Further development of a Computable General Equilibrium-Model for the long-run investigation of global impacts of GHG-mitigation policies

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Abstract:

The Paper presents NEWAGE, a Computable General Equilibrium modeling system, which was developed at the IER in Stuttgart. It comprehends a national, European and world component. The text gives a detailed description of the model features and focuses then on the world part NEWAGE-W. The model reveals interdependencies and spill-over effects of national GHG-abatement policies on a global level. Two additionally implemented scenarios represent the US rejection of the Kyoto-Protocol and consider the changed effective reduction targets induced by the COP6 negotiations in Bonn. The last part of the paper concentrates on the illustration of the planned further developments of the model.

Key words: Climate Change, CGE-model

1.Introduction:

The third assessment report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) confirmed the assumption of an anthropogenic factor in the occurrence of climate Change. However, the dissensions concerning an appropriate climate change policy remain. In March 2001 the president George W. Bush declared the US withdrawal from the Kyoto Protocol arguing that the fixed reduction targets in the Kyoto Protocol imply unacceptable high economic costs to the US, whereas no emission constraints are imposed to developing countries.

Another important event in the context of climate change were the agreements of the 6th Conference of the Parties (COP6) in Bonn in July 2001, which actually prepared the Protocol for its final ratification. The result of the negotiations led to a revised version of the Kyoto Protocol. The EU gave up its ‘hard position’ and accepted the application of carbon ‘sink’ credits. This led to effective weakening of initial reduction targets.

In the economic evaluation of climate change mitigation policies, the application of Computable General Equilibrium Models takes an important place. These types of models are especially suited to reveal spill over effect and interdependencies of policy measures, which are discussed and realized when dealing with climate change matters.

Therefore the Institute of Energy Economics and rational use of Energy (IER) developed a comprehensive CGE-modeling tool with the name NEWAGE. Due to its flexible structure it is open for the applications in the context of different policy issues and for the further developments to adopt it to the new or more complex problems.

In the next chapter I am giving a general introduction of the NEWAGE model. Afterwards, I am presenting a more detailed description of the world-component of the model, where we integrated in the current version of the NEWAGE-W component two additional scenarios, which intend to reflect the weakening of the reduction targets due to the agreements in Bonn and the rejection of any emission constraints by the US. Chapter 3 describes model structure, scenarios and results of the recent applications. In the last chapter I am presenting the further development we plan to realize within the framework of NEWAGE in the future.

2. NEWAGE – General Description

NEWAGE[1] is a computer-aided modelling system, which allows the investigation of the macroeconomic impacts of energy- and environmental policy measures. The name already indicates that it belongs to the group of General Equilibrium Models. This implies that the theoretical background of the model is based on the assumptions of the Arrow-Debreu-Equilibrium.[2]

This type of model is very suitable to estimate the changes on the allocation of scarce goods within an economic space induced by a policy measure.

NEWAGE is applicable to a wide range of problems thanks to its flexibility:

- *Flexibility in the regional dimension:* It is possible to adapt NEWAGE for the investigation of different regional levels. If the impacts on the German economy are of special interest, NEWAGE provides the 'D-component' as a research-tool. NEWAGE-EU enables to estimate the effects of national policy measures on trade relations and international competitive abilities within the European Union. Spill-over effects and interdependencies between economies on a global level are examined with the NEWAGE-W. Therefore, this module is very suited for the analysis of policies, which have a strong global aspect. The reduction quotas of GHG-Emissions, which have been proposed in the Kyoto Protocol and the instruments to reach these targets do not only affect the countries, which have an explicit reduction commitment in the Kyoto Protocol (Annex-B countries). Calculations with NEWAGE-W clarify the effect of the complex international relations even on those countries, which have no explicit emission limit according to the Kyoto Protocol (Non-Annex B countries).
  For the further development of NEWAGE we will focus on the World-Component. International policies for carbon abatement induce a clear burden sharing problem. This claims a more detailed investigation on a global level.

- *Flexibility on the sectoral dimension:* It's possible to apply NEWAGE with any disaggregation at the supply side (sectors of production) as well as at the demand side (differentiation of the households) corresponding to the matter of research.

- *Bottom-up – top down flexibility*
  One special quality of NEWAGE-D and NEWAGE-EU is the hybrid description of the production side of an economy: A partial analysis approach is applied to depict the energy

[1] The acronym stands for *National, European and Worldwide Applied General Equilibrium Modelling System*
[2] Zero profit condition, no excess demand and income balance (Shoven/Whally 1992).

sectors. The linear activity analysis (bottom-up) provides a more detailed description of the technological processes. This is especially important in the context of climate change policies, where the ability to replace high GHG emitting technologies to technologies with lower impacts on the environment plays a crucial role in the achievement of GHG reduction targets.
The non-energy sectors are represented ‘top-down’ by constant-elasticity-of-substitution (CES) functions, which are usually applied in Computable General Equilibrium models (CGE).
The hybrid approach combines the advantages of ‘top-down’ and ‘bottom-up’ analyses. The aggregated, macroeconomic specification of the economy reveals spill-over effects and interactions between special sectors and the economy as a whole. Due to its abstract form it reduces the complexity of the model. However, the ‘bottom-up’-representation maintains the complexity in these production fields, which are of special interest for the investigated problem.[3]

- *Flexibility on the temporal dimension*
  The adaptation to policy measures can be depicted by the assumption of static expectations of the economic agents. In the context of climate change policy analysis the evaluation of long-term developments is an important aspect. Therefore, a dynamic representation of adaptation processes provides a stronger analytical meaning than a simple static examination.
  The different components of NEWAGE allow the investigation of the economic reaction to a policy shock by either static or dynamic assumptions depending on the particular cases.

3. NEWAGE-W – Recent Application

3.1 Model structure

In its current version NEWAGE-W is a fully dynamic (intertemporal) CGE-model. The world is separated in thirteen regions.[4] The economic structure of each region consists of four production sectors, one non-energy sector and three fossil fuel sectors traded internationally for coal, gas and oil.[5] A country-specific price for coal and natural gas is defined by supply and demand in every region, but world supply and world demand determine the world price of oil. The energy prices of each country include taxes and subsidies. The carbon free backstop energy carrier is treated as a perfect substitute for the three fossil fuels. It is available in infinite supply at one price. This price is assumed to be a multiple of the world oil price in the benchmark year. So it establishes an upper bound on the world oil price.

The composite energy good is produced by fossil fuels (coal, gas and oil) through a nested CES technology. The input of the backstop resource is mapped by a Leontief production function. The production of the aggregated non-energy macro good is represented by a nested CES production technology. Inputs are labour, capital and the composite energy good. A CES transformation function determines the division of the macro good either for domestic use or for export.[6]

There is a distinction between the energy good, which is produced for the industry an the one, which meets the demand of the households. A representative agent performs final demand. This is

[3] For a hybrid description of production possibilities the general equilibrium problem has to be formulated in the complementary format (Boehringer 1998).
[4] See Table 3-1-1 Annex for a detailed description of the countries/regions.
[5] Table 3-1-2 Annex shows the sector-labels
[6] See Annex Figure 1 Annex for graphical depiction of the NEWAGE-W intermediate demand and production structure and Table 3-1-3 Annex for an overview of key elasticities.

composed of a consumption good – an aggregate between imports and domestically produced goods – and the energy good.[7] Households fund final demand by their endowments of labour, capital, energy specific resources and tax revenues.

International trade is based on the assumption of an Armington structure: Imports are not perfect substitutes for the domestically produced good. The possibility to substitute the imports for domestically produced goods is expressed by the Armington elasticity of substitution. International trade is admitted for energy as well as for the composite non-energy good. In the model the regions buy and sell one homogenous oil good in the world market. International capital flows reflect borrowing and lending at a world interest rate. They are determined endogenously subject to an intertemporal balance of payments considering no changes in net indeptedness over the entire model horizon.

In its current version NEWAGE-W covers a time perspective until 2030. It describes a Ramsey dynamic structure[8]. The representative agents posses a perfect foresight. For each region a representative agent maximizes the discounted utility over the entire time horizon and the investment behavior is fully forward-looking. The return on investment is balanced against the cost of capital. Hence, investment currency units are placed in the area, where they will receive the highest return. Primary factor inputs such as capital and energy yields the output of period t. Output is used for the consumption and investment. Investment augments the capital stock in the next period. Primary factors provide incomes, which can either be spend for the consumption or saving. Saving equals investment according to the identity, which is assumed generally in economic theory[9].

In the current version of NEWAGE benchmark data stem from the GTAP3 database and IEA energy statistics. The exogenous baseline assumptions for GDP-growth, energy production and consumption correspond to the POLES-model of the IEPE.[10] NEWAGE implements autonomous energy efficiency (AEEI) factors[11], which scale energy demand functions in order to match GDP forecasts with the projections of energy production.

Exogenous assumptions on fossil fuel production determine a reference emission level for the world. In the baseline world carbon emissions grow from 6 billion metric tons in 1990 to more than 11 billion metric tons by the year 2030. At the regional level emission limits induce a system of emission permits tradable within a country so that the marginal costs of abatement are equalized across domestic sources. The permit price is then equivalent to the domestic carbon tax, which would be necessary to achieve the given emission limit. Revenues from permits or likewise carbon taxes are refunded lump-sum back to the representative consumer in the abating country. Emission trajectories for each country imply the measure to which potential reduction obligations with respect to a base year (in the model: 1990) are binding for the future.

[7] See Figure 3-1-2 Annex for graphical depiction of the NEWAGE-W final demand structure
[8] See Pahlke 2000 for a comprehensive discussion of dynamic CGE-models. He integrated a model with overlapping generations in NEWAGE-D
[9] See Figure 3-1-3 Annex for a graphical depiction of the dynamics of NEWAGE-W
[10] Criqui 1998, p.5; see Table 3-1-4 for the GDP growth rates underlying NEWAGE-W in its prevailing form.
[11] AEEI capturers the rate of improvement in energy efficiency independent of price changes (see Mann/Richels 1990 for a detailed description of the AEEI)

3.2. Objectives and scenarios

NEWAGE-W in its current version was applied to evaluate welfare effects caused by international climate protection policies leading to international and national GHG-emissions reduction targets. The Kyoto Protocol imposes greenhouse gas emission constraints on industrialized countries (Annex B), whereas no limits apply for developing (non-Annex B) countries[12]. Reallocation of domestic resources in industrialized countries induces changes in the international market prices. Calculations with NEWAGE-W should give a more detailed insight in the possible burden-shifting processes from abating to non-abating countries caused by international trade relations.

For the abatement scenario the country-specific emission reduction targets stated in the Kyoto Protocol were adopted for the model[13]. It was assumed that carbon emissions in 2000 must not exceed 1990 levels and subsequently have to be cut back linearly yielding the respective Kyoto reduction target in 2010. Governments in abating countries apply carbon taxes sufficient to meet this exogenous emission reduction profile over time. Revenues were returned lump-sum to the representative agent in each abating country. For the period after 2010 carbon emissions of the industrialized countries were kept constant at 2010 levels. Appropriate to the Kyoto Protocol no emission constraints were imposed to non-Annex-B countries.

Since this last application of NEWAGE-W[14] the international negotiation process in the context of climate change policies at a global level has experienced a some basic changes. In March 2001 president Bush definitely refused the ratification of the Kyoto Protocol for the United States. To prevent the Kyoto Protocol from a total failure the Conference of the Parties in Bonn (COP6) in July 2001 adopted a revised version of the initial protocol.[15] Countries are now allowed to realize credits for carbon dioxide sinks.[16] This leads to an effective weakening of the originally stated emission reduction targets.

To reflect these new developments in NEWAGE, we implemented two additional scenarios in the model. For the scenario BON we replaced the initial Kyoto-reduction targets by the less restricting constraints derived from the negotiations in Bonn.[17] The BWU-scenario is calculated with the Bonn targets for all abating countries except USA. The reduction target for the USA was deleted. Like the non-Annex-B countries it is not confronted with any emission constraints.

NEWAGE-W allows to diversify the main scenario calculations by different assumptions according to some key parameters (sensitivity analysis). A more technological based representation of the energy sector is a main task for the further development of NEWAGE.[18] To get a first idea of the effects of different technological developments, we varied these core parameters, which implicit different assumptions on the existence and the price of non-carbon emitting technologies. The Projections of the world carbon emission paths and the costs of the fossil fuels replacing backstop technologies depend on these assumptions. To analyze the effects on the result we calculated the three abatement scenarios (KYO, BON and BWU) with different values for these parameter: We

[12] UN 1997: Kyoto Protocol
[13] The targets were applied to carbon dioxide as the most important GHG, other GHG were not considered.
[14] It was applied within the scope of the ‚Shared Analysis'-Project for the European Commission
[15] UN 2001.
[16] Sinks are areas of forests and farmland with an absorption-capacity for carbon dioxide.
[17] See Table 3-2-1 Appendix for the different emission reduction targets applied for the scenario KYO and the scenarios BON and BWU.
[18] See chapter 4.

run the model under the assumption of a middle, low or high emission path and with either high or low backstop costs.[19]

3.3. Results and conclusion

The calculations, which were carried out before withdrawal of the US and the revision of the initial commitments conveyed two broad insights: First, Kyoto targets involve significant economic costs for abating countries. Second, the actions of Annex-B countries produce substantial spill-overs to non abating countries. Emission reduction targets restrict fossil fuel input. This implies a less productive use of primary factors. The productivity loss associated with fuel shifting or energy savings translates into a welfare reduction.[20] Application of the decomposition method allowed a break-down of the full policy effect into the domestic policy effect (i.e., domestic adjustment abstracting from the changes in the international prices) and international spill-over-effects (i.e., changes in terms of the trades)[21]. The result confirmed that some of the abating countries are able to shift part of their economic burden to non abating countries.[22] Hence, emission targets do not only induce welfare loss in abating countries, but also in non-Annex B countries, which don't have an explicit reduction obligation according to the Kyoto Protocol.

The calculations with the new scenarios reproduce in principle the findings of the last model application.[23] The relaxation of the Kyoto-targets leads to mitigation of the welfare losses induced by the original Kyoto Protocol for all regions, Annex-B as non-Annex-B countries as well. The biggest amelioration accrues to those countries, which benefit the most from the possibility to use "sink"-credits to meet their emission constraints. The welfare measures of regions like Japan, New Zealand, Canada or the Former Soviet Union, which dispose over huge forest or agricultural areas differ the most in the BON compared to the KYO-scenario. These welfare gains can be traced back to the fact that lower reduction targets induce lower carbon taxes to reach the target. Compared to the KYO-scenario carbon taxes in the BON-scenario are noticeably lower for all abating countries.[24] Canada especially experiences a big improvement in the projection of its future marginal abatement costs[25].

The results of the BWU-scenario point out the relevance of international spill-over effects of the national abatement policies.[26] The rejection of the emission constraints does not only lead to welfare benefits for the US compared to the BON scenario with US reduction targets. The Latin and South American regions and Canada obtain an evident welfare increase due to lower production prices in the country of its most important trade partner. Another 'winner'-group of the US withdrawal from the Kyoto Protocol are the main exporters of fossil fuels, which profit by the increasing fossil fuel demand in the US. This explains the comparative big changes in the welfare measures of China and Middle East.

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[19] See Figure 3-2-1 Annex for the different emissions paths. For low backstop cost assumptions we set the oil-price multiplier to 4, a high backstop price is calculated with a oil-price-multiplier of 6.
[20] See Biggar/Bernstein/Montgomery/Rutherford for a comparison of different welfare measures.
[21] Product heterogeneity implied by the Armington assumption enables abating countries to pass of the increas of higher production prices to trading partners.
[22] See Kempfert/Fahl/Voss (2000) for a more detailed description of the results.-
[23] See Table 3-3-1 Annex for numerical results.
[24] See Table 3-3-2 Annex for marginal abatement costs of Annex-B countries in 2030.
[25] See Figure 3-3-1 Annex the marginal abatement cost path for Canada for each scenario.
[26] See Table 3-3-1 Annex for numerical results.

Consistent with the above described results scenarios based on a low carbon emission path in the baseline lead to a decrease of welfare loss in all represented regions.[27] Particularly developed countries with high emission levels like Japan, Europe or the US benefit from the assumptions of low emission developments.

The price of the backstop technologies shows a quite clear influence on the welfare measure under high world carbon emissions projections. A low backstop price decreases welfare losses compared to a high backstop price. The effect is getting sharper under the additional assumption of more restricting emission reduction targets (KYO-scenario)[28].

The results of the additional scenario calculations confirm the importance of spill-over effects and interdependencies in the context of climate change policies. Climate policy makers have to consider burden sharing problems even then when e.g. in the Kyoto Protocol, concrete reduction obligations are only imposed to the industrialized countries. Direct and indirect effects must also be taken into the account. To get a deeper insight in an international complexity and relations a more detailed regional dissagregation of the model might be helpful.

The main source of the welfare losses due to GHG-abatement policies lies in the increasing marginal abatement costs. The availability of the practicable and affordable less carbon-emitting technologies plays a crucial role in the future development of the world's carbon emission and, hence, in the development of GHG-mitigation costs in particular and the global economic development in general. The integration of a more technological based assumption in the economic context of global, intertemporal General Equilibrium Models is therefore an interesting challenge.

4. Further development

The above demonstrations showed that NEWAGE is already suitable to point out complex interrelations. But to adopt it to the new and more differentiated problems, the model requires some further developments.

- *Regional Disaggregation:* In a first step we plan to enlarge the regional dimension of the present model. The data for the 66 regions, which is provided by the GTAP5 database will be aggregated to about 30 regions. Background for this proceeding is the differentiated consideration of the members of the European Union. The initial Kyoto Protocol imposed a GHG-reduction target of -8%[29] to the EU as a whole. Additionally, in NEWAGE-W the EU is treated as one homogenous region with a unique emission target. In the Council of Ministers in June 1998, the individual Member States agreed to an 'EU burden sharing' mechanism, which distributed the overall target to the single countries. Actually, the 'burden sharing' agreement imposes quite different reduction levels to the individual Member States[30]. The results described above shows clearly the impacts of varying reduction targets and interdependent spill-over effects on the overall economic welfare. The consideration of each European country as a single region within a global context may yield to some interesting insight in mechanism and the impact of the European Burden sharing agreement. This question is especially interesting facing

[27] See Table 3-3-3 Annex for numerical results.
[28] See Table Annex 3-3-4 for numerical results.
[29] Percent of change in GHG-emissions for 2008 to 2012 relative to 1990 base year levels
[30] See Commission of the European Communities, p. 10 for a listing of the European reduction commitments

the fact that the Member States of the EU not only have varying emission targets but also show quite different tendency to reach these goals.[31]

- *Enlargement of the time-horizon until 2050 with a view to 2100:* We plan to extent the time horizon of NEWAGE to at least more than 20 years. Impacts of global warming as well as the effects of mitigation policies usually occur with a significant time lag. To include these long term effects in the model assumptions requires a sufficient dynamic perspective.
  Assumption of future development for the BAU-scenario are adopted from the IIASA B2-scenario of the IPCC TAR (Third Assessment Report), which provides estimations of the most important model-related quantities (GDP, population, carbon emissions, energy demand) until 2100.

- *Bottom-up description of the energy sector:* One special feature of NEWAGE-D and NEWAGE-EU is the hybrid approach[32], which allows a more technological based representation of a certain sector. The economic impacts of the environment and energy political measures depend crucially on the technological adaptability of an economy. So we attempt to integrate a more detailed and technological based mapping of the energy sector in NEWAGE-W also.

- *Link with a resource model:* NEWAGE in its present form already assumes that the depletion of the fossil fuel resources leads to the increasing fossil fuel prices under a constant demand. But the relation between depletion of a resource and the actual supply are ignored. The model does not consider the current stock of the resource in each period. Resource development is unquestionably a crucial aspect in the context of climate change. The availability of fossil fuels influences the price of the 'traditional' high carbon energy inputs. This can play an important part in the technological development and the commercial acceptance of the technologies, which are less harmful in the context of climate change. A stronger consideration of the resource depletion in the CGE-model is therefore an interesting issue. We will link NEWAGE to a Resource-model, which is developed at the IER also. At first the connection of the two models will be implemented over a soft link, which only implies a reciprocal data exchange. In the long run we plan an integration of the Resource model in NEWAGE.
  To facilitate the integration it is advisable to consider the later combination already at the short-run developments of NEWAGE.

[31] See EEA 2002 for the DTI (Distance-to-targets) of EU Member States
[32] See chapter 2

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Annex

Table 3-1-1: Countries/Regions in NEWAGE-W

Regions	
Labels	*Long name*
ASIA	India and other Asia (Republic of Korea, Indonesia, Malaysia, Philippines, Singapore, Thailand, China, Hong Kong, Taiwan)
AUS	Australia
CAN	Canada
CHN	China
EU15	European Union
FSU	Russia, Eastern and Central Countries
JPN	Japan
LSA	Latin and South America (Mexico, Argentina, Brazil, Chile, Rest of Latin America
MIDE	Middle East and North Africa
NZL	New Zealand
ROW	Other countries
SSA	Sub Saharan Africa
USA	United States of America

Table 3-1-2: Sectors in NEWAGE-W

Sectors	
Labels	*Long name*
COL	Coal
GAS	Natural gas
OIL	Crude oil
MACRO	Non-energy macro good aggregate

Figure 3-1-1: Intermediate Demand and Production Structure in NEWAGE-W

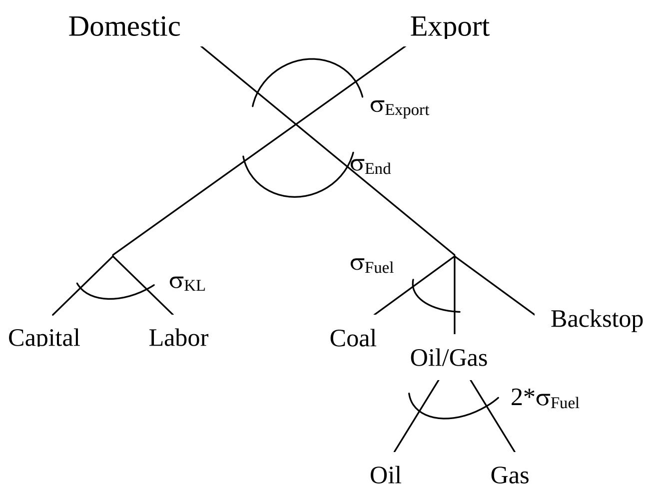


Table 3-1-3: Overview of key elasticities

Type of elasticity	*Description*	*Central Value*
Armington elasticity of substitution: $\sigma_{Armington}$	Degree of substitutability ➢ between macro imports from different regions ➢ between import aggregate and domestically produced macro good	 2 1
Armington elasticity of transformation: σ_{Export}	Degree of substitutability between macro good produced for the domestic market and macro good destined for export markets	2
Elasticity of fossil fuel supply:	Degree of response of international fossil fuel prices to changes in fossil fuel supply ➢ for coal ➢ for gas, oil	 1 4
Elasticity of substitution between non-energy and energy composite in production and final demand: σ_{End}	Value increases linearly over time to reflect empirical evidence on difference between short-run and long-run adjustment costs. ➢ for Annex B-countries ➢ for non Annex-B-countries	 0.25-0.5 0.20-0.4
Interfuel elasticity of substitution: σ_{Fuel}	Degree of substitutability between fossil fuels ➢ final demand ➢ intermediate demand: oil and gas ➢ intermediate demand: coal and oil-gas aggregate	 0.5 2 1

Figure 3-1-2: Final Demand Structure in NEWAGE-W

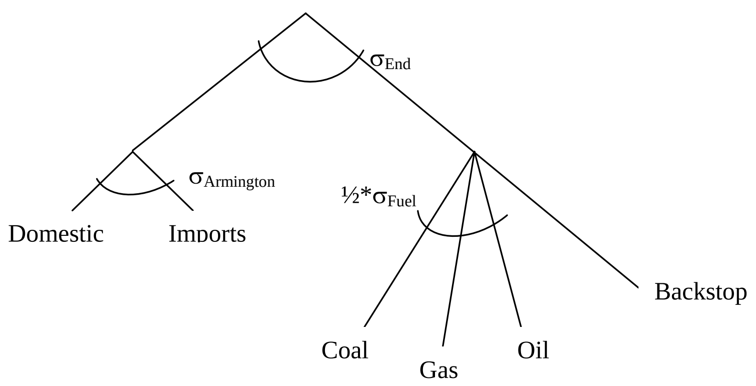
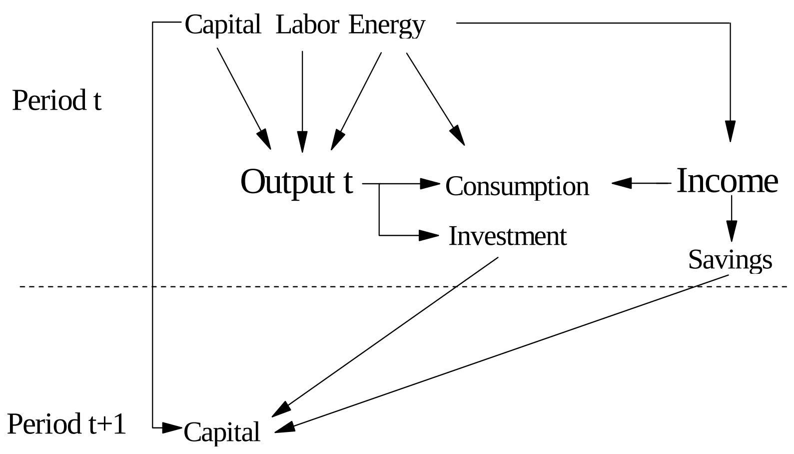


Table 3-1-4: GDP growth rates for the 13 regions (proceeded by POLES)[33]

	1992-2000	*2001-2005*	*2006-2010*	*2011-2015*	*2016-2020*	*2021-2025*	*2026-2030*
ASIA	4.7	4.4	4.4	3.9	3.9	3.3	3.3
AUS	2.7	3.6	3	3.2	2.7	2.7	2.7
CAN	2.7	2.4	2.4	2.1	2.1	1.7	1.7
CHN	8.8	8.4	5.0	4.0	4.0	3.2	3.2
EU15	2.1	2.3	2.3	1.9	1.9	1.5	1.5
FSU	-0.7	4.1	3.4	3.4	2.9	2.9	2.9
JPN	0.7	2.4	2.4	1.5	1.5	0.9	0.9
LSA	2.9	4.7	4.7	3.9	3.9	3.2	3.2
MIDE	4.2	4.6	3.7	3.6	3	3	3
NZL	2.7	3.6	3	3.2	2.7	2.7	2.7
ROW	2.8	3.3	2.9	2.9	2.5	2.5	2.5
SSA	3.6	4.4	3.6	4	3.3	3.3	3.3
USA	2.8	2.4	2.4	2.0	2.0	2.0	1.7

Figure 3-1-3: Dynamics of NEWAGE-W

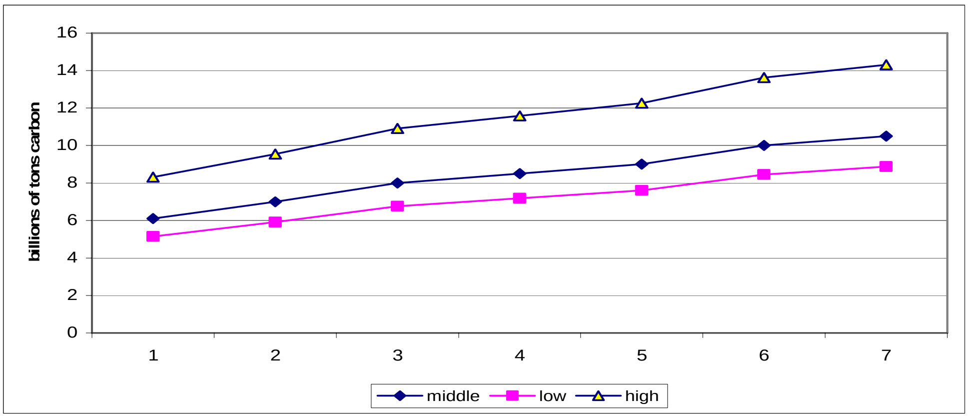


[33] Growth rates corresponding to the Poles-model (Criqui, 1998, p.5)

Table 3-2-1: GHG-Emission targets (% of 1990 base year emissions)

Region	***'Kyoto'-Targets***	***'Bonn'-Targets***[34]
JPN	0.94	0.992
USA	0.93	0.968
EU15	0.92	0.948
CAN	0.94	1.079
AUS	1.08	1.107
NZL	1.00	1.079
FSU	0.98	1.047

Figure 3-2-1: World carbon emissions paths



[34] Percent values according to Boehringer 2001

Table 3-3-1: Welfare Implications of the different abatement scenarios (in % Hicksian equivalent variation in lifetime income from baseline)

	KYO	*BON*	*BWU*
ASIA	-0,12	-0,10	-0,07
CHN	-0,60	-0,56	-0,32
EU15	-0,12	-0,07	-0,06
JPN	-0,01	0,03	0,02
LSA	-0,13	-0,10	-0,05
MIDE	-0,64	-0,55	-0,39
ROW	-0,05	-0,04	-0,06
SSA	-0,34	-0,29	-0,21
USA	-0,30	-0,20	-0,03
AUS	-0,39	-0,34	*-0,15*
NZL	-0,08	0,02	*0,05*
CAN	-0,43	-0,18	-0,06
FSU	0,00	0,01	-0,03

Key: KYO: Emission targets according to the initial Kyoto Protocol; US abating
BON: Emission targets according to the Bonn Conference; US abating
BWU: Emission targets Bonn; USA non abating

Table 3-3-2: Marginal abatement costs (carbon taxes) for abating countries in 2030 (in $ per ton carbon)

	KYO	*BON*	*BWU*
AUS	70	52	48
CAN	322	123	120
EU15	317	266	264
JPN	357	261	257
NZL	260	149	147

Figure 3-3-1: Marginal abatement costs (carbon taxes) for Canada (in $ per ton carbon)

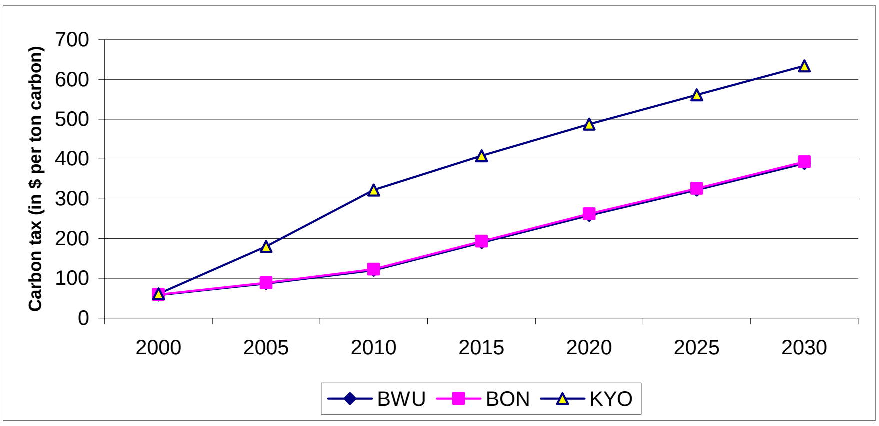


Table 3-3-3: Welfare Implications of the different abatement scenarios (in % Hicksian equivalent variation in lifetime income from baseline) in assumption of different world carbon emissions paths

	High carbon emissions path			*Low carbon emissins path*		
	KYO	***BON***	***BWU***	***KYO***	***BON***	***BWU***
ASIA	-0,15	-0,14	-0,10	-0,04	-0,02	-0,02
CHN	-0,68	-0,65	-0,37	-0,25	-0,17	-0,10
EU15	-0,36	-0,28	-0,26	0,05	0,05	0,05
JPN	-0,16	-0,09	-0,10	0,06	0,05	0,04
LSA	-0,22	-0,18	-0,09	-0,02	0,00	0,00
MIDE	-0,89	-0,80	-0,54	-0,17	-0,11	-0,08
ROW	-0,11	-0,10	-0,11	-0,01	0,00	-0,01
SSA	-0,48	-0,44	-0,30	-0,09	-0,05	-0,04
USA	-0,70	-0,53	-0,04	0,03	0,03	0,00
AUS	-0,61	-0,54	-0,28	-0,15	-0,09	-0,06
NZL	-0,39	-0,20	-0,14	0,07	0,02	0,02
CAN	-0,88	-0,45	-0,27	0,01	-0,01	0,00
FSU	-0,06	-0,05	-0,07	0,02	0,02	0,00

Table 3-3-3: Welfare Implications of the different abatement scenarios (in % Hicksian equivalent variation in lifetime income from baseline) in assumption of high and low backstop prices

	High backstop price			***Low backstop price***		
	KYO	***BON***	***BWU***	***KYO***	***BON***	***BWU***
ASIA	-0,15	-0,14	-0,10	-0,12	-0,11	-0,08
CHN	-0,68	-0,65	-0,37	-0,63	-0,61	-0,35
EU15	-0,36	-0,28	-0,26	-0,31	-0,24	-0,22
JPN	-0,16	-0,09	-0,10	-0,14	-0,08	-0,09
LSA	-0,22	-0,18	-0,09	-0,20	-0,17	-0,09
MIDE	-0,89	-0,80	-0,54	-0,86	-0,77	-0,52
ROW	-0,11	-0,10	-0,11	-0,10	-0,09	-0,09
SSA	-0,48	-0,44	-0,30	-0,46	-0,42	-0,28
USA	-0,70	-0,53	-0,04	-0,57	-0,44	-0,03
AUS	-0,61	-0,54	-0,28	-0,58	-0,52	-0,28
NZL	-0,39	-0,20	-0,14	-0,36	-0,20	-0,15
CAN	-0,88	-0,45	-0,27	-0,76	-0,42	-0,26
FSU	-0,06	-0,05	-0,07	-0,05	-0,04	-0,07