2001.

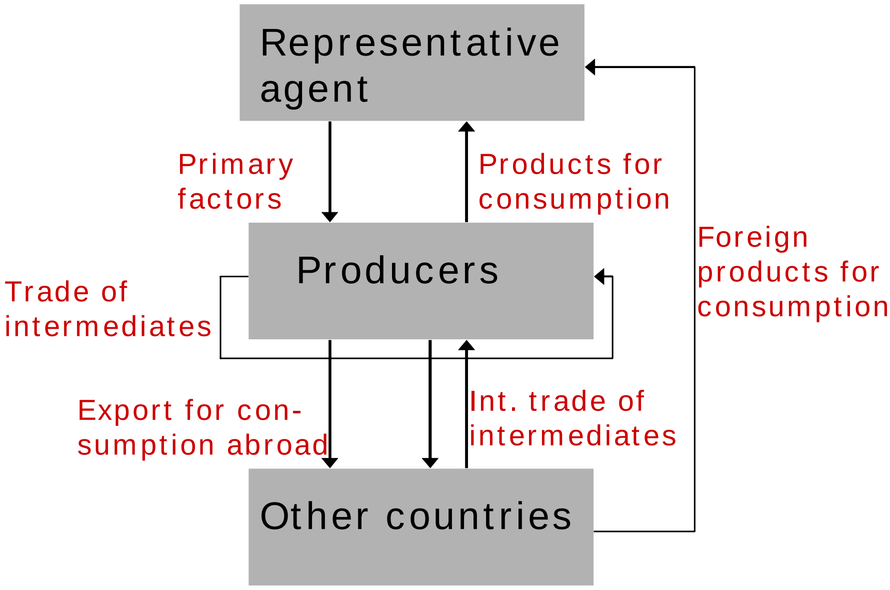
The backbone of the model is the GTAP database. In the current database the world is divided into 78 geographical regions and 58 industrial sectors. In the present project, this has been aggregated to 28 regions and 22 sectors to make the simulation process and presentation lighter. A list covering sector and region aggregation is seen in appendix A and Appendix B respectively. The data cover the regions demand and supply of goods and factors, international transport and trade, capital movements and government taxation. Also included are volume data on region and sector-specific energy use.

A.1 Basic structure of the model

The model is a static, multi-region, multi-sector computable general equilibrium model, with perfect competition and constant returns to scale. Bilateral trade is handled via the Armington assumption. This assumption states that firms' and consumers' preferences for domestic and foreign goods are reflected in the observed trade patterns. These trade patterns react somewhat sluggishly[9] to changes in the international relative prices, as domestic and imported goods are only imperfect substitutes. So, even though the EU climate change policy will diminish European Union competitiveness to some extent, European firms will still export goods and services to extra-EU countries, as these have Armington preferences for European goods

The basic structure of the model is rather simple. Each region can be illustrated (a little simplified) as in Figure A.1 below.

Figure A.1: Basic GTAP structure



Each economy is represented by a representative agent, who supplies the primary production factors to the companies and in exchange consumes goods produced domestically as well as abroad. The domestic companies produce goods by the use of primary production factors and intermediates produced domestically as well as abroad. The goods are consumed by domestic and foreign consumers and producers.

For further information about the standard GTAP model, we refer to the official model documentation *Global Trade Analysis: Modelling and Applications*, by T.W. Hertel (ed.).

A feature of the model that is work-in-progress is the balance-of-trade, which in the present version of GTAP-ECAT is exogenously fixed. This has very small effects on the allowance price and the traded quantities, but unfortunately, the welfare measure will be severely affected by strong biases. This is caused by effects on the terms of trade, which are described

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[9] This "sluggishness" is specified through the so-called Armington elasticities. Typically, a 1% increase in relative prices may induce a 4% reduction in the relative quantities.

in detail in Appendix C. Until an endogenous balance-of-trade has been implemented, the welfare measure is not reliable.

In the present GTAP-ECAT simulations, the 78 regions and 58 sectors of the database are aggregated to 28 regions and 22 sectors,[10] as reporting from many of the sectors and regions do not add to the understanding of the effects of a European allowance market. Throughout this report many results are reported for five aggregated regions, namely:

- EU15
- the New (EU) Member States (EU10)
- JI/CDM countries which includes on the one hand non-EU countries in CEE commonly seen as hosts for JI projects (Russia, Ukraine, Romania, Bulgaria and Croatia) and on the other hand non-Annex I countries where CDM projects can be implemented.
- the other so-called Annex I countries, which are the countries outside EU25 with a reduction obligation
- USA and Australia, which have not ratified the Kyoto protocol and therefore have neither reduction targets nor the possibility for implementing JI and CDM projects.[11]

Any CGE model is heavily dependent on the underlying database, and differences between sectors and regions will explain most of the results. A brief overview of the database's national account data is given in Table A.1.

Table A.1: GDP (1997 billion USD)

	Final consumption	Investment	Exports	Imports	Total GDP
EU15	6378	1488	2455	2362	7958
EU10	239	66	124	151	278
JI/CDM countries	5327	1769	1961	2012	7045
Annex I countries	3788	1439	925	787	5365
USA+Australia	6697	1398	873	1023	7945
Total	22430	6160	6337	6336	28591

Source: The GTAP 5.4 database. Note: The GDP is accounted for from the demand side, through the identity Y+M=C+G+I+X

As can be seen from the table, the European economies are approximately the same size as that of the USA, whereas total JI and CDM countries are

[10] A number of smaller African, Asian and South-American countries have been aggregated, as has some specialised food-producing and other sectors.

[11] The list of countries/regions, sectors and aggregations can be found in Appendix B.

slightly smaller. The remaining group of Annex I countries are almost 60 % the size of USA.

There are some differences between regions with respect to the composition of GDP. In the highly industrialised EU15 and USA, final consumption is relatively large, whereas investments are relatively small compared with the other regions. The European countries and the JI and CDM countries are rather open compared with the USA and the Kyoto countries (dominated by Japan and Canada), as trade in the former is around or above 30 % of GDP, and around 15 % in the latter, see Table A.2

Table A.2: Regional expenditure as share of GDP (per cent)

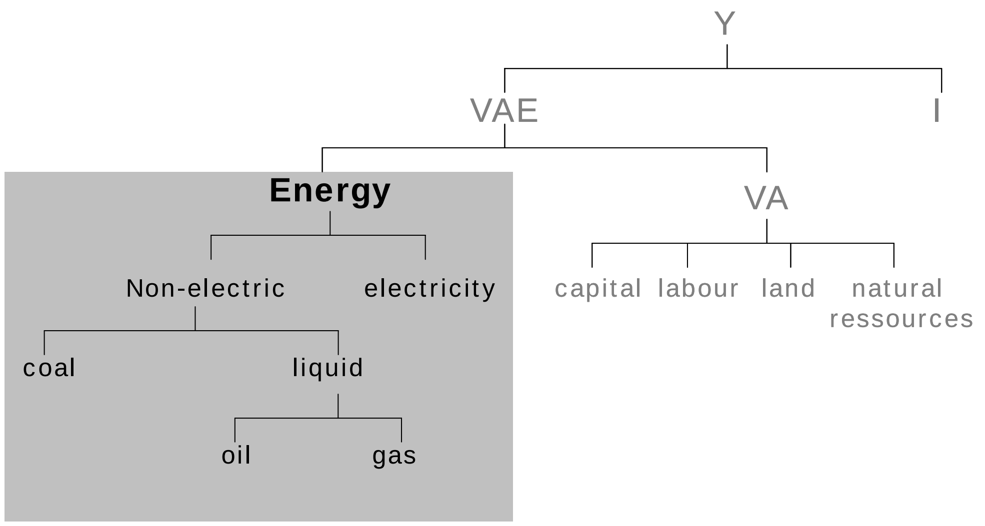
	Final consumption	Investment	Exports	Imports
EU15	80%	19%	31%	30%
EU10	86%	24%	45%	54%
JI/CDM	76%	25%	28%	29%
Annex I	71%	27%	17%	15%
USA+Australia	84%	18%	11%	13%
Total	78%	22%	22%	22%

Source: The GTAP database version 5.4

A.2 Energy demand

Formulation of energy substitution in production as well as in private demand is based on an energy version of GTAP, called GTAP-E, developed by M. Berniaux and T. Troung as well as GTAP-EG, developed by T. Rutherford and S. Paltsev. The demand for energy intermediates in the production is illustrated below.

Figure A.2: Energy-related nesting structure of the production functions



Note: VA is an abbreviation for the value-added composite; VAE is value-added-energy. I is non-energy intermediates. Y is the sector's output. Electricity from renewable sources are also accounted for within 'electricity'.

The producers utilises energy inputs (coal, oil, gas and electricity) and non-energy intermediates *(I)* in the production of output (Y). Energy is a composite of electricity and non-electricity respectively. Non-electricity good is a composite of coal and liquid energy, the last again being a composite of oil and gas. The value added (VA) stems from input of primary factors, and in GTAP-ECAT these are divided into capital, labour, land and natural resources.

Each composite illustrates existing substitution between its inputs. The substitution elasticities are as follows[12]:

- Value-Added-Energy (VAE) composite versus non-energy intermediates: 0
- Between all primary factor inputs: 1
- Energy composite versus value-added (VA) composite: 0.5
- Non-electricity composite versus electricity: 0.1
- Coal versus liquid composite: 0.5
- Oil versus gas: 2

The choice of substitution elasticities is thoroughly discussed in the documentation of GTAP-E, see *GTAP-E: An Energy-Environmental Version of the GTAP Model (2002)* by M. Berniaux and T. Troung.

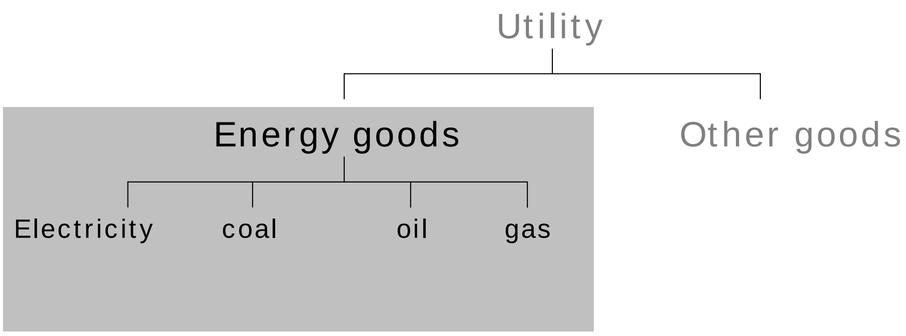
[12] A substitution elasticity of x means that demand for the one good will change by x% when the price of the other good is changed by 1%

All energy products are produced contrary to primary production factors (capital, labour, natural resources and land), which are scarce in the sense that a certain exogenous amount is available. As can be seen, changes in relative prices of energy types will result in substitution between different energy types. Furthermore, the fact that energy goods are produced implies that lower demand (resulting from increased prices, e.g. caused by carbon taxation) means that production of energy goods will decline. This would not be the case if the energy good was a primary factor, which are all fully utilised (if the demand is present), independently of the factor price.

At the demand side the consumer enjoys consumption of energy products along with consumption of non-energy products. Energy is defined as a composite of the four energy products of the model (electricity, coal, oil and gas) with a substitution elasticity of 1 between the energy products. 'Other goods' is a corresponding composite of non-energy goods. The nesting structure is illustrated in Figure A.3 below.

For both production and consumption side of the model the final energy products are characterised by Armington substitution. The energy substitution in GTAP-ECAT is, with a few exceptions[13] the same as in GTAP-EG.[14]

Figure A.3: Energy demand from final consumption



The cause of carbon emissions is combustion of energy goods for the production of energy, which is a very important input in the economy. The combustion of fossil energy is shown in Table A.3.

[13] In GTAP-E, there is substitution between a capital/energy composite good and other primary factors of production, whereas GTAP-EG has substitution between all primary factors and energy, although production of fossil energy goods is treated specially. GTAP-ECAT has substitution between energy and primary factors, but no special treatment of fossil fuel production.

[14] The interested reader is referred to *GTAPinGAMS and GTAP-EG: Global Datasets for Economic Research and Illustrative Models (2000)* by T. Rutherford S. Paltsev.

Table A.3 Combustion of fossil energy by region, 1997 (exajoule)

	ETSe	NTSe	Final use	Total
EU15	17.0	20.8	11.6	49.5
EU10	4.6	2.4	1.3	8.3
JI/CDM	74.9	58.2	20.2	153.3
Annex I	9.9	12.2	4.8	26.9
USA+Australia	32.3	33.7	13.6	79.6
Total	138.6	127.3	51.6	317.5

Source: The GTAP database, version 5.4. Note: This table accounts for coal, natural gas and refined petroleum products.

The use of energy is of course strongly dependent on the economic activity, and in this respect the table has a lot of similarities with Table A.1. The relative composition of the energy combustion is shown in Table A.4.

Table A.4 Composition of fossil fuel combustion, 1997 (share of total)

	ETSe	NTSe	Final use
EU15	34 %	42 %	23 %
EU10	55 %	29 %	16 %
JI/CDM	49 %	38 %	13 %
Annex I	37 %	45 %	18 %
USA+Australia	41 %	42 %	17 %
Total	44 %	40 %	16 %

Source: The GTAP database, version 5.4. Note: This table accounts for coal, natural gas and refined petroleum products.

A topic of special interest for a model of energy use and carbon emission allowance trading is the raw energy price. Higher raw energy prices means lower demand for energy and thus lower emissions and lower allowance prices. As mentioned, the database used in GTAP-ECAT has its base year in 1997. The typical 1997 European raw energy prices of the GTAP database are presented in Table A.5 below.

Table A.5: Typical European GTAP raw energy input prices excl. taxes 1997

Crude oil	130 USD / toe
Gas	120 USD / toe
Coal	70 USD / toe

Source: The GTAP 5.4 Database. Note: Energy input prices excl. taxes may differ between countries because of different levels of competition and transportation prices.

Crude oil is a dominating raw energy source, and the price of gas and coal closely follows the price of crude oil. Most of the fluctuations in the crude oil price are caused by the business cycle, political unrest in the Middle East and OPEC price manipulation, whereas the underlying trends are affected mainly by the world oil demand and supply. For these reasons, the energy prices are difficult to forecast, and they are likely to have significant influence on the allowance price. This topic will be subject to discussion and sensitivity analysis in the Final Analysis.

A.3 Carbon allowance trading

The important difference between the COWI-developed GTAP-ECAT and many other CGE models with energy substitution is the detailed treatment of (especially European) carbon allowance trading. Most models (including GTAP-E and GTAP-EG) implements emission reductions by applying a carbon tax or quota (the latter implies a shadow price of carbon emissions) for each region or selected groups of regions covering all sectors of the economy.

In the real world, only few firms emit carbon in quantities justifying the transaction costs of carbon market trading. For the rest of the economy it makes sense to let the government apply policy measures that reduce emissions, e.g. flexible mechanisms, a carbon tax or legislation promoting energy efficiency. In a perfect world the tax ought to mimic the carbon allowance price exactly to minimise the social costs of reduction. In the real world, however, the policy- maker faces choices about allocation of allowances to the trading firms and purchases of emission reductions in other countries. Imperfect knowledge and political restrictions may easily stop the carbon tax from matching the allowance price.

GTAP-ECAT accommodates the fact that (at least in Europe) carbon allowances will be traded only between a few energy-intensive sectors, the so-called Emission Trading Sectors (ETSe).[15] The rest of the emission reduction fulfilment will be achieved through taxation of the Non-Emission Trading Sectors (NTSe), including government and private consumption as well as governmental implementation of flexible mechanisms (i.e. JI, CDM and trade of flexible mechanisms according to specified rules). The ETSe may also undertake such trade to an extent specified by the modeller.

With this distinction between ETSe and NTSe, GTAP-ECAT can be used for analyses of the connection between allocation of allowances and the use of flexible mechanism credits. Social costs, allowance market prices and flows of allowances and money between the trading regions can also be evaluated.

[15] In the EU25 they are Petroleum Refineries, Iron&Steel, Non-metallic Minerals (cement), Paper-Pulp&Printing and Electricity&Heat generation.

Finally, some countries have chosen not to ratify the Kyoto treaty and thus have no reduction target. By choice of the modeller, GTAP-ECAT can analyse the effects of ratification and participation of these countries in the Kyoto efforts, e.g. a situation where the U.S. decided to participate in the Kyoto efforts.

A.3.1 Sectoral CO_2 emissions

In GTAP-ECAT, CO_2 emission is included as an additional primary factor of production (again, a scarce resource that cannot be produced, only used). The energy goods coal, gas and oil are modelled as composites of the actual energy type and CO_2 emissions. There is no substitution between the fossil fuel and CO_2 emissions (using the so-called Leontief technology), meaning that the energy type and CO_2 emissions will be demanded in fixed proportions. This resembles physical emission coefficients, whose magnitudes are shown in Table A.6.

Table A.6 Emission coefficients for the three fossil fuel types

	Coal	Oil	Gas
Emissions (kg CO2/GJ)	90.5	67.9	49.4

Source: GTAP-E model.

These emission coefficients are used together with the energy use of the specific sectors to determine the CO_2 emissions from each sector in each region. The coefficients used in here and in GTAP-E are average coefficients, reflecting both GTAP database energy use and actual emissions.

B Country and Sector Aggregations

B.1 Regions

Modelled regions

AUT	Austria
BLX	Belgium and Luxembourg
DNK	Denmark
FIN	Finland
FRA	France
DEU	Germany
GBR	United Kingdom
GRC	Greece
IRL	Ireland
ITA	Italy
NLD	Netherlands
PRT	Portugal
ESP	Spain
SWE	Sweden
CSK	Czech Republic and Slovakia
HUN	Hungary and Slovenia
POL	Poland
BAL	Baltic States
NOR	Norway
CHE	Switzerland
XEU	Other Europe and Former Soviet Union except Russia
RUS	Russia
CHN	China
IND	India
USA	United States and Australia
AX1	Japan, New Zealand and Canada
NIC	Newly Industrialised Countries
ROW	Rest of the World
AUT	Austria

Region mapping

AUS	Australia	USA
NZL	New Zealand	AX1
CHN	China	CHN
HKG	Hong Kong	CHN
JPN	Japan	AX1
KOR	Korea, Republic of	NIC
TWN	Taiwan	NIC
IDN	Indonesia	NIC
MYS	Malaysia	ROW
PHL	Philippines	NIC
SGP	Singapore	NIC
THA	Thailand	NIC
VNM	Viet Nam	ROW
BGD	Bangladesh	ROW
IND	India	IND
LKA	Sri Lanka	ROW
XSA	rest of South Asia	ROW
CAN	Canada	AX1
USA	United States	USA
MEX	Mexico	NIC
XCM	Central America and Caribbean	ROW
COL	Colombia	ROW
PER	Peru	ROW
VEN	Venezuela	ROW
XAP	rest of Andean Pact	ROW
ARG	Argentina	NIC
BRA	Brazil	NIC
CHL	Chile	NIC
URY	Uruguay	NIC
XSM	rest of South America	ROW
AUT	Austria	AUT
BEL	Belgium	BLX
DNK	Denmark	DNK
FIN	Finland	FIN
FRA	France	FRA
DEU	Germany	DEU
GBR	United Kingdom	GBR
GRC	Greece	GRC
IRL	Ireland	IRL
ITA	Italy	ITA
LUX	Luxembourg	BLX
NLD	Netherlands	NLD
PRT	Portugal	PRT
ESP	Spain	ESP
SWE	Sweden	SWE
CHE	Switzerland	CHE
XEF	rest of EFTA	NOR
ALB	Albania	XEU

BGR	Bulgaria	XEU
HRV	Croatia	XEU
CZE	Czech Republic	CSK
HUN	Hungary	HUN
MLT	Malta	XEU
POL	Poland	POL
ROM	Romania	XEU
SVK	Slovakia	CSK
SVN	Slovenia	HUN
EST	Estonia	BAL
LVA	Latvia	BAL
LTU	Lithuania	BAL
RUS	Russian Federation	RUS
XSU	former Soviet Union	XEU
CYP	Cyprus	XEU
TUR	Turkey	XEU
XME	rest of Middle East	ROW
MAR	Morocco	ROW
XNF	rest of North Africa	ROW
BWA	Botswana	ROW
XSC	rest of SACU	ROW
MWI	Malawi	ROW
MOZ	Mozambique	ROW
TZA	Tanzania, United Republic of	ROW
ZMB	Zambia	ROW
ZWE	Zimbabwe	ROW
XSF	rest of southern Africa	ROW
UGA	Uganda	ROW
XSS	rest of sub-Saharan Africa	ROW
XRW	rest of world	ROW

B.2 Sectors

Sectors modelled

agr	Agriculture
fpr	Food products
oil	Crude oil
col	Coal transformation
gas	Gas production and distr
p_c	Refined oil products
omn	Mining
twl	Textiles wearing apparel
lum	Lumber
ppp	Paper pulp and print
crp	Chemical industry
i_s	Iron and steel
nfm	Non ferrous metals

nmm	Non metallic minerals
trn	Transport equipment
ome	Other machinery
omf	Other manufacturing
ely	Electricity
cns	Construction
t_t	Trade and transport
ser	Public and private servi
dwe	Dwellings
agr	Agriculture

Sector mapping

pdr	paddy rice	agr
wht	wheat	agr
gro	cereal grains nec	agr
v_f	vegetables, fruit, nuts	agr
osd	oil seeds	agr
c_b	sugar cane, sugar beet	agr
pfb	plant-based fibers	agr
ocr	crops nec	agr
ctl	bovine cattle, sheep and	agr
oap	animal products nec	agr
rmk	raw milk	agr
wol	wool, silk-worm cocoons	agr
for	forestry	agr
fsh	fishing	agr
col	coal	col
oil	oil	oil
gas	gas	gas
omn	minerals nec	omn
cmt	bovine cattle, sheep and	fpr
omt	meat products	fpr
vol	vegetable oils and fats	fpr
mil	dairy products	fpr
pcr	processed rice	fpr
sgr	sugar	fpr
ofd	food products nec	fpr
b_t	beverages and tobacco pr	fpr
tex	textiles	twl
wap	wearing apparel	twl
lea	leather products	twl
lum	wood products	lum
ppp	paper products, publishi	ppp
p_c	petroleum, coal products	p_c
crp	chemical, rubber, plasti	crp
nmm	mineral products nec	nmm
i_s	ferrous metals	i_s
nfm	metals nec	nfm

fmp	metal products	ome
mvh	motor vehicles and parts	trn
otn	transport equipment nec	trn
ele	electronic equipment	ome
ome	machinery and equipment	ome
omf	manufactures nec	omf
ely	electricity	ely
gdt	gas manufacture, distrib	gas
wtr	water	omf
cns	construction	cns
trd	trade	t_t
otp	transport nec	t_t
wtp	water transport	t_t
atp	air transport	t_t
cmn	communication	ser
ofi	financial services nec	ser
isr	insurance	ser
obs	business services nec	ser
ros	recreational and other s	ser
osg	public admin. and defenc	ser
dwe	ownership of dwellings	dwe

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