Between Liberalization and Protection: Four Long-term Scenarios for Trade, Poverty and the Environment

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Abstract

The impact of globalization on poverty and the environment was a central issue during the Doha development round table and the mass demonstrations on the streets of Cancun. This paper deals with the complex interaction between agricultural trade regimes, poverty and the environment given two key uncertainties. First, a world where Doha succeeds and globalization proceeds versus a world that moves to regionalism with a stronger orientation toward bilateral and regional trade agreements. Secondly, a world that focuses on economic incentives and economic growth and a limited role for the government versus a world where public and private institutions value also environment and ecology. In our analyses we quantify the impact of trade liberalization on developing countries and the environment. We found that liberalization leads to economic benefits. The benefits are modest in terms of GDP and unequally distributed among countries. Developing countries gain relatively the most. However, between 70 and 85 per cent of the benefits for developing countries is the result of their own reform policies in agriculture. South-South trade liberalization is key to the "development" part of this round. Liberalization can be helpful in gaining welfare; however uncoordinated liberalization can lead to unbearable pressures on the environment. In the liberalizing scenarios most of these shifts occur, indicating that liberalization should be performed with care. Trade liberalization will necessary have environmental consequences, which might be positive or negative for a region. What seems crucial is that environmental and trade agreements and policies must be sufficiently integrated or coordinated, to assure that they work together to improve the environment and attain the benefits of free trade.

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1. Introduction

The last few years the World Trade Organization (WTO) was often in the news because of failures in negotiations on liberalization. Mass demonstrations against globalization and free trade dominated the news and the alleged negative impact of free trade on environmental resources was a major theme during these demonstrations. On the other hand people demonstrated for free trade in agriculture because the high protection of agriculture in OECD countries is supposed to increase poverty in developing countries.

Given the expected beneficiary effects of liberalization, agriculture has been one of the major causes of discontent between developed and developing countries within the WTO. After a period of nearly 20 years of preparing, negotiating and implementing the Uruguay Round Agreement on Agriculture (URAA), subsidies and protection remained high, in particular in OECD countries. Therefore, developing countries indicated that any new trade round or multilateral trade agreement should particularly benefit the developing world to be meaningful. The first time that they were able to effectively express this view was in 1999 in Seattle. As each member country has one vote, the developing world claimed that any new WTO round should serve the objectives of the majority of the WTO members. Two years later in Doha, November 2001, consensus was reached on a mandate to dedicate the new round of trade liberalization to serve development and environment and produce an outcome that specifically benefits the developing world.[1] However, in September 2003, the Fifth WTO Ministerial in Cancun failed to reach an agreement. The first key question is if and how the discussions and negotiations in the WTO Doha Round can be revitalized and whether a successful outcome is possible.

In contrast with the high media attention academic studies that deal with the complex relation between trade liberalization and environmental resources are very limited. The effects of trade on the environment may be due to scale, structure, technology and other factors (Nordstrom and Vaughan, 1999). Scale and size effects from trade liberalization may induce an increase in production which might be negative for the environment because it uses resources valuable to environment and it may be accompanied by increases in waste products that must be disposed in the environment. On the other hand, trade can be good for conservation and environment through the “environmental Kuznets curve” – trade stimulates economic growth, and richer people demand more conservation of stocks and protection of the environment which higher income countries can now afford to protect (Antweiler et al. 2001). Studies of trade and the environment have produced mixed results (Huang and Labys, 2001). Economists argue that when there are negative results the right response in such cases is to address the underlying problem through domestic regulation or environmental treaties and not to restrict trade (see, Bulte and Barbier, 2004). A second key question is whether the political climate is such that institutions can be created to deal with the possible negative impact on environment.

The goal of this paper is to deal with the complex interaction between trade, environment and poverty given the uncertainties related to the two key questions. We combine these future uncertainties in one consistent modeling framework, quantify and analyze the long-term economic and environmental consequences of different scenarios. In 2000 the Intergovernmental Panel on Climate Change (IPCC) published four long-term greenhouse gas emission scenarios (see Special Report on Emission Scenarios (SRES; Nakicenovic et al.,

[1] In the discussions and on-going negotiations afterwards, this mandate has been referred to as the Doha Development Agenda.

2000). These scenarios cover a range of driving forces such as from demographic and to socio-economic development and the technological progress and form the basis for our scenario analysis of four agricultural futures. To be able to perform region-specific analyses in developing regions, which are necessary to assess whether domestic agricultural reform and international trade liberalization can reduce poverty in developing countries, we used the further translation of the SRES scenarios performed by the Central Planning Bureau of the Netherlands (CPB, 2003).

To perform the analysis a consistent modeling framework was constructed, existing of an economic model (GTAP) and a more ecological-environmental based model framework (IMAGE). GTAP is a general equilibrium model of the Global Trade Analysis Project (GTAP, Hertel, 1997). The Integrated Model to Assess the Global Environment (IMAGE; Alcamo et al., 1998; IMAGE Team, 2001) is a dynamic integrated assessment modeling framework for global change. The main objective of IMAGE is to support decision-making by quantifying the relative importance of major processes and interactions in the society-biosphere-climate system.[2]

In our analysis we focus on the influence of the trade liberalization policies on the developing countries, since recent studies (e.g. World Bank; 2003, OECD, 2003a) suggest that domestic agricultural reform and international trade liberalization is recognized as a key strategy to bring economic benefits and reduce poverty in developing countries.

So far not many studies assessed the environmental consequences of different liberalization futures. The OECD is one of the few organizations that examine the environmental implications of subsidy reform and trade liberalization qualitatively (OECD 2003b; OECD 2003c). The relationship between trade liberalization, agriculture and the environment is complex. Estimations of the effects on an aggregate basis must rely largely on stylized observations, like has been done in this study. The aggregate environmental impacts of trade growth can in theory be measured by the sum of: (a) allocative efficiency effects; (b) scale of economy; (c) output composition; (d) technology effects, and (e) changes in environmental policies. An important effect of the farming sector on biological diversity revolves around issues of land-use change: habitat alteration, degradation or fragmentation linked with an expansion, contraction or shift in the characteristics of arable land. In addition to land use change, the adoption of production intensification methods has important impacts on the environment. Examples include the reliance on a narrow and homogenous range of plant genetic resources for the bulk of the world's food outputs, or impacts linked to capital inputs, including farm machinery or the use of fertilizers and pesticides. Each of these characteristics has important implications for biological diversity (UNEP, 2002). In this study we restrict the environmental analysis to changes in land cover, changes in pressures on land-use and changes in biodiversity.

In Section 2, we elaborate on the scenarios and the methodology used to assess the economic and environmental consequences. In Section 3 we show the economic and environmental consequences of the scenarios. We pay special attention to the contribution of trade and domestic policies and to the impact on developing countries. Section 4, discusses the most important conclusions of our study.

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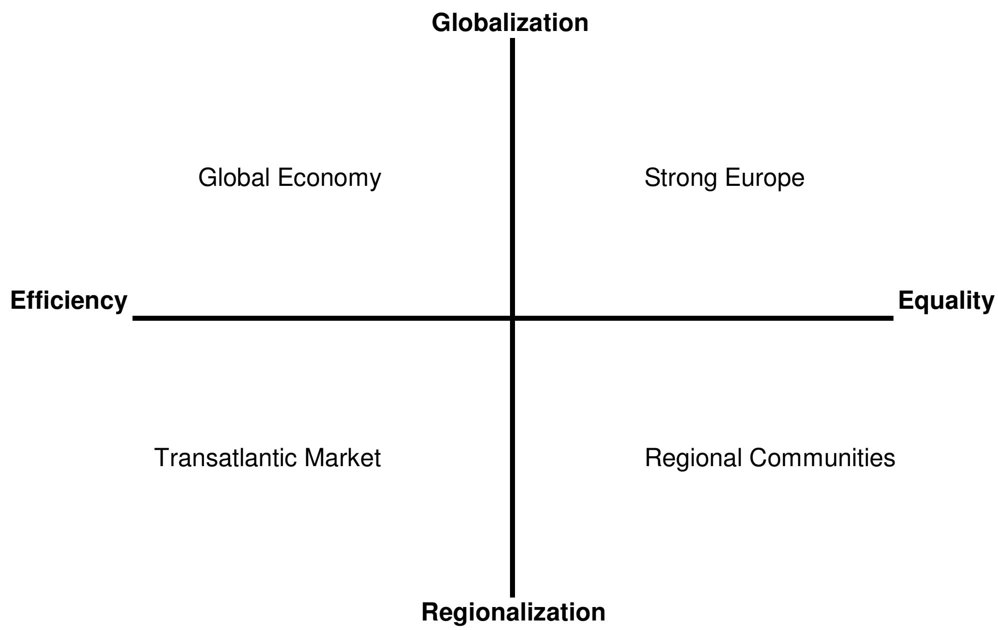
[2] IMAGE was also used for the recent SRES scenarios and for the scenario analyses in the Global Environment Outlook of UNEP (GEO-3, 2002).

2. Methodology

2.1 Scenarios

The four scenarios, developed to assess the economic and environmental consequences of different liberalization options deal with two key uncertainties. First, a world where Doha succeeds and globalization proceeds versus a world that moves to regionalism with a stronger orientation toward bilateral and regional trade agreements. Secondly, a world that focuses on economic incentives and economic growth and a limited role for the government versus a world where public and private institutions value also environment and ecology.

Figure 1. Four scenarios in a nutshell (see CPB, 2003)



Our scenarios are an elaboration of the four emission scenarios of the IPCC, as published in its Special Report on Emission Scenarios (SRES; Nakicenovic et al., 2000). The two axes lead to a world that can evolve in four different directions, depending on people's dominant drivers and world visions. The rationale for these four scenarios is based on the acknowledgement that different worldviews exist and that it is impossible to predict which world vision will become dominant. A globalized world that is totally focused on material wealth and economic growth is as much as likely as a regionalized world where local cultural values are cherished and where equity and sustainability are the highest values. Therefore, these four SRES scenarios will lead not only to different economic development paths and structural changes but also to totally different emission profiles and hence, to different temperature pathways and environmental consequences (IPCC, 2001; IMAGE-team, 2001). In 2003, CPB published a detailed revision of the IPCC scenarios with focus on Europe, but also with more regional and sectoral disaggregation (CPB, 2003). These scenarios enable us to perform region and sector specific analyses. Moreover, for these scenarios climate policies are implemented and the consequences for climate change are assessed (Bollen et al., 2004), which enable us to use the climatic consequences as one of the environmental pressures on the land system. We turn now to a more detailed description of each of the four scenarios (see Figure 1). Table 1 describes two key indicators of each scenario: (i) the implied macro economic growth rate of GDP

(CPB, 2003) and (ii) the population growth rate (IMAGE implementation of the SRES scenarios, 2001).

The Global Economy (equivalent of A1 of SRES) scenario assumes multilateral cooperation on economic issues and the WTO negotiations are successfully. Global trade will be fully liberalized and a successful economic integration in Europe results in further eastwards EU enlargement (including Turkey and some former Soviet Union states like Ukraine and Belarus). Global integration puts poor countries on a path of catching up and high growth. Technological change is high and driven by economic profit and not directed to or hampered by planet and people considerations (GMOs are accepted, little environmental restrictions). As the result the rapid economic development accompanied by fast population growth is expected in this scenario. Contrary to economic integration, international cooperation in non-trade issues fails, which may lead to environmental problems.

Similarly, to the Global Economy scenario, the Strong Europe (equivalent of B1 of SRES) scenario assumes that international cooperation is successfully and trade will be liberalized. However, society values not only consists of profit but also people and planet (e.g. climate change). This implies that contrary to the GE scenario domestic support in agriculture will partly be sustained because subsidies will be linked to nature and environment. Technological change is directed to both economic and non-economic targets. This leads to lower productivity growth in economic terms and a lower economic development than in Global Economy scenario. Catching up in poor countries is high because rich people are concerned with reducing poverty (people dimension).

Table 1: Macro assumptions (% growth per year)

	GDP				Population			
	Global Economy	Strong Europe	Transatlantic Market[3]	Regional communities	Global Economy	Strong Europe	Transatlantic Market	Regional communities
Western Europe	2.6	1.8	2.2	1.0	0.33	0.33	0.13	-0.05
Eastern Europe	3.7	3.6	3.0	2.1	-0.05	-0.05	0.03	-0.12
Canada	2.8	2.2	2.2	1.8	0.58	0.58	0.62	0.66
USA	3.0	2.4	3.0	2.0	0.80	0.80	0.91	0.72
Oceania	2.5	1.9	1.9	1.5	0.29	0.29	0.39	0.37
Japan	1.6	0.9	1.2	0.7	0.04	0.04	0.01	-0.02
East Asia	6.1	5.3	3.7	4.8	0.43	0.43	1.07	0.61
Southeast Asia	4.8	4.2	2.9	3.8	0.91	0.91	1.34	1.06
South Asia	7.1	6.6	4.1	5.4	1.32	1.32	1.57	1.37
Central America	4.0	3.8	2.0	3.1	1.09	1.09	1.61	1.12
South America	3.7	3.5	1.7	2.8	1.09	1.09	1.61	1.12
Former USSR	3.7	3.4	3.3	1.9	0.07	0.07	0.37	-0.08
Turkey	4.2	4.2	2.6	3.3	1.78	1.78	2.14	1.65
Middle East	4.2	4.2	2.6	3.3	1.78	1.78	2.14	1.65
Northern Africa	5.0	5.0	3.2	3.9	1.70	1.70	2.11	1.65
Central Africa	7.9	8.5	6.6	5.5	3.53	3.53	3.78	3.86
Southern Africa	4.8	5.4	3.9	2.9	2.23	2.23	2.42	2.48

[3] The economic results are different from CPB (2003), since results from a sensitivity run are used where Latin America will not become member of the EU – US trade block. Latin America is kept out of this trade block to assess the consequences of different major agricultural trade blocks that are not co-operating.

In Transatlantic Market scenario (equivalent of A2 of SRES) the focus is on the one hand on markets and economic incentives and on the other hand national interests prevails. Multilateral trade liberalization fails and the United States and EU are pursuing their own interest by creating a Trans-Atlantic internal market. The economic focus implies high tech change in developed countries and especially in countries that join the transatlantic market. Technological change is lower in developing countries whose markets become more segmented and separated. This yields welfare gains in EU and the United States in contrast with poverty in Eastern Europe and developing countries. This is accompanied by slow population growth in industrial countries and fast population growth in developing countries due to continuing poverty.

In Regional Communities (equivalent of B2 of SRES) scenario the focus is on both economic and non-economic values, but national interests prevail. Trade and agricultural polices remain almost unchanged, except for export subsidies that are abolished because this kind of "dumping" is socially not accepted. EU integration is only partial and technological change is limited because of segmented markets and the focus on non-economic issues (GMOs not allowed, environment important). The resulting economic growth is lower than in other scenarios. Social values lead to catching up of developing countries because they can adopt existing technologies from developed countries.

We followed the IPCC storylines to implement specific trade liberalization and agricultural policies (see Table 2). These policies are in line with the two axes as discussed above and are considered possible directions of coming WTO rounds. A detailed description of all the scenario assumptions is given the Table A5 of the Annex.

Table 2. Four scenarios for global agriculture and liberalization

	Base situation	Global Economy	Strong Europe	Transatlantic Market	Regional Communities
Export subsidies	EU Agenda 2000	Abolished	Abolished	No change	Abolished
Import tariffs		Abolished	Abolished	No change	No change
Domestic support		Abolished	-/-50% linked to env. and social targets	No change	+10%, linked to env. and social targets
Trade blocks		Turkey, FSU accede EU	Turkey, FSU accede EU	EU-USA	FTAA (North + South America)
Sugar and milk quota (EU25)		Abolished	Abolished	Self sufficient EU	Self sufficient EU
Non trade concerns	situation 1997		Global SPS & TBT leading to 2.5% price increases in all countries except EU and Japan		Different SPS and TBT between trade blocks: increase non tariff barriers with 10%

2.2 The modeling framework

A modeling framework based on two models, GTAP and IMAGE, is used to obtain the economic and environmental impact of the scenarios. GTAP - the multiregion, multisector, computable general equilibrium model - is used to access the economic consequences of the scenarios, including effects of specific policies[4]. IMAGE - a dynamic integrated assessment

[4] For a methodological classification of applied economic models, see Tongeren, Meijl and Surry (2001).

modeling framework for global environmental changes - use the GTAP outcomes to calculate land use changes and environmental consequence. Simultaneous use of these models makes it possible to translate qualitative scenario story lines to model related shocks and then to mutually consistent economic and environmental quantitative results. Figure 4 gives an overview of this modeling framework. In the next two sub-sections, the GTAP and IMAGE models are briefly described. Subsection 2.2.3 describes the scenario implementation and the linkage of the models.

2.2.1 GTAP

The economic analysis is carried out with an extended version of the general equilibrium model of the Global Trade Analysis Project (GTAP; Hertel, 1997). The standard model is characterized by an input-output structure (based on regional and national input-output tables) that explicitly links industries in a value added chain from primary goods, over continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption. In the model, a representative producer for each sector of a country or region makes production decisions to maximize a profit function by choosing inputs of labor, capital, and intermediates to produce a single sectoral output. In the case of crop production, farmers also make decisions on land allocation. Intermediate inputs are produced domestically or imported, while primary factors cannot move across countries. Markets are typically assumed to be competitive. When making production decisions, farmers and firms treat prices for output and input as given. Primary production factors land and capital are fully employed within each economy, and hence returns to land and capital are endogenously determined at the equilibrium, i.e., the aggregate supply of each factor equals its demand.

Prices on goods and factors adjust until all markets are simultaneously in (general) equilibrium. This means that we solve for equilibria in which all markets clear. While we model changes in gross trade flows, we do not model changes in net international capital flows. Rather our capital market closure involves fixed net capital inflows and outflows. To summarize, factor markets are competitive, and labor and capital are mobile between sectors but not between regions.

Taxes and other policy measures are included in the theory of the model at several levels. All policy instruments are represented as *ad valorem* tax equivalents. These create wedges between the undistorted prices and the policy-inclusive prices. Production taxes are placed on intermediate or primary inputs, or on output. Trade policy instruments include applied most-favored nation tariffs, antidumping duties, countervailing duties, price undertakings, export quotas, and other trade restrictions. Additional internal taxes can be placed on domestic or imported intermediate inputs, and may be applied at differential rates that discriminate against imports. Where relevant, taxes are also placed on exports, and on primary factor income. Finally, where relevant (as indicated by social accounting data) taxes are placed on final consumption, and can be applied differentially to consumption of domestic and imported goods.

For the purpose of the study the standard GTAP model is extended with a quota module in GTAP (see, Meijl and Tongeren 2003). In our model both the EU milk quota and the sugar quota are implemented at the national level. Technically, this is achieved by formulating the quota as a complementarity problem. This formulation allows for endogenous regime switches from a state when the output quota is binding to a state when the quota becomes non-binding. In addition, changes in the value of the quota rent are endogenously determined.

The data come from a number of sources. Data on production and trade are based on national social accounting data linked through trade flows. These social accounting data are drawn directly from the most recent version of the Global Trade Analysis Project (GTAP) data set, version 5.3 (Dimaranan and McDougall, 2002). The GTAP version 5 data set is benchmarked to 1997, and includes detailed national input-output, trade, and final demand structures. The basic social accounting and trade data are supplemented with trade policy data, including additional data on tariffs and non-tariff barriers. The data on tariffs are taken from the WTO's integrated database, with supplemental information from the World Bank's recent assessment of detailed pre- and post-Uruguay Round tariff schedules and from the UNCTAD/World Bank WITS data set. All of this tariff information has been concorded to GTAP model sectors. The social accounting data have been aggregated to 14 sectors (see Table 3). The sectoral aggregation distinguishes 11 agro-food sectors and 3 non food sectors as the study concentrates on the agricultural sector and land-use. To analyse the impact on developing countries and to be consistent with the IMAGE aggregation we distinguish 22 countries or regions (see Table 3 and Table A1 in the Annex).

Table 3: Regional and sectoral aggregation

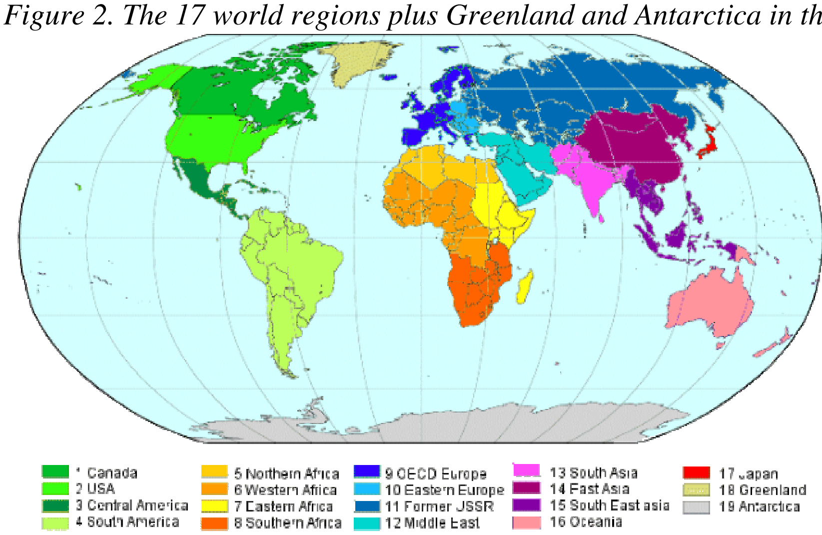
Model country/region	Acronym	Model sector	Acronym
The Netherlands	Netherlands	Rice	Rice
Rest of U15	R_EU15	Grains	Grains
CEEC accessing counties	CEEC_EU	Sugar beets and sugar	Sugar
Rest of CEEC	Baltic	Oils	Oils
Baltic countries	R_CEEC	Horticulture	Horticulture
Rest of Europe	R_EUROPE	Other crops	Other_crops
Canada	Canada	Cattle, sheep, goats (incl. meat)	Cattle_SG
USA	USA	Pigs and poultry (incl. meat)	Pigs_Poultry
Oceania	Oceania	Dairy	Dairy
Japan	Japan	Other Agriculture	OtherAgri
East Asia	E_Asia	Processed food	Proc_food
South-East Asia	SE_Asia	Mining	Mining
South Asia	S_Asia	Manufacture	Manufacture
Central America	C_America	Services	Services
South America	S_America		
Former Soviet Union	USSR		
Turkey	Turkey		
Middle East	M_EST		
North Africa	N_Africa		
Central Africa	M_Africa		
South Africa	S_Africa		
Rest of the World	R_World		

2.2.2 IMAGE

The Integrated Model to Assess the Global Environment (IMAGE) is a dynamic integrated assessment modeling framework for global environmental change. The main objectives of IMAGE are to contribute to scientific understanding and support decision-making by quantifying the relative importance of major processes and interactions in the society-biosphere-climate system. In the standard IMAGE 2.2 framework the general equilibrium economy model, WorldScan, and the population model, PHOENIX, feed the basic information on economic and demographic developments for 17 world regions (see Figure 2) into three linked subsystems (see Figure 3):

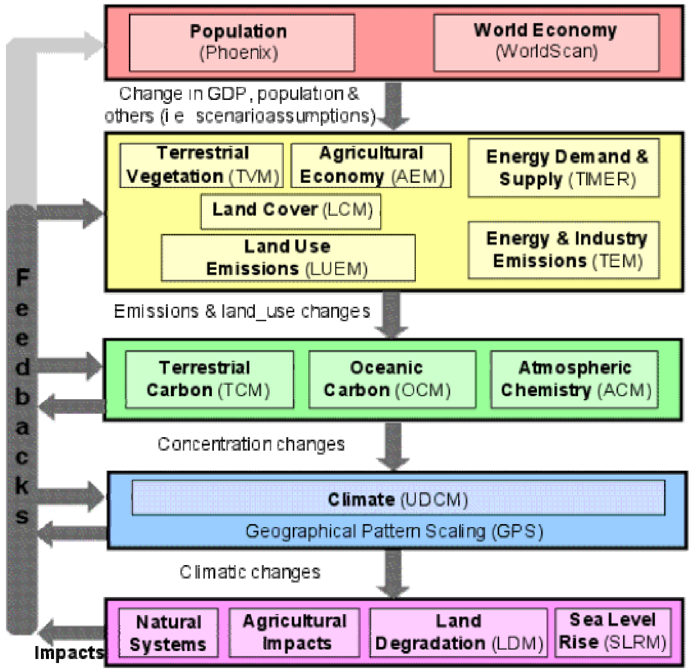
- The Energy-Industry System (EIS), which calculates regional energy consumption, energy efficiency improvements, fuel substitution, supply and trade of fossil fuels and renewable energy technologies. On the basis of energy use and industrial production, EIS computes emissions of greenhouse gases (GHG), ozone precursors and acidifying compounds.
- The Terrestrial Environment System (TES), which computes land-use changes on the basis of regional consumption, production and trading of food, animal feed, fodder, grass and timber, with consideration of local climatic and terrain properties. TES computes emissions from land-use changes, natural ecosystems and agricultural production systems, and the exchange of CO_2 between terrestrial ecosystems and the atmosphere.
- The Atmospheric Ocean System (AOS) calculates changes in atmospheric composition using the emissions and other factors in the EIS and TES, and by taking oceanic CO_2 uptake and atmospheric chemistry into consideration. Subsequently, AOS computes changes in climatic properties by resolving the changes in radiative forcing caused by greenhouse gases, aerosols and oceanic heat transport.

Figure 2. The 17 world regions plus Greenland and Antarctica in the IMAGE model



In this study we focus our analysis on the output of the terrestrial models (the Terrestrial Vegetation Model and the Land Cover Model) of the IMAGE framework to analyze the environmental consequences of the different agricultural futures. The Terrestrial Vegetation Model (TVM) simulates the potential distribution of natural vegetation and crops on the basis of climate conditions and soil characteristics on a spatial resolution of 0.5 degree latitude by 0.5 degree longitude. It also estimates potential crop productivity, which is used by Land Cover Model (LCM), to determine the allocation of the cropland to different crops. First, TVM calculates 'constraint-free rainfed crop yields' accounting for local climate and light attenuation by the canopy of the crop considered (FAO, 1981). The climate-related crop yields are adjusted for grid-specific conditions by a soil factor with values ranging from 0.1 to 1.0. This soil factor takes into account three soil quality indicators: (1) nutrient retention and availability; (2) level of salinity, alkalinity and toxicity; and, (3) rooting conditions for plants. The adjustment factor is calibrated using historical productivity figures and also includes the fertilization effect of changes in the atmospheric concentration of CO_2. The CO_2 concentration is determined by the Terrestrial Carbon Model (TCM) model that distinguishes different parameter settings per land cover type (Leemans et al., 2002). The resulting crop productivity, called 'reduced potential productivity of crops', is used in the land-cover model.

Figure 3. Flow diagram of the IMAGE framework



The objective of the Land Cover Model (LCM) is to simulate global land-use and land-cover changes by reconciling the land-use demand with the land potential. The basic idea of the LCM is to allocate gridded land cover within different world regions until the total demands for this region are satisfied. The results depend on changes in the demand for food and feed as computed by the Agricultural Economy Model (AEM) and by changes in the potential vegetation and yield as simulated by the Terrestrial Vegetation Model (TVM). In this analysis the results from AEM come from GTAP. The allocation of land-use types is done at grid cell level on the basis of specific land allocation rules like crop productivity, distance to existing agricultural land, distance to water bodies and a random factor (Alcamo et al., 1998).

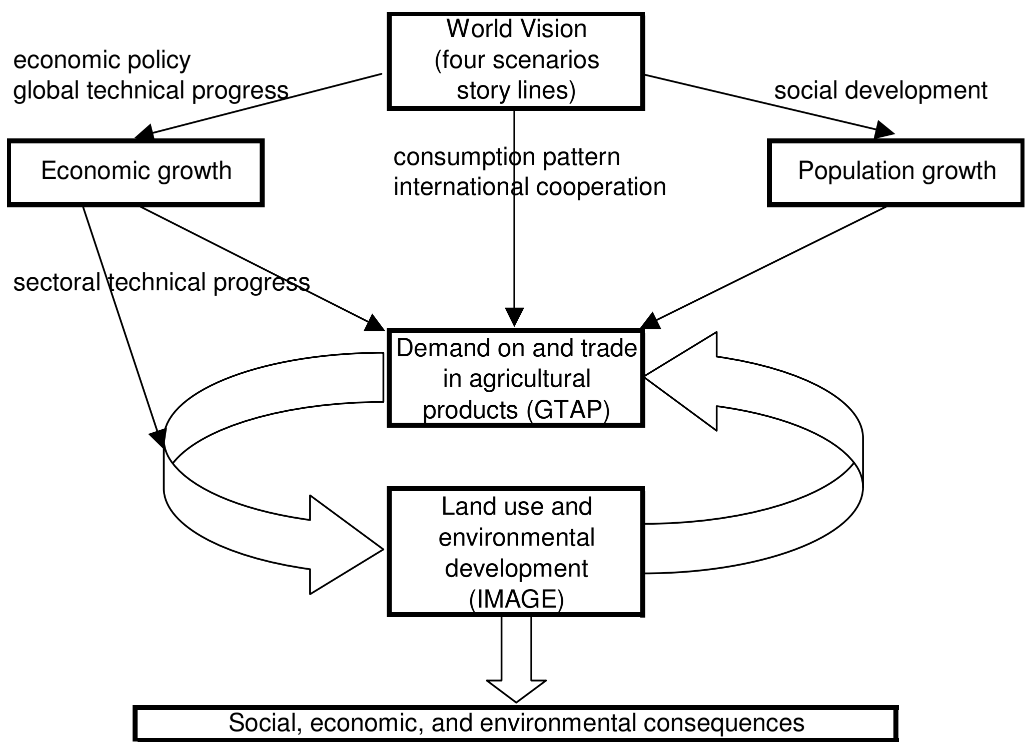
IMAGE uses the historical data for the 1765-1995 period to initialize the carbon cycle and climate system. Simulations cover the 1970-2100 period. Data for 1970-1995 are used to calibrate EIS and TES sub-systems. Simulations up to the year 2100 are made on the basis of scenario assumptions on, for example, demography, food and energy consumption and technology and trade.

2.2.3 Model linkage and scenario implementation

In Figure 4, the linkages between GTAP and IMAGE are visualized. The consequences for the energy system are taken from Bollen et al. (2004). The consequences for the agricultural system, on the basis of the assumptions shown in Table 1 and 2, are calculated by GTAP. The output of GTAP is, among others, sectoral production growth rates. These are in turn used by IMAGE model to calculate the demand for land. This in fact means the GTAP is replacing the Agricultural Economy Model (AEM) of IMAGE. Using this GTAP input, IMAGE calculates the land demand and environmental indicators. The land demand from IMAGE is compared with GTAP calculations. In case of differences, the land growth assumptions in GTAP model are changed to achieve consistent results.

The comparative static GTAP model has been used to generate four projections for 1997-2030 based on the four scenarios. The projections are constructed through recursive updating of the database such that exogenous GDP targets are met, and given exogenous estimates on factor endowments -skilled labor, unskilled labor, capital and natural resources- and population. For this procedure see Hertel et al. (1999), the exogenous macro assumptions are from CPB (2003, see Table 1). It is assumed that the employment growth rate is equal to population growth and that growth rates of capital and natural resources are equal to GDP growth rate and 75% of GDP growth rate respectively. TFP growth depends on scenario characteristics. Productivity growth in the crop sectors is exogenous and scenario specific assumptions are based on deviations (see annex Table A4) of the FAO yield projections (FAO, 2003, annex Table A3). TFP for non-crop sectors is endogenous and scenario specific, but conform the method used by CPB (CPB, 2003) common trends for relative sectoral TFP growth are introduced.

Figure 4. The modeling framework of GTAP and IMAGE



The FAO crop yields are also used for the Land Cover Model of IMAGE. A key aspect of the Land Cover Model is that it uses a crop- and regionally-specific management factor (MF) to represent the gap between the theoretically feasible crop yields simulated by the crop production model, and the actual crop yield which is limited by less than optimal management practices, technology and know-how. Regional management factors are used to calibrate the model to regional estimates of crop yields and land-cover for the period 1970-1995 from FAO. For years after 1995 the management factor is a scenario variable, which is generally assumed to increase with time as an indication of the influence of technological development on crop yields. In this analysis we used the same estimates of the productivity increases from

FAO as was used in our GTAP calculations (FAO, 2003). In the four scenarios we deviated from these productivity growth estimates on the basis of regional GDP growth.

Land use is assumed to be endogenous between boundaries. Boundaries are taken from FAO (2003) World agriculture towards 2015/2030 (see Table 5).[5] This mechanism is implemented as a complementarity problem. Within the boundaries we assume that real land prices (relative to consumer price index) are fixed for developed countries and for developing countries we assume that the land price is fixed relative to the price of unskilled labor. If land growth hits a boundary than land prices are free to adjust for these regions. Regions where land use is bounded are indicated by "yes" in Table 5. We used the assumption concerning land growth rates to achieve the consistency between GTAP and IMAGE results.

Table 5: Land growth assumptions (% growth per year)

Region	Bounds		Land on limit			
	Min.	Max.	Global economy	Strong Europe	Transatlantic. Market	Regional communities.
Netherlands	-0.87	-0.87	Yes	Yes	Yes	Yes
R_EU15	-0.43	No	Yes	Yes		
CEEC_EU	No	No				
Baltic	No	No				
R_CEEC	No	No				
R_EUROPE	-0.12	No	Yes	Yes		Yes
Canada	0.00	No				
USA	0.00	No				
Oceania	-0.42	No				
Japan	-2.46	No				
E_Asia	No	0.13	Yes	Yes	Yes	Yes
SE_Asia	No	1.17	Yes	Yes	Yes	Yes
S_Asia	No	0.76	Yes	Yes	Yes	Yes
C_America	No	1.33	Yes	Yes	Yes	Yes
S_America	No	1.88				
USSR	No	No				
Turkey	No	0.59	Yes	Yes	Yes	Yes
M_EST	No	1.33	Yes	Yes	Yes	Yes
N_Africa	No	1.03	Yes	Yes	Yes	Yes
M_Africa	No	1.77	Yes	Yes	Yes	Yes
S_Africa	No	1.95	Yes	Yes	Yes	Yes
R_World	-0.87	-0.87	Yes	Yes	Yes	Yes

As we mentioned above, the results from GTAP are used to replace Agricultural Economy Model (AEM) in IMAGE. There are several advantages of such an approach. Firstly, GTAP is a global model describing the whole economy and not only the agricultural sector as in the terrestrial system of IMAGE. Therefore using GTAP we can model non-agricultural sectors impact on the agriculture. Secondly, GTAP allows a more complex modeling of trade flows than AEM, which calculate trade flows base on self-sufficiency ratios. Finally, GTAP makes

[5] The minimum or maximum growth rates for land are a facor two times the FAO prognosis in the period 2000-2030 (except the Netherlands). Industrialized countries have received a minimum bound, developing countries a maximum bound, for transition countries no bounds have been set.

it possible to distinguish between effects of different economic policy measures. Therefore, using GTAP, we can calculate impact of these policies on land use and environment.

Another important aspect of land use is the need of pasture for grazing cattle. The production of this commodity is not taken into account by GTAP. In this analysis the changes in desired production levels of meat are taken from GTAP. Within IMAGE, these production levels are used to determine the number of animals and the demand for animal feed, using animal productivity changes from FAO (2003). On the basis of feed diets the demand for grass and fodder is calculated, assuming that grazing animals such as cattle, goats and sheep depend mainly on pasture and fodder species, while pigs and poultry rely primarily on crops. For the historical period the composition of the feed was calibrated against data from the literature for various regions. After 1995 the feed mix is scenario-driven. We assumed the importance of food crops in the animal diet increases at the cost of pasture and fodder species and crop residues, along with increasing intensity of production on the basis of recent trends observed. More details of the IMAGE grazing simulation are described in Bouwman et al. (2004).

3. Simulation results

In this section we present results of simulation experiments. Since in our analysis, differences between scenario outcomes are very important, we focus more on scenario comparison than on the description on the individual scenarios. We pay special attention on an analysis of importance of macro versus policy effects and their impact on agricultural sectors and developing countries. We start with presentation of economic indicators. The analysis of environmental impacts follows.

3.1 Production development

Production growth is highest for products with a high-income elasticity (services, manufacture, and within agriculture pigs/poultry, oils and processed food). For cereals the growth is very limited due to a low-income elasticity. This also implies that world production growth for rice and cereals is more or less similar between the scenarios. The difference in income between the scenarios does not create additional demand for these products (see Table 6). Production growth of products with the high-income elasticity is mainly driven by assumed the growth in GDP or its counterpart technological change. As a result, the world production growth is highest in the Global Economy (GE) scenario and then it decreases from Strong Europe (SE) to Transatlantic Market (TM) and to Regional Communities (RC) scenarios.

Despite of agricultural production growth, the share of agriculture in domestic production declines for all countries and regions between 1997 and 2030 (see Table 7). This is a continuation of the observed long-term trend. This result is driven by the lower income elasticities of demand for agricultural products compared with other commodities in combination with a relatively high productivity growth. In the Regional Communities scenario the share of agriculture stays relatively high because agricultural technological change and overall economic growth are lower than in other scenarios, and trade becomes more protected such that efficiency gains due to using comparative advantage are less.

The liberalization scenarios lead in general to the lowest shares of the agro-food sector in domestic production for food importing countries. For food exporters, such as Oceania, the

USA and South America, trade liberalization creates opportunities to stop the agri-food share from falling. This is especially true for Oceania, which initial level of protection is very low.

Table 6: World output growth (% growth per year)

Scenarios Commodities	Global economy	Strong Europe	Transatlantic Market	Regional Communities
Rice	0.97	0.93	1.02	0.90
Grains	1.34	1.30	1.34	1.23
Sugar	1.58	1.51	1.34	1.27
Oils	2.39	2.21	1.69	1.83
Horticulture	1.66	1.55	1.51	1.43
Other_crops	1.83	1.72	1.38	1.36
Cattle_SG	1.55	1.24	1.30	0.99
Pigs_Poultry	2.47	2.02	1.68	1.67
Dairy	1.55	1.43	1.25	1.11
OtherAgi	3.04	2.76	2.00	2.15
Proc_food	2.17	1.89	1.70	1.52
Mining	1.74	1.62	1.44	1.31
Manufacture	2.54	2.12	1.90	1.64
Services	2.57	2.17	1.98	1.65

The drop in shares is highest for developing countries for which agriculture is relatively important in 1997. For Middle Africa the agri-food share drops from 31% to 18% in the GE scenario and to 26% in the SE scenario. For South Asia the agri-food share drops from 26% to 16% in the GE scenario and to 18% in the SE scenario.

Table 7: Share of agro-food sector in domestic production (% growth per year)

	Base 1997	Global economy 2030	Strong Europe 2030	Transatlantic Market 2030	Regional Communities 2030
EU15	7.5	4.8	5.6	4.8	6.0
CEEC_EU	16.1	9.5	9.4	10.8	11.8
Baltic	18.6	9.0	10.1	11.5	13.0
R_CEEC	28.2	19.4	18.8	21.4	26.7
R_EUROPE	7.0	4.6	5.6	4.4	5.3
Canada	8.2	6.5	7.0	5.7	6.7
USA	5.7	4.1	4.6	3.5	4.2
Oceania	10.1	9.0	10.0	7.2	8.1
Japan	6.0	4.3	4.7	5.0	5.5
E_Asia	12.8	9.8	10.0	11.5	11.0
SE_Asia	14.8	11.1	11.4	12.0	10.9
S_Asia	26.2	15.5	16.4	19.9	17.5
C_America	17.9	12.8	12.6	17.4	13.2
S_America	18.5	14.2	14.0	18.5	13.8
USSR	14.8	7.6	7.7	8.1	9.9
Turkey	19.8	15.3	15.3	19.1	16.2
M_EST	8.9	5.4	5.2	8.7	7.5
N_Africa	19.1	11.5	11.2	16.9	14.8
M_Africa	31.3	17.9	15.6	20.6	25.9
S_Africa	14.5	11.4	9.6	11.9	13.8
R_World	21.8	17.8	19.0	19.3	19.0
Total	9.4	7.3	7.9	7.0	8.2

3.2 Impact of trade liberalization of the world trade growth

World trade growth shows clearly big differences between liberalization and non-liberalization scenarios (see Table 8). Liberalization and high-income growth (Global Economy) create the highest expansion in world trade. Table 8 also gives the contribution of changes in policies to the world trade growth of products. Reducing agricultural domestic support in the Global Economy (GE) and Strong Europe (SE) scenarios has a negative impact on world trade because it leads to higher world prices and therefore less demand. The impact is only negative for grains and to a lesser extent for cattle because these are the sectors where domestic support is highest. Reducing border support by eliminating import tariffs and export subsidies has an important impact on the growth of world trade in the GE and SE world. The contribution of abolishing of border support in total world trade growth is more than half for rice and cattle, sectors where border protection is highest. It is over 40% for processed food and about 30% for grains and sugar. For manufacturing the contribution of eliminating border support is only 10% because the market has already been substantially liberalized in the former WTO rounds. In the Transatlantic Market (TM) scenario the contribution of border support is marginal because only the market between the US and the EU is liberalized and the contribution in the Regional Communities scenario (RC) is negative because border support increases due to an increase in non-tariff barriers, which is caused by differences in SPS and TBT measures.

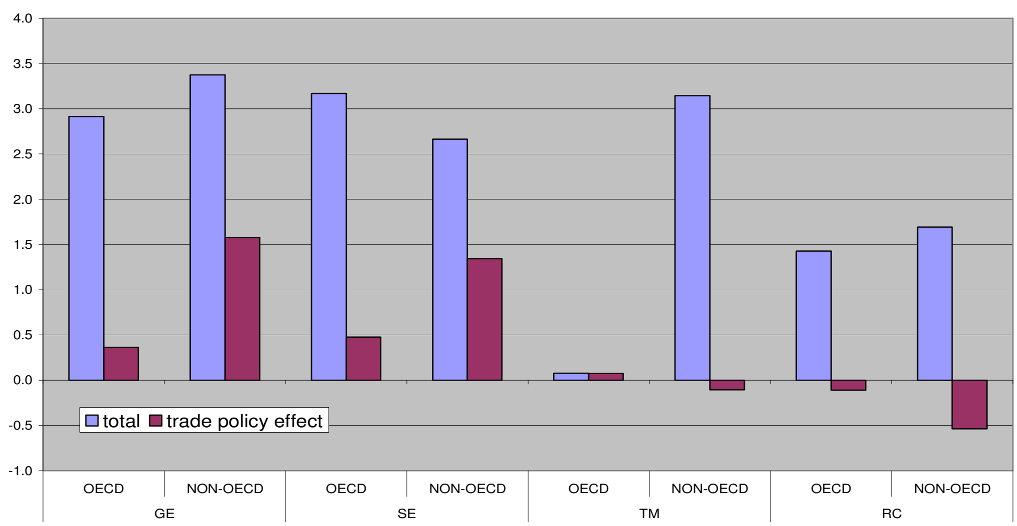
Table 8: World trade growth (% growth per year): total and policy changes effect

Scenarios	Global economy			Strong Europe			Transatlantic Market			Regional Communities		
	Total	agricultural support	border support	Total	agricultural support	border support	Total	agricultural support	border support	total	agricultural support	border support
Rice	2.8	0.0	1.6	2.7	0.0	1.8	1.2	0.0	0.1	0.7	0.0	-0.2
Grains	2.7	-0.3	0.7	2.8	-0.2	0.9	1.0	0.0	0.0	1.4	0.1	-0.3
Sugar	2.9	0.0	1.0	2.8	0.0	1.1	1.8	0.0	0.1	1.0	0.0	-0.5
Oils	4.1	-0.1	0.9	3.9	0.0	1.3	2.0	0.0	0.1	2.2	0.0	-0.3
Horticulture	2.5	0.0	0.8	2.3	0.0	0.9	1.2	0.0	0.1	0.8	0.0	-0.2
Other_crops	2.2	0.0	0.4	1.9	-0.1	0.5	1.7	-0.1	0.0	1.2	-0.1	-0.3
Cattle_SG	2.9	0.0	1.4	2.5	0.0	1.6	0.9	0.0	0.2	0.4	0.0	-0.2
Pigs_Poultry	3.8	-0.1	0.8	3.2	0.0	1.1	1.5	0.0	0.1	1.4	0.0	-0.3
Dairy	2.6	0.0	1.1	2.5	0.0	1.3	0.8	0.0	0.1	0.5	0.0	-0.2
OtherAgi	2.1	0.0	0.3	2.0	0.0	0.3	1.1	0.0	0.0	0.8	0.0	-0.3
Proc_food	3.2	0.0	1.3	3.0	0.0	1.7	1.5	0.0	0.2	0.9	0.0	-0.3
Mining	1.5	0.0	0.1	1.4	0.0	0.1	1.0	0.0	0.0	0.9	0.0	0.0
Manufacture	2.8	0.0	0.3	2.3	0.0	0.4	1.6	0.0	0.0	1.5	0.0	0.1
Services	2.8	0.0	0.1	2.5	0.0	0.1	1.9	0.0	0.0	1.7	0.0	0.0

Figure 5 shows the total growth of trade and the contribution of trade policies in the four scenarios for OECD and non-OECD countries for crops. In the liberalization scenarios (GE and SE) the total growth of trade and the contribution of eliminating trade policies for both OECD and non-OECD countries is highest. An important finding is that the contribution of trade policies to trade growth is especially substantial for non-OECD countries in these scenarios. About 50% of the total trade growth for non-OECD countries can be explained by trade policy changes. This is due to the higher protection rates on products that are important for non-OECD countries (especially rice and sugar). The trade growth is less in the TM and RC scenarios. The exception is the high growth for non-OECD countries in the TM scenario. This surprising result is caused by the macro-economic drivers that cause a divergence between countries in the EU-USA FTA and other countries. In the developing countries income growth is relatively low in this scenario and population growth is relatively high. This causes factor prices to increase much slower than in the OECD countries. Together with the assumption that crop productivity growth is about the same as in OECD countries, this causes that products from non-OECD countries become cheap. The lower prices in non-OECD countries relatively to OECD countries imply that trade expands relatively fast in non-OECD countries.

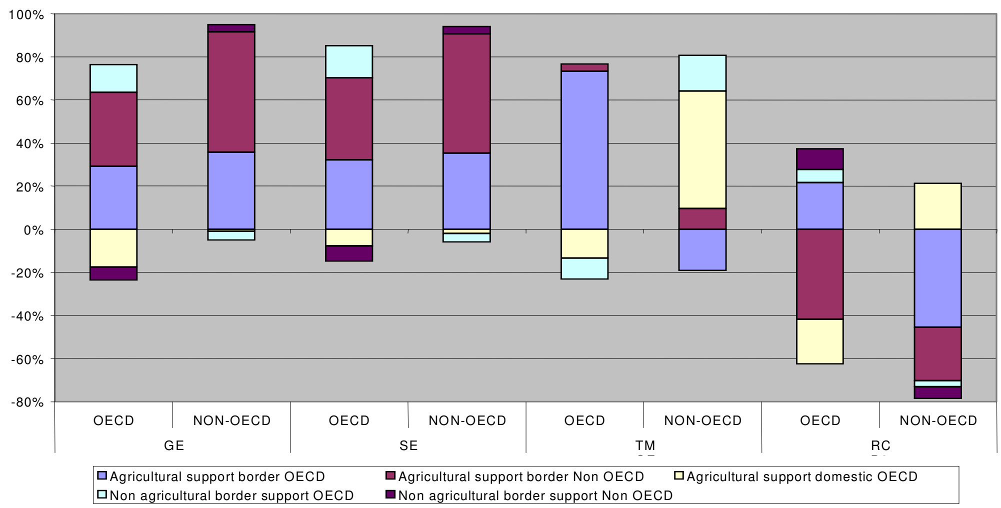
The contribution of policy changes in the TM scenario is slightly positive for OECD countries and slightly negative for non-OECD countries. This is caused by trade creation effects and trade diversion effects from the EU-USA FTA. Trade creation (trade induced between the new EU-USA FTA member countries through removal of bilateral tariffs) is positive for OECD countries and trade diversion (trade initially provided by non-member countries will be replaced by trade of member countries because they get preferential market access) is negative for non-OECD countries. In the RC scenario the impact of trade policies is negative due to the higher non-trade barriers between trade blocks. This hurts especially non-OECD countries.

Figure 5. Crop trade growth in OECD and non-OECD countries (% growth per year)



In the global trade liberalization scenarios (GE and SE) the agricultural border support reduction of non-OECD countries stimulates crop exports more than the similar support reduction of OECD countries. The agricultural domestic support of OECD countries is an important factor hampering OECD cereal exports in all analyzed scenarios (see Figure 6).

Figure 6. Shares of trade policy instruments in policy generated crop exports



3.3 Welfare effects of policy changes

Table 9 shows the welfare changes of the four scenarios due to policy changes. As expected, the results show high positive impact of trade and agricultural policy liberalization on welfare in GE and SE scenarios. In the TM, only OECD and the non-OECD Europe gain from the EU-US trade liberalization and the EU enlargement. The RC scenario shows global welfare losses as result of 10% higher domestic support and increase of non-tariff barriers due to different SPS and TBT measures. For Central and South America and for South Africa this welfare loss is more than compensated by the gains from liberalizing manufacturing in the regional FTA's and for non-OECD Europe by EU enlargement.

Table 9: Welfare changes in scenarios due to policy changes (mld $ per year)

	GE	SE	TM	RC
Total*	100568	99911	5826	-10843
OECD	43944	42689	9866	-7862
Non-OECD Europe	2219	2214	2073	1830
E_Asia	22166	22302	-1278	-2917
SE_Asia	4670	4679	-627	-1109
S_Asia	4692	4740	-321	-910
C_America	304	622	-786	1776
S_America	7404	6937	-586	2903
M_EST	7843	8112	-1034	-1564
N_Africa	4962	5135	-269	-940
M_Africa	-188	-158	-94	-750
S_Africa	1919	1905	-122	1079

** Including the Rest of World*

Table 10 shows the welfare changes due to various policy changes in the GE scenario. The total welfare impact is positive for almost all regions and the impact is higher for developing regions than for the OECD countries. So, developing regions have more to gain from trade liberalization. The impact is also highly positive for non-OECD Eastern European countries, which is mainly due to the EU enlargement.

Table 10. Welfare changes in GE scenario due to policy changes

	TOTAL		Agricultural support effect			Non agricultural border support effect	
			Border		Domestic		
Regions	mld $	% of GDP	OECD	Non OECD	OECD	OECD	Non OECD
OECD	43944	0.20	26030	9058	9312	-16327	15871
Non-OECD Europe	2219	2.82	475	290	13	1444	-3
E_Asia	22166	1.27	1256	6019	-335	10574	4652
SE_Asia	4670	0.72	1969	189	-28	3202	-662
S_Asia	4692	0.89	0	635	-106	3598	565
C_America	304	0.06	975	-141	-640	-66	176
S_America	7404	0.50	4363	1038	575	835	593
M_EST	7843	1.48	-529	3790	-559	2186	2955
N_Africa	4962	2.41	521	3723	-426	1705	-561
M_Africa	-188	-0.12	845	-81	-184	8	-776
S_Africa	1919	1.05	686	324	-35	210	734

An important exception is Middle Africa were especially the abolition of non-OECD border support for non-agricultural products is negative. However, these regions gain from increased market access to OECD for agricultural products (0.5% of GDP) and it loses from diminishing of domestic support in OECD countries. This is due to the fact that this region is a net food importing region of subsidized products (especially grains). Abolition of subsidies raises the world and therefore import prices of this region.

The contribution of improved market access to OECD countries for agricultural products is important for Middle Africa, South Africa, South America and South-East Asia. For North Africa, the Middle East, East and South Asia improved market access to non-OECD countries is more important than to OECD countries. Abolition of domestic support raises the world price of cereals and to lesser extent cattle. Most developing countries are net importers of these products and lose in terms of welfare. The exception is South America which is a large net exporter of these products and gains from the higher world price (terms of trade gain).

For developing countries increased market access in manufacturing is also important for Asia, Middle East and North and South Africa. For Latin America and Middle Africa liberalization in manufacturing is less important.

In general we can conclude that liberalization is beneficial but that in some cases countries might even lose from liberalization. The scale of the welfare effects for a region is dependent on the initial level of protection that a region levies on imports and on the other hand engages on exports, the importance of trade in production and the net export position.

The results presented above clearly confirm that developing countries can profit significantly from liberalization of their own agriculture markets. Liberalization of own non-agricultural markets brings also positive welfare effect for these countries with the exception of South-East Asia and African countries. Central America, Middle East and North Africa gain more from the own trade policies liberalization than from OECD trade liberalization.

In Table 11 we compare our results with results from other studies. The welfare effects of trade liberalization calculated for GE scenario are similar to Francois et al. (2002) results and place between the World Bank results, which predicts higher welfare gains, and USDA results (see Diao et al. (2002)), which show lower gains. The other studies confirm also the importance of developing countries trade liberalization for welfare improvement in these countries.

Table 11: Income effects of trade liberalization in agriculture and food only (additional income in 2015 compared to baseline, 1997 bln US$). Earlier studies compared with the four scenarios in this study.

	Benefits to low and middle income countries		Benefits to high income countries		Benefits for all countries	
	static	dynamic	static	dynamic	Static	dynamic
Anderson (1999)						
Developing countries liberalise	31		11		42	
Developed countries liberalise	12		110		122	
All countries liberalise	43		121		164	
Diao et al. (2002)						
All countries liberalise	3	35	28	35	21	56
Francois et al. (2002)						
Developing countries liberalise 50%	6		5		11	
Developed countries liberalise 50%	5		12		17	
All countries liberalise 50%	11		17		28	
This study: A1-Global economy						
Developing countries liberalise	**16**		**9**		**25**	
Developed countries liberalise	**10**		**27**		**37**	
All countries liberalise	**26**		**36**		**61**	
World Bank GEP 2004						
Developing countries liberalise	80	167	23	19	103	185
Developed countries liberalise	20	75	64	100	84	174
All countries liberalise	101	240	91	117	193	358

Some general observations:

- The largest part of the world welfare benefits of agricultural liberalization accrue to industrial countries. Only in the Worldbank studies benefits for developing countries are higher.
- Welfare benefits for developing countries vary between $11 billion and $43 billion in the non-Worldbank studies. This is equal to 0.2% and 0.7% of GDP of developing countries. In the Worldbank study welfare effects vary between $101 billion (static) and $120 billion (dynamic). The most optimistic Worldbank scenario adds 1.7% to the GDP of developing countries.
- In terms of GDP the additional welfare effects of agricultural liberalization in non-Worldbank studies are very modest. The optimistic Worldbank scenario ads 1.7%, which is substantial but not so high given current rates of growth of some countries like China (7% annually). Welfare gains for developing countries from liberalizing agricultural policies in Industrial (OECD) countries vary between $5 billion and $20 billion. This is equal to 0.1% and 0.3% of GDP in developing countries. The gains from liberalization are therefore limited.

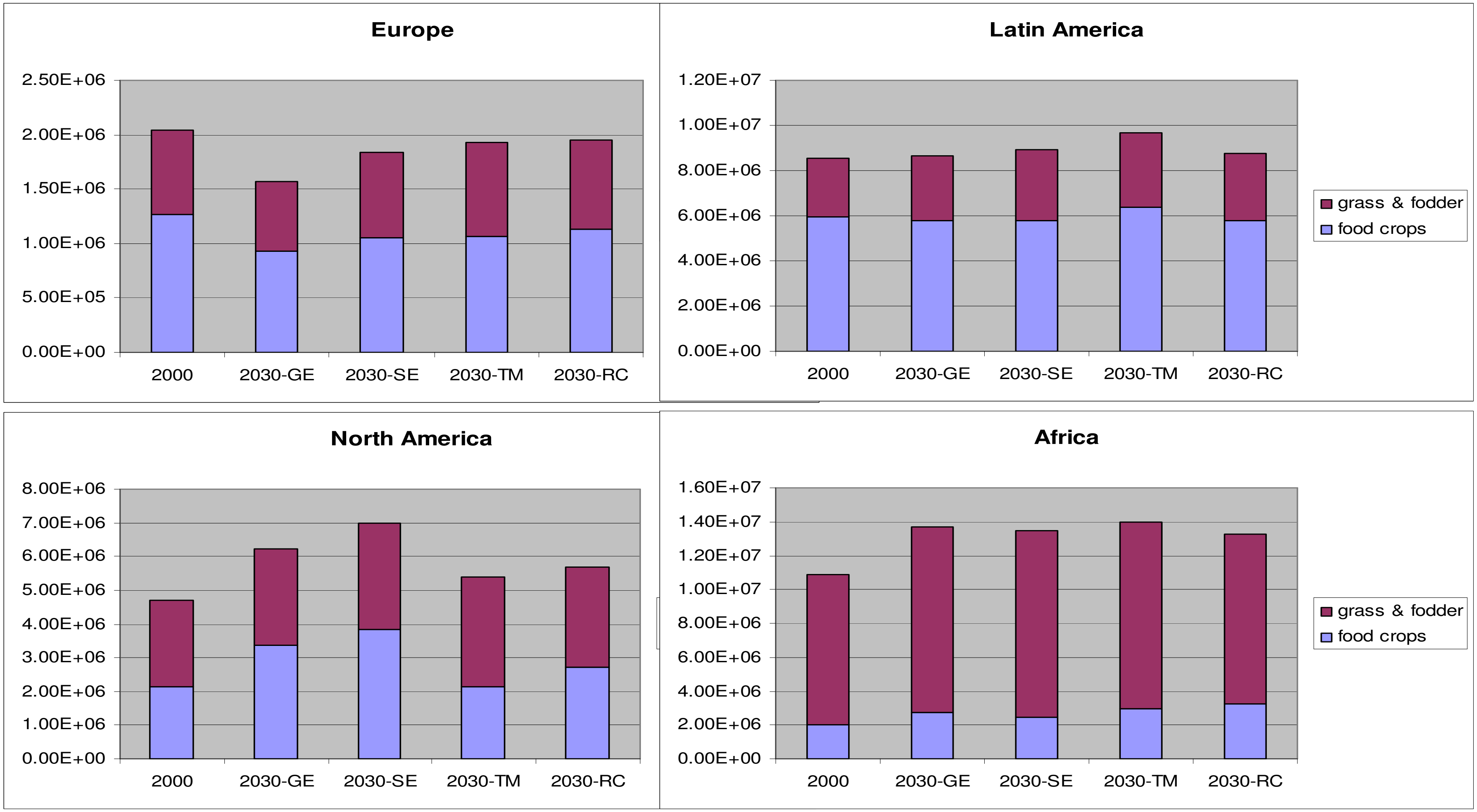
- Between 70 and 85 per cent of the benefits for developing countries is the result of their own reform policies in agriculture.

3.4 Consequences for land-use

The consequences of the different outcomes on desired production levels for the size of the agricultural land are plotted in Figure 7 for four major regions. For Europe, a decrease in agricultural land is projected in all scenarios. In GE the decrease is most profound because of high productivity improvements and a further decline of the agro-food production due to increasing imports (Table 7). Further intensification of the meat sector also contributes to this decrease. In Table 12 we have separated the influence of trade policy effects and show the changes in total agricultural land, which combines cropland, grassland and land for biofuels (based on demand for modern biofuels from Bollen et al., 2004). Europe agricultural land decreases with 23% GE, but without trade liberalisation the reduction would only be 8%. In Strong Europe, the decrease in agricultural land is less than in GE because of extensification measures in the animal sector and even results in an increase in agricultural land when no trade policy effects are assumed (in GE a large increase in biofuel area is assumed).

Most of the increase in global agricultural land occurs in Africa, being a result of the expected population increase in Africa in the coming 30 years. Moreover, changes in diet towards more meat also contributes to a further increase of land for grass and fodder to feed the animals. Figure 7 clearly shows that the two scenarios aimed at economic efficiency and welfare (GE and TM) result in the highest need for agricultural land in Africa because of high meat demands (see also Table 6). Table 12 shows that liberalization also influences the need for land in Africa: in GE the land expansion reaches an increase of 43% and in SE an increase of 41%, whereas the increase would be less (37 and 32% respectively) if no trade policies are assumed. However, results from TM show that a slow demographic transition and a slow economic growth can have a destructive effect on land use: an increase of almost 50% of the agricultural land is needed to feed the people of Africa. In RC, with focus on local cultural identities, the expansion of land in Africa is lowest.

Figure 7. Size of grassland and cropland in 2000 and 2030 for the regions Europe, Latin America, North America and Africa for the four scenarios (in km^2).



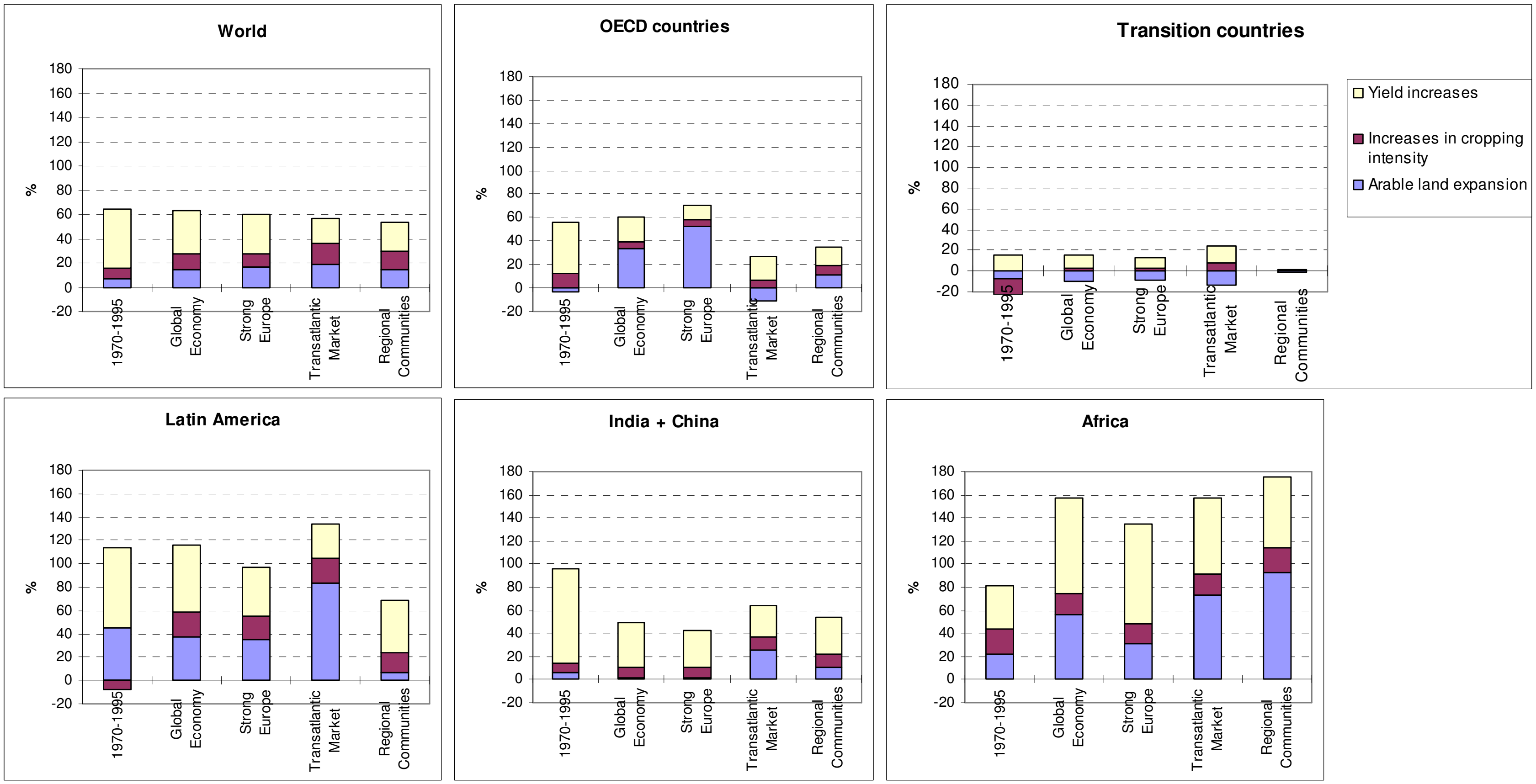
Results for other OECD regions besides Europe show that liberalization has a major effect on the growth of agricultural land. These results follows from the fact that North America and Oceania benefit most from liberalization, whereas the agricultural sector in Europe declines when liberalization is assumed. The largeshifts in the agricultural production levels can have a major impact on the size of agricultural land, and therefore on the nature in regions like Africa and North America.

Table 12. Increase in total agricultural land (between 2001 and 2030) for default scenarios and under the assumption no trade policies are implemented in the scenarios

	GE-2030		SE-2030		TM-2030		RC-2030	
	No trade policy	Default with trade policy	No trade policy	Default with trade policy	No trade policy	Default with trade policy	No trade policy	Default with trade policy
World	**8%**	**14%**	**11%**	**17%**	**18%**	**20%**	**12%**	**14%**
Europe	-8%	-23%	11%	-5%	5%	0%	8%	6%
Other OECD	8%	31%	27%	53%	3%	6%	21%	19%
Asia	14%	8%	9%	2%	19%	19%	13%	16%
Africa	37%	43%	32%	41%	45%	48%	34%	37%
Latin America	-7%	6%	-3%	7%	24%	25%	2%	2%
Former Soviet U.	-27%	-24%	-21%	-18%	-9%	-6%	-23%	-18%

When we analyze the sources of growth in crop production (Figure 8), it becomes clear that the liberalizing scenarios (GE and SE) in the OECD countries differ from the non-liberalizing scenarios: a major increase in crop production is expected and since the yield increase in these countries is already very high, this crop production most come from expansion of arable land (as already shown in Table 12). In India and China most of the increase in crop production has taken place in the last 30 years (FAO, 2003). Future crop production growth mainly comes from additional yield increase, since expansion of arable land will become more difficult. Since the yield increase is smaller in the regionalized scenarios (slower economic growth in TM and RC in these regions; see Table 4), the expansion of arable land contributes relatively more to crop growth production. Figure 8 also shows that most of the changes in crop production in the coming 30 years are expected to occur in Africa: in TM and RC this mainly comes from arable land expansion, whereas in GE and SE yield increase plays a more important role.

Figure 8. Sources of growth in crop production from 1970 to 1995 (FAO, 2003) and from 2000 to 2030 (four scenarios) for the world in total and for five regions.



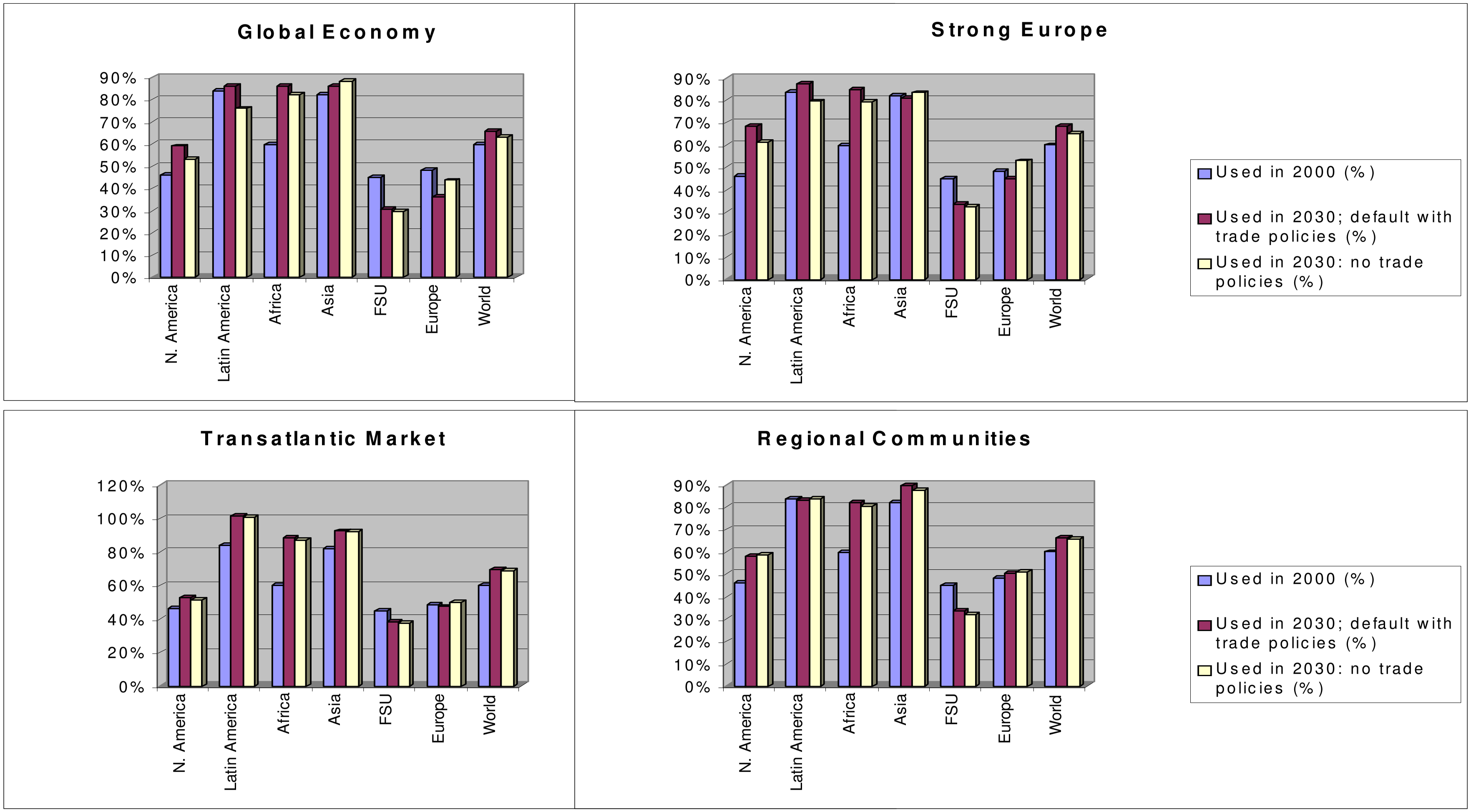
3.5 Changes in quality of land-use

The size of agricultural land does not say anything about the vulnerability of a region for external changes. In Figure 9, we plotted the percentages of agricultural land that is located on high-productive areas. The high-productive areas are a result from the crop production model of IMAGE. For each region the potential productivity of the best-growing crop type in that region is chosen as indicator for the size of high-productive areas. When the potential productivity of that crop type falls below the 20% of the theoretical maximum productivity, the land is called marginal. Therefore, regions with a percentage of non-marginal lands used by agriculture near the 100% is a good indicator for the vulnerability of that region.Any change in potential productivity because of, for example, climate change or any change in desired production levels, can lead to expansion of agriculture to marginal lands. From Figure 9, it is clear that Latin America and Asia are the most vulnerable regions in 2000: arable land expansion will immediately lead to agricultural practices on marginal lands.

In the scenario results, Africa shows the biggest increase in arable land expansion and therefore, a major shift towards more vulnerable levels of agricultural practices. From these results it is clear that in liberalizing worlds non-vulnerable regions like Europe or the Former Soviet Union experience a decrease in their arable land, whereas vulnerable regions like Latin America become more vulnerable because of trade policies. The implementation of trade policies in GE and SE implies an increase in agricultural land in Latin America compared to a decrease in agricultural land in GE and SE without trade policies. From Figure 9, it becomes clear that small changes in area expansion because of the implementation of trade policies (e.g. Latin America and Africa) can have a major impact on the quality of land, since these additional expansions occur in regions that are very vulnerable to arable land expansion.

Other environmental standards (e.g. for fertilizer and pesticide application) are not assessed in this study, but it becomes clear from our analysis that the agricultural production is shifting towards regions where environmental standards are lower than in Europe. The current trend is that agricultural production more and more shifts towards areas, which can be easily mechanized, and which are often located near infrastructure that provide rapid access to processing industries and consumers. This is in particular the case for high-value products, e.g. horticulture and pig and poultry. Evidence from NAFTA suggests that trade liberalization has led to the concentration of very large scale, or factory-type, livestock production areas as a means to lower production costs and remain competitive (UNEP, 2002). These trends will be strengthened by further trade liberalization, leading to risk of local pollution in these intensively farmed areas. Despite low emissions per kg product, the emission per ha may exceed environmental standards. Bouwman et al. (2004) conclude that the use of chemcial of fertiliser and inputs from biological N fixation have strongly increased between 1970 and 1995, and will continue to grow in all world regions in the coming three decades. Increasing N fixation is primarily related to the increasing demand for soybeans as an animal feed resource. Since in liberalizing worlds the increase in animal productions is the highest, we can expect further problems with eutrophication of surface waters in regions in Latin America, Africa and Asia that are already vulnerable.).

Figure 9. Percentage of used arable land on non-marginal lands in the different regions. The influence of he implementation of trade policies are included in each figure

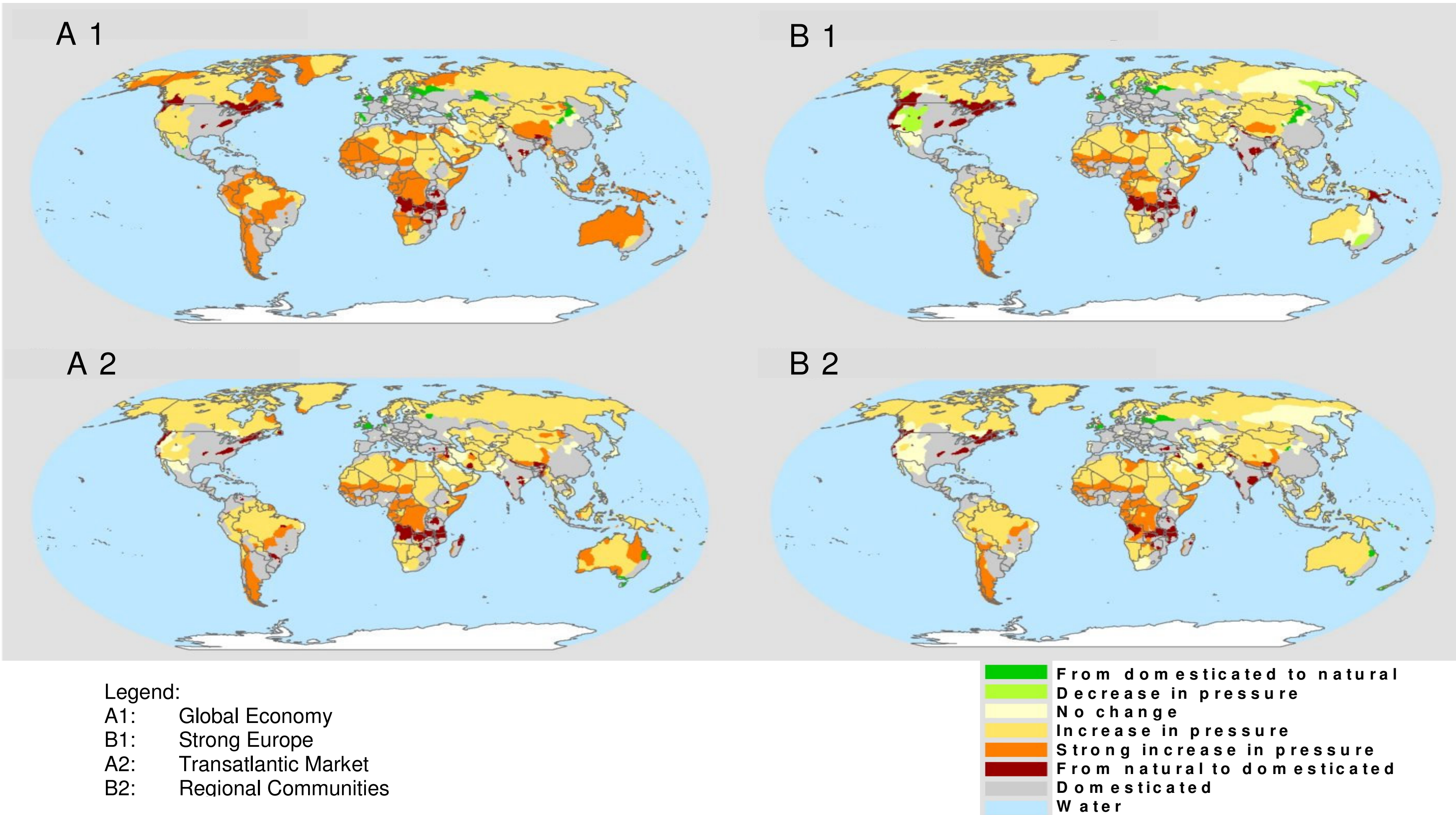


3.6 Effects on biodiversity

Finally, we look at the development of biodiversity in the four scenarios. Biological diversity – or biodiversity - is the term given to the variety of life on earth and the natural patterns formed. This diversity is often understood in terms of the wide variety of ecosystems (terrestrial and aquatic), plants, animals and micro-organisms, including genetic diversity of food crops and domestic animals. Biodiversity loss at the species level occurs when natural ecosystems are reduced through conversion to agricultural or urban use (loss of quantity) and/or when natural ecosystems are degraded (loss of quality). Such degradation of terrestrial and aquatic systems occurs due to a mix of human influences, such as climate change, chemical pollution, disturbance due to fragmentation from infrastructural developments or due to forms of exploitation such as tourism, hunting and gathering. All such influences reduce both the distribution and the abundance of animal and plant species. A general effect is that the abundance of many rare species declines, while the abundance of some – mostly common – species increases, resulting in increased uniformity. However, lack of data and lack of knowledge on the relations between species abundance and changes in external factors are a well-known problem in this field. Therefore, we only look at a number of proximate drivers (or pressures) as a crude measure for ecosystem quality. This pressure-based natural capital index provides an indication of the future state of natural terrestrial ecosystems compared to the current state as a result of four pressures. Four pressures were selected to approximate ecosystem quality: i) population density; ii) primary energy use; iii) rate of temperature change; and iv) clear-cutting of forest and abandoning agricultural land. Pressure (iv) addresses re-conversion processes, such as re-generation from logging and restoration of abandoned agricultural land.

In Figure 10, we plotted the changes in pressure on ecosystems and also plotted the areas that become available after abandonment of agricultural land. Because of high economic activities, GE results in high pressure on the ecosystems, whereas an economic less active world like TM shows lower pressures. Here, the results confirm that although liberalization can be beneficial for the welfare in developing countries, the pressure on the ecosystems through high economic activities and a large increase in arable land expansion can be very high as well. In a total analysis, these kinds of drawbacks for the environmental system should be considered in studies looking at the consequences of liberalization as well. Figure 10, however, shows that in a liberalizing world, in which there is also much focus on sustainability (e.g. Strong Europe), the pressures on the environment can be lowered by implementing policies on persisting environmental problems like climate change (in SE stringent climate policies are implemented; see Bollen et al., 2004).

Figure 10: Changes in pressure on the land-use system for each scenario between 2000 and 2030



4. Conclusions

In this paper we focused on the complex relation between trade, poverty and environment.

With regard to the current Doha round we found that trade liberalization leads to economic benefits. The benefits are modest in terms of GDP and unequally distributed among countries. We found that some countries might loose from liberalization. Developing countries gain relatively the most. However, between 70 and 85 per cent of the benefits for developing countries is the result of their own reform policies in agriculture. Welfare gains for developing countries from liberalizing agricultural policies in Industrial (OECD) countries vary between 0.1% and 0.3% of GDP in developing countries.

South-South trade liberalization is key to the "development" part of this round (see, also Francois et al., 2003). However, this is downplayed in the current negotiations by all WTO partners, with emphasis instead on exemptions for developing countries. Another question is whether developing countries and the poor in particular are able to reap the ex ante benefits calculated by the model studies. Imperfect markets and institutions (credit, human capital), instable political climate, a bad infrastructure and enhanced quality standards by Western countries may lead to lower benefits. Therefore complementary investments (e.g. infrastructure, education) are needed to reap the potential benefits.

Liberalization can be helpful in gaining welfare. Economic growth in developing regions is necessary to alleviate poverty. However uncoordinated liberalization can lead to unbearable pressures on the environment. In the Global Economy scenario non-vulnerable regions like Europe experience a decrease in arable land, whereas the arable area increases in vulnerable regions like Latin America and Africa. However the opposite of liberalization, continuation of trade-blocks throughout the world, can also work out negative. E.g. the Transatlantic Market (EU-USA FTA) scenario is a disastrous scenario: low economic growth in developing countries but nevertheless large pressures on the natural system.

Other environmental impacts, such as water use and emissions of nitrogen compounds have not been assessed in this study. Taking these into account can shift the results and can lead to 'surprises' in regions where major shifts can occur in land use practices. In the liberalizing scenarios most of these shifts occur, indicating that liberalization should be performed with care. Trade liberalization will necessary have environmental consequences, which might be positive or negative for a region. What seems crucial is that environmental and trade agreements and policies must be sufficiently integrated or coordinated, to assure that they work together to improve the environment and attain the benefits of free trade.

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APPENDIX

Table A1: Regional aggregation: the relationship between regional aggregation and original GTAP regions

Model Country/Region	Model code	Original GTAP v5 sector
The Netherlands	Netherlands	Netherlands
Rest of U15	R_EU15	Austria, Belgium, Denmark, Finland, France, Germany, United Kingdom, Greece, Ireland, Italy, Luxembourg, Portugal, Spain, Sweden
CEEC accessing counties	CEEC_EU	Czech Republic, Hungary, Poland, Slovakia, Slovenia
Rest of CEEC	Baltic	Albania, Bulgaria, Croatia, Romania, Serbia & Montenegro, Macedonia
Baltic countries	R_CEEC	Estonia, Latvia, Lithuania
Rest of Europe	R_EUROPE	Switzerland, Rest of European Free Trade Area, Malta
Canada	Canada	Canada
USA	USA	United States
Oceania	Oceania	Australia, New Zealand
Japan	Japan	Japan
East Asia	E_Asia	China, Hong Kong, Korea, Taiwan
South-East Asia	SE_Asia	Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam
South Asia	S_Asia	Bangladesh, India, Sri Lanka, Rest of South Asia
Central America	C_America	Mexico, Central America, Caribbean
South America	S_America	Colombia, Peru, Venezuela, Rest of Andean Pact, Argentina, Brazil, Chile, Uruguay, Rest of South America
Former Soviet Union	USSR	Russian Federation, Rest of Former Soviet Union
Turkey	Turkey	Turkey
Middle East	M_EST	Cyprus, Rest of Middle East
North Africa	N_Africa	Morocco, rest of North Africa
Central Africa	M_Africa	Uganda, rest of Sub-Saharan Africa
South Africa	S_Africa	Botswana, Rest of South Afr C Union, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe, Other Southern Africa
Rest of the World	R_World	Rest of world

Table A2: Sectoral aggregation: the relationship between sectoral aggregation and original GTAP sectors

Model sector	Model code	Original GTAP v5.3 sector
Rice	Rice	Paddy rice, processed rice
Grains	Grains	Wheat, cereals grains nec
Sugar beets and sugar	Sugar	Sugar cane, sugar beet, sugar.
Oils	Oils	Oil seeds, vegetable oils and fats
Horticulture	Horticulture	Vegetables fruit nuts
Other crops	Other_crops	Crops nec, Plant-based fibers
Cattle, sheep, goats (incl. meat)	Cattle_SG	Cattle, sheep, goats, horses, meat: cattle, sheep, goats, horse
Pigs and poultry (incl. meat)	Pigs_Poultry	Animal products nec, meat products nec
Dairy	Dairy	Raw milk, dairy products
Other Agriculture	OtherAgri	Wool, silk-worm cocoons, forestry, fishing
Processed food	Proc_food	Food products nec, beverages and tobacco products
Mining	Mining	Coal, oil, gas, minerals nec.
Manufacture	Manufacture	Textiles, wearing apparel, leather products, wood products paper products, publishing, petroleum, coal products, chemical, rubber, plastic products, mineral products nec, ferrous metals, metals nec, metal products, motor vehicles and parts, transport equipment nec, electronic equipment, machinery and equipment nec, manufactures nec.
Services	Services	Electricity, gas manufacture, distribution, water, construction, trade, transport nec, sea transport, air transport, communication, financial services nec, insurance, business services nec, recreation and other services, public administration, defense, health, education, dwellings

Table A3: Land productivity, FAO prognosis for 2030

	Netherlands	R_EU15	CEEC_EU	Baltic	R_CEEC	R_EUROPE	Canada	USA	Oceania	Japan	E_Asia
Rice	20	20	**-7**	**-7**	-7	**-7**	**25**	25	6	23	28
Grains	35	35	18	27	11	24	37	22	42	27	48
Sugar	28	28	33	5	53	17	37	20	22	8	84
Oils	12	12	27	46	34	5	27	79	31	25	39
Horticulture	15	15	18	38	23	4	14	39	36	24	84
Other_crops	18	18	35	29	6	27	28	47	52	19	66
Cattle_SG	12	12	0	11	27	1	16	6	11	36	45
Pigs_Poultry	5	5	-9	0	-10	-15	13	29	19	7	13
Dairy	6	6	3	46	-1	8	1	10	26	13	46

	SE_Asia	S_Asia	C_America	S_America	USSR	Turkey	M_EST	N_Africa	M_Africa	S_Africa	R_World
Rice	33	50	22	47	14	9	25	16	72	104	33
Grains	42	68	47	46	27	36	45	59	64	48	35
Sugar	34	59	28	34	11	28	23	13	64	18	40
Oils	29	39	-3	33	34	23	53	53	73	61	37
Horticulture	55	39	37	39	36	35	29	36	53	22	48
Other_crops	24	107	45	30	14	10	36	34	59	45	45
Cattle_SG	83	63	45	26	13	29	63	48	89	42	23
Pigs_Poultry	70	150	38	40	16	86	94	66	101	32	12
Dairy	105	37	29	17	30	33	41	44	37	18	7

Table A4: Land productivity (in kg/ha or kg/animal); relative difference with FAO prognosis for 2030

	Canada	USA	Central America	South America	North Africa	Western Africa	Eastern Africa	Southern Africa	Non EU W- Eur	Rest E Eur (w.o. CEEC)	Rest FSU (w.o. Baltics)
GE	5%	5%	0%	0%	0%	2,5%	2,5%	2,5%	5%	5%	5%
SE	0%	0%	0%	0%	-5%	7,5%	7,5%	7,5%	0%	5%	5%
TM	-5%	-5%	-10%	-10%	-10%	-5%	-5%	-5%	-5%	-5%	-5%
RC	-5%	-5%	-5%	-5%	-5%	-5%	-5%	-5%	-5%	-5%	-5%

	Middle East	South Asia	East Asia	South-East Asia	Oceania	Japan	Rest of EU15	CEEC	Baltic countries	Turkey	Netherlands
GE	0%	0%	0%	0%	5%	5%	5%	5%	5%	0%	5%
SE	-5%	-5%	-5%	-5%	0%	0%	0%	5%	5%	-5%	0%
TM	-10%	-10%	-10%	-10%	-5%	-5%	-5%	-5%	-5%	-10%	-5%
RC	-5%	-5%	-5%	-5%	-5%	-5%	-5%	-5%	-5%	-5%	-5%

Table A5: Assumption for the four CPB scenarios

Variable	Default value	Global Economy	Strong Europe	Transatlantic Market A2	Regional Communities
Policy					
- Export subsidies - Import tariffs	EU: Agenda 2000, with addition of decrease dairy prices (part of 30 June 2003 agreement) Rest: situation 1997	Abolished for all sectors	Abolished for all sectors	No general change for tariffs and subsidies	Tariffs: no change Export subsidies are abolished (to avoid dumping)
Trade agreements (Free trade agreement (FTA) implies that all bilateral tariffs are eliminated. Custom union (CU) implies that members have common external tariffs towards third countries on top of FTA).					
EU enlargement	Elimination of bilateral tariffs and common external tariff between all CEEC and EU15. CEEC gets domestic agricultural support and milk/sugar quota conform December agreement.				
Turkey-EU	Turkey outside EU	Elimination of bilateral tariffs and common external tariff	Elimination of bilateral tariffs and common external tariff		
Former Soviet Union-EU	No specific arrangements	Elimination of bilateral tariffs in manufacturing (EU-FSU)	Elimination of bilateral tariffs in manufacturing (EU-FSU)		
EU-USA	No specific arrangements			Elimination of bilateral tariffs (and common external tariff) between EU and US	
USA-Latin America and Caribbean, TUR-Middle East and North Africa, Rest Africa-FSU	No specific arrangements				Elimination of bilateral tariffs in manufacturing
Domestic support in agriculture	EU: Agenda 2000, but support partly decoupled (60% meat, 75% grains) rest: situation 1997	Abolished	50% reduction of domestic support (to be linked to env. and social targets)	No change (in order to secure food supply)	+10% (to be linked to environmental and social targets)
Sugar quota (EU25)	Agenda 2000	Abolished	Abolished	Self sufficiency EU	Selfsufficiency EU

Milk quota (EU25)	Agenda 2000	Abolished	Abolished	Self sufficiency EU	Selfsufficiency EU
Non trade concerns	situation 1997		Global SPS and TBT leading to 2.5% cost price increase for agricultural products in all countries except EU15 and Japan		Non trade concerns agr. products: different SPS and TBT between trade blocks: increase non tariff barriers with 10%, for trade blocks see table footnote*
Environmental and climate policies					
Transport costs	situation 1997		Increase international transport costs of all products with 10%		
Consumer preferences					
Preference for regional products	situation 1997			Preference for products from own IMAGE region: 5% pref. shift?	Preference for products from own IMAGE region: 5% pref. Shift
Consumption of animal protein		Endogenous outcome	Income elasticity 10% lower?	Endogenous outcome	Income elasticity 10% lower
Macro assumptions					
GDP per region		CPB outcomes provided by MNP	CPB outcomes provided by MNP	CPB outcomes provided by MNP	CPB outcomes provided by RIVM
Technological change		Endogenous for non-agricultural sectors. Exogenous for agricultural sectors. The latter assumptions are scenario specific and based on FAO 2030 prognosis.	Endogenous for non-agricultural sectors. Exogenous for agricultural sectors. The latter assumptions are scenario specific and based on FAO 2030 prognosis.	Endogenous for non-agricultural sectors. Exogenous for agricultural sectors. The latter assumptions are scenario specific and based on FAO 2030 prognosis.	Endogenous for non-agricultural sectors. Exogenous for agricultural sectors. The latter assumptions are scenario specific and based on FAO 2030 prognosis.
Employment growth per Region		CPB outcomes to be provided by MNP	CPB outcomes to be provided by MNP	CPB outcomes to be provided by MNP	CPB outcomes to be provided by MNP
Capital growth per region		CPB outcomes to be provided by MNP	CPB outcomes to be provided by MNP	CPB outcomes to be provided by MNP	CPB outcomes to be provided by MNP
Land occupation per Region	no change, except NL: -25% in 2003				
Population growth per Region	FAO assumptions	IPCC assumptions provided by MNP	IPCC assumptions provided by MNP	IPCC assumptions provided by MNP	IPCC assumptions provided by MNP
Population Netherlands		18,9	18,3	17,2	16,3

* Regional blocks: 1 Netherlands / rest of EU15 / CEEC / Baltic countries / Rest of Europe; 2 Canada / USA / Central America / South America; 3 Oceania; 4 Japan; 5 East Asia / South-east Asia; 6 South Asia; 7 Middle Africa / South Africa; 8 Turkey / Middle East / North Africa; 9 Rest of World.