Agricultural trade liberalisation and greenhouse gas emissions
A simulation study using the GTAP-IMAGE modelling framework

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This report explores the effects of agricultural trade liberalisation on greenhouse gas emissions and on changing commodity production areas by coupling of the modeling tools GTAP and IMAGE. Four scenarios are explored with developments up tot 2050. The scenarios include a baseline, full liberalisation and two partial liberalisation scenarios for which the latter scenarios include removal of trade barriers or removal of milk quota by 2015 only. The results indicate that liberalisation leads to a further increase in greenhouse gas emissions adding to an already observed increase in emissions observed in the baseline scenario. CO_2 emission increase is caused by vegetation clearance due to a rapid expansion of agricultural areas in South America and South East Asia. Increased methane emissions are also calculated in these areas caused by less intensive cattle farming. Global production of the commodities milk, dairy and beef does not change between full liberalisation and the baseline but clear shifts from North America and Europe to South America and South East Asia are expected.

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Preface

By the end of 2006 the European Commission launched its ambitious target to reduce 20% of greenhouse gas emissions by 2020. Emissions from European agriculture are, with a share of circa 10% of total emissions, modest compared to other sectors. However, agriculture is the main source of methane and nitrous oxide emissions. These two greenhouse gasses have a much larger warming potential than does CO_2. Therefore, reduction of one unit of these two gasses will have a relatively large positive effect decreasing global warming. The further globalisation and liberalisation of international agricultural trade may have large effects on greenhouse gas emissions and may therefore, positively or negatively, affect the EU emission target. We studied the effects of agricultural trade liberalisation on greenhouse gas emissions with the modelling tools GTAP and IMAGE. Both GTAP (economic model) and IMAGE (environmental model) operate on a global scale.

This project was financed by the Dutch Ministry of Agriculture, Nature and Food quality, directie Platteland. The Dutch Ministry supports research to study the implications its policy changes on climate change and mitigation and adaptation measures that are needed to reduce climate change effects. We thank H.J. Haanstra of the Ministry for his counselling during this project and Hans van Meijl, Floor Brouwer and Huib Silvis of LEI for their valuable comments during the course of this project and draft versions of this manuscript.

Prof Dr R.B.M. Huirne
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Summary

The importance of reforming agricultural support policies in industrialised countries and improving market access, in particular for developing countries, has been recognised at the top political level. During the Doha round, the World Trade Organisation (WTO) is focussing on trade liberalisation of protected markets, such as agriculture. Trade liberalisation may result in a change in agricultural land use towards countries with currently low agricultural production. Such shifts may also affect greenhouse gas emissions. In particular agriculture is one of the main anthropogenic sources of the greenhouse gasses methane (CH_4) and nitrous oxide (N_2O). These greenhouse gasses are, amongst others, associated with milk production. Hence, the aim of this study is to explore the impacts of reforming the EU Common Agricultural Policy (CAP) and liberalisation, with special emphasis on the milk sector, of international trade on emissions of greenhouse gasses by means of four contrasting scenarios in the GTAP-IMAGE modelling framework for the reference years 2015, 2030 and 2050. The scenarios that are explored in this study are:

- a baseline scenario that imagines a world developing over the next decades very much as it does today. This baseline scenario has strong resemblance with the OECD baseline scenario previously published by the MNP (2006);
- a full liberalisation scenario where trade barriers and quotas of the whole agricultural sector are fully phased out by 2015;
- a scenario of trade barrier elimination of the EU within the milk sector is implemented in such way that by 2015 the associated import and export subsidies of raw milk and dairy products are fully eliminated;
- finally an abolition of milk quota scenario in the EU is implemented where the domestic support and milk quota are fully phased out by 2015.

In the baseline scenario a further 63% increase of greenhouse gas emissions is seen
In the baseline scenario world GDP increases with circa 3% per year up to a 179% increase by 2050. Global production of milk and beef increases with 1.9% per year up tot 2030, and with 1.4% annually from 2030 to 2050. Global production of dairy is smaller than for milk and beef and growths with 1.4% to 1.3% annually up tot 2050. In the baseline scenario the emissions of greenhouse gasses (CO_2 equivalents) will rise globally up to 63% in 2050 compared to the year 2000. The increase in greenhouse gas emissions up to 2030 is strongest in respectively China, South Asia including India, South East Asia including Indonesia, and Africa. From 2030 onwards largest increments are found in respectively South Asia including India, Africa, and Middle East. The emissions of CO_2 decrease on the long term, the emissions of CH_4 (methane) strongly increase up to 2050, while the emissions of N_2O (nitrous oxide) show the smallest increase over time. Up to 2020 a strong increase of CO_2 emissions is found caused by land clearing of natural vegetation for agricultural land use in Africa, Latin America, South East Asia including Indonesia, and South Asia including India. The continued increase of methane emissions are caused by increasing the number of

cattle in the different regions. Increased beef production contributes more to the observed methane emissions than milk and dairy production. The increased emissions are due to increasing population density and a stronger demand for animal food caused by increased income.

Land clearing and extensive cattle farming leads to a strong increase of CO_2 and methane emissions with full liberalisation

Full liberalisation leads to production shifts of beef from Europe and Japan/Korea region towards Brazil, rest of Latin America and Africa. This in turn adds an extra 50% of CO_2 emissions by 2015, while a reduction of 30% is found in 2050 compared to the baseline scenario. The increased CO_2 emissions in the full liberalisation scenario are caused by additional land clearing for agriculture in these regions. Because animal husbandry in these regions is much more extensive than in the regions where this production was originally located (i.e. Europe and Japan/Korea) more cattle is needed to produce the same quantity of beef. Therefore full liberalisation also adds an extra 5% of methane emissions up to 2050 since ruminants are the most important source of methane. Full liberalisation leads to a production shift of milk and dairy from North America, Europe, Japan/Korea and Africa towards OECD pacific (Australia and New-Zealand), Russia, South Asia (India) and the rest of Latin America (excluding Brazil). Moreover, full liberalisation leads to an increase of milk but a decrease of dairy production in South East Asia (Indonesia). Methane emissions are therefore also increasing in OECD pacific (Australia and New-Zealand), South Asia and South East Asia. Finally, full liberalisation leads to an additional 1.7% of N_2O emissions globally, but this increased amount of emissions decrease over time. By 2050 N_2O emissions in full liberalisation are equal to the baseline.

Removal of trade barriers or milk quota hardly affects global emissions but leads to regional production shifts of agricultural commodities

Both removal of trade barriers and removal of milk quota had very small extra emission effects on CO_2, methane and N_2O emissions globally. Among both partial liberalisation scenarios the effects of trade barrier removal on the regional shifts of dairy and milk production are clearer, larger and more consistent over time than found in the abolition of milk quota scenario. Trade barrier removal leads to a production shift of both dairy and milk from Europe, North America, Japan/Korea, Africa and South East Asia (for the latter region in dairy production only) towards OECD pacific, Russia, South Asia (India) rest of Latin America (excluding Brazil) Eastern Europe/Central Asia (dairy only), and South East Asia including Indonesia (the latter region for milk production only). Mostly in OECD pacific an increase in methane emissions can be found. Milk quota removal leads to a small production decline of dairy in North America and OECD pacific, while for milk production a consistent decline is found in OECD pacific and North America. In 2030 an increase in milk production is found in South East Asia, while in 2050 this increase is also observed in Russia, China and the rest of Latin America excluding Brazil. In this year a strong reduction of milk production is also observed in Europe.

Liberalisation leads to a production decline of dairy and milk in Europe as a whole, but to an increase in the Netherlands and in new EU member states

Dividing the IMAGE Europe region into EU-14 (old member states), EU-12 (new member states) and the Netherlands show that full liberalisation in EU-14 leads to a production decline of beef (circa 23% reduction), dairy (circa 5% reduction) and milk (circa 6% reduction) while in EU-12 an increased production of milk (circa 6% increase), dairy (circa 22% increase), and a decreased production of beef (circa 6% reduction) is observed. In the Netherlands both milk and dairy production strongly increase (with circa 40% increase for milk and circa 35% increase for dairy) while beef production strongly decrease (circa 57% reduction) with full liberalisation. The increase of dairy and milk production in EU-12 and in the Netherlands can almost fully be explained by the abolition of milk quota. Trade barrier removal had hardly any or small negative effects on production.

1. Introduction

1.1 Current greenhouse gas emissions in the agricultural sector

European agriculture currently contributes to nearly 10% of all EU (EU-15) greenhouse gas emissions, including CH_4 and N_2O (Gugele et al., 2005; Eurostat, 2005). By ratification of the Kyoto protocol, EU member states have targeted an emission reduction by 8% in the 2008-2012 commitment period, compared to the base-year level 1990. Between 1994 and 1999, emissions from agriculture were nearly stable, around 495 million tons of CO_2 equivalents. From 1999 (circa 494 million tons) to 2003 (468 million tons) a 6% reduction was seen (Eurostat, 2005). Within the Netherlands a similar trend was be observed; from a circa 14.4% contribution to all greenhouse gas emissions in 1990 to an 11.4% contribution in 2005 (Klein Goldewijk et al., 2005; VROM report, 2005). These reductions in the Netherlands were the result of Dutch policy on manure (Minas) and EU policy on milk quota.

Although the contribution of agriculture to the total amount of CO_2 emissions is relatively low compared to other sectors, agriculture is one of the main anthropogenic sources of the greenhouse gasses methane (CH_4) and nitrous oxide (N_2O). Within the OECD, agriculture contributes to circa 40% of the total methane emissions and 43% of nitrous oxide emissions (e.g. Storey, 1997). Enteric fermentation by ruminants accounts for nearly 71% of agricultural methane emissions, of which 72% produced by dairy cows. Manure management is responsible for circa 29% of methane emissions. Sources of N_2O in agriculture are more diffuse however, but most N_2O emits from agricultural soils and are caused by application of (artificial) fertiliser. The observed decline in greenhouse gas emissions of circa 6% by agriculture can therefore be explained by the reduction in the number of dairy cows and reduction of animal waste, hence a reduction of CH_4 and N_2O (Eurostat, 2005; Klein Goldewijk et al., 2005). Because methane and nitrous oxide have relatively high global warming potentials of respectively 23 and 296 CO_2 equivalents, it pays off to reduce these two greenhouse gasses to meet the Kyoto targets.

1.2 Agricultural trade and greenhouse gas emissions

Domestic US and EU agriculture are protected by trade barriers and receive substantial support. The importance of reforming agricultural support policies in industrialised countries and improving market access, in particular for developing countries, has been recognised at the top political level. During the Doha round, the World Trade Organisation (WTO) emphasised on trade liberalisation of protected markets, such as agriculture. Changes in the European Common Agricultural Policy (CAP) and agreements concerning the international trade liberalisation may have an important impact on the agricultural sector and land use in Europe, as well as elsewhere in the world. Although a straightforward relation between trade liberalisation, economic growth and environmental improvements might be assumed, only very few studies have explicitly evaluated this relation. Recently Van Meijl et al. (2006) have studied the relation between visions of global trade on land-use changes, using the modelling framework of the global trade model GTAP (Hertel, 1997; Van Meijl et al., 2006) and the global environmental model IMAGE (Alcamo et al., 1998; IMAGE Team, 2001). Using the GTAP-IMAGE modelling framework, agricultural land-use was modelled using four contrasting global market scenarios.

Van Meijl et al. (2006) found that agricultural trade liberalisation leads to changes in agricultural land use. In developing regions like Africa, Asia, South and Central America highest growth of agricultural land use is found while in Europe agricultural land declines (Van Meijl et al., 2006). Similar simulation results were obtained for crop and livestock production. Such regional changes may also affect greenhouse gas emissions since the production of ruminant livestock increases methane emissions strongly. Cropland and pastures might store CO_2 to a certain extent. Crops take up carbon, while agricultural soils may also store carbon depending on, amongst others, local groundwater tables (e.g., Freibauer et al., 2004). Increased emissions due to livestock production on one hand and uptake of carbon by vegetation on the other hand make it difficult to predict shifts in regional greenhouse gas emission rates caused by agricultural policy reform. While in the EU greenhouse gas emissions might reduce in the agricultural sector due to liberalisation, emissions worldwide might increase.

The complex interactions between regional shifts in agriculture, intensification of agriculture by increased productivity, regional shifts in the main agricultural sectors like crop or livestock production and macro economic effects caused by trade liberalisation, such as a further increase in world population and changing food diets by increased income, make it difficult to predict future levels of greenhouse gasses. Using the modelling framework GTAP-IMAGE the effects of different agricultural trade liberalisation scenarios on future greenhouse gas emissions are studied.

1.3 Scenarios and storylines on agricultural trade

Scenario studies are often used to study the impacts of decision making, especially within the climate change debate. Because demography, technology, economics and the political arena interact in such a complex manner, simple predictions of possible outcomes cannot be made. Scenarios are not predictions as such. They are an approach to help manage the inherent uncertainties of decision making. The Intergovernmental Panel on Climate Change (IPCC) published a set of scenarios in the Special Report on Emissions Scenarios (SRES) (IPCC, 2000). These scenarios are based on a thorough review of the literature, the development of narrative 'storylines' and the quantification of these storylines using different integrated models from different countries. These storylines were constructed on two axes, i.e. the degree of globalisation versus regionalisation, and the degree of orientation on material and economic values versus an orientation on social and ecological values. The EURURALIS project elaborated on these four distinct story lines in such way that the axis depicting the economic versus social-environmental orientation in the SRES scheme is replaced by an axis that indicate the level of governmental regulation (e.g. Klijn et al., 2005).

In other words, in EURURALIS a world moving towards more economic values is associated with lean governments while a world moving towards social and environmental values requires ambitious governmental regulation.

In this paper impacts of various agricultural policies on greenhouse gas emissions are elaborated on by using four agricultural scenarios while keeping all other (trade) policy options constant. These agricultural scenarios, which are described in the next section, are based on the notion that production subsidies and trade barriers in European and OECD agriculture might drastically change in the near future. Emphasis is given to the agricultural policy of the milk sector, since current milk production is very highly supported in most OECD countries. A comparative approach is used in which the liberalisation scenarios, such as full liberalisation and the partial liberalisation scenarios removal of trade barriers in the milk sector or abolition of milk quota, are evaluated against a baseline scenario. This baseline scenario is derived from the latest figures from OECD on economic growth (Gross Domestic Product, GDP) and technological developments. For the four presented scenarios the baseline scenario and the full liberalisation scenario can be considered as opposite world views. While the baseline scenario reflects the current state of affairs within the agricultural sectors (CAP with trade barriers, quotas and subsidies) for future reference years 2015, 2030 and 2050, the full liberalisation scenario include complete trade liberalisation, with abandonment of trade barriers, export subsidies and quotas, of all agricultural sectors. With respect to the levels of greenhouse gas emissions, the two scenarios may also form the upper and lower bound levels. The two partial liberalisation scenarios, removal of trade barriers or removal of milk quota, can be considered as intermediates between the two extreme baseline and full liberalisation scenario. In the following section a short description of the four developed scenarios is given.

1.3.1 Baseline scenario

The baseline scenario is taken from the study published by the Netherlands Environmental Assessment Agency (2006). This baseline is 'a no-new policies scenario by design'. It imagines a world developing over the next decades very much as it does today, without anticipating deliberate interventions or responses to the projected developments (MNP, 2006). Moreover, no policies for emissions reductions (Kyoto protocol) are implemented in the baseline scenario.

1.3.2 Scenario of full liberalisation in all agricultural sectors

The full liberalisation scenario has a strong resemblance with the A1 global economy scenario of EURURALIS and SRES. In this world vision, trade barriers in all agricultural sectors are gradually eliminated and CAP subsidies are phased out in Europe (e.g., Westhoek et al., 2006). While in the A1 scenario of EURURALIS a gradual reduction of trade barriers and quota was implemented in such a way that by 2030 a full liberalisation was accomplished, the full liberalisation scenario presented in this study has fully phased out factor price subsidies, trade barriers and quotas worldwide by 2015.

1.3.3 Scenario of elimination of trade barriers within the milk sector

The historical use of trade measures, such as trade tariffs and subsidies, reflect the past European agriculture towards production oriented policy. In many OECD countries, the support of the milk sector is provided by measures such as quotas, tariffs and export subsidies, called *market price support* (OECD, 2004). In OECD countries market price support was an effective tool to protect domestic dairy producers. The OECD calculates the level of support provide to producers, using the agricultural policy measure Producer Support Estimate (PSE). In the EU-15 the PSE ranged from 63% in 1986 to the declining level of 48% in 2002 (OECD, 2004). In all OECD countries the PSE of market price support reduced from 89% in 1986 to 86% in 2002. This latter value corresponds to circa 35,432 million US dollars annually. These values indicate that financial support is very high and the concomitant trade distortions are high as well. The scenario of trade barrier elimination is implemented in such way that by 2015 the associated import and export subsidies of raw milk and dairy products that form the basis of trade barriers are fully eliminated in this scenario.

1.3.4 Scenario on abolition of milk quota

The WTO round of agricultural trade negotiations in Doha considered a liberalisation of the milk sector, including commitments to substantially improve market access by reducing, with a view to phasing out, all forms of export subsidies. For the abolition of milk quota scenario presented in this report the domestic support and milk quota are fully phased out by 2015.

1.4 Aim of this study and research questions

The aim of this study is to explore the impacts of CAP reform and agricultural trade liberalisation on emissions of greenhouse gasses. Four contrasting scenarios are developed: a baseline scenario, a full liberalisation scenario and two partial liberalisation scenarios of removal of trade barriers in the milk sector and abolition of milk quota only. Specific questions that are elaborated on in this study are:

- Which regions face the largest shifts in production and associated greenhouse gas emissions?
- Are regional shifts in production caused by a further increase of the agricultural area for dairy cattle?
- Do changes in greenhouse gas emissions result from a further intensified agricultural practice (increased productivity) like cattle density?

2. Modelling framework, methods and data

2.1 IMAGE model

The Integrated Model to Assess the Global Environment (IMAGE) has been the central tool for the analysis reported here. IMAGE has initially been developed as an integrated assessment model to study anthropocentric climate change (Rotmans et al., 1990). Later it was extended to include a more comprehensive coverage of global change issues in an environmental perspective (Alcamo et al., 1994; IMAGE team, 2001). The current 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.

IMAGE provides a dynamic and long-term assessment of the systemic consequences of global change up to 2100. The model was set up to give insight into causes and consequences of global change up to 2100 as a quantitative basis for analysing the relative effectiveness of various policy options for addressing global change. Figure 2.1 provides an overview of the IMAGE modelling framework used in this analysis. The population projection is taken from the UN directly and is one of the inputs for the OECD ENV-Linkages model.

- The TIMER model (see De Vries et al., 2001) 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, emissions of greenhouse gases (GHG), ozone precursors and acidifying compounds are computed.
- Agricultural demand, production and trade is calculated by the GTAP model (see section 2.2).
- The Terrestrial Environment System (TES) computes land-use changes based on regional production of food, animal feed, fodder, grass and timber, with consideration of local climatic and terrain properties, and changes in natural vegetation due to climate change. Consequently, emissions from land use changes, natural ecosystems and agricultural production systems, and the exchange of CO_2 between terrestrial ecosystems and the atmosphere are calculated.
- The Atmospheric Ocean System (AOS) calculates changes in atmospheric composition using the emissions from the TIMER model 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 (see Eickhout et al., 2004).

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 analyse 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 rain fed 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; (3) rooting conditions for plants. The adjustment factor is calibrated using historical productivity figures and also includes the fertilisation effect of changes in the atmospheric concentration of CO_2. The CO_2 fertilisation is determined by the Terrestrial Carbon Model (TCM) 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.

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 LCM is to allocate crop production on grid cells within the world regions until the total demand for this region is satisfied. The results depend on changes in the demand for food and feed as computed by 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 1765-1970 period to initialize the carbon cycle and climate system. Actual simulations cover the period 1970-2050. Data for 1970-2000 are used to calibrate the TIMER model and TES subsystems. Simulations up to the year 2050 are driven by the input from the TIMER model and GTAP, and by additional scenario assumptions on e.g. technology development, yield improvements and efficiencies of animal production systems.

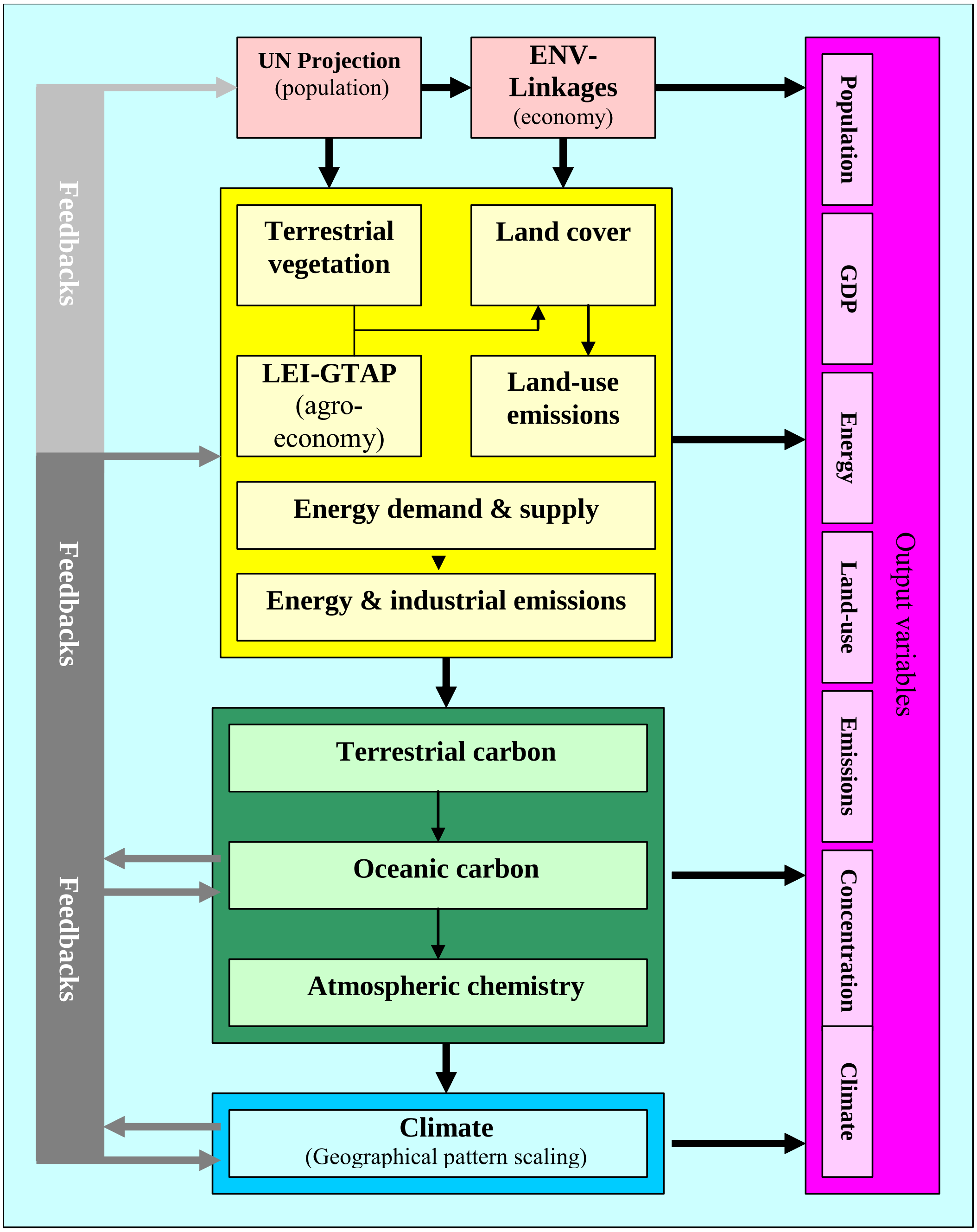

Figure 2.1 Flow diagram of the IMAGE framework

2.2 GTAP model

2.2.1 Standard GTAP model

The economic analysis was done with an extended version of the general equilibrium model of GTAP (Hertel, 1997). The GTAP model is a multi-regional, static, applied general equilibrium model based on neoclassical microeconomic theory. The standard model is characterized by an input-output structure (based on input-output tables of nations and groups of nations) 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 maximise a profit function by choosing inputs of labour, capital, and intermediates. Each sector produces one type of output. Perfect competition is assumed in all sectors. In the case of crop and livestock 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 labour and capital are fully employed within each economy, while the use of land is determined by the interaction of demand and supply. Returns to land and capital are endogenously determined at the equilibrium, i.e., the aggregate supply of each factor equals its demand. Each region is equipped with one regional household which distributes income across savings and consumption expenditures according to fixed budget shares. Consumption expenditures are allocated across commodities according to a non-homothetic CDE expenditure function with variable income elasticities.

In contrast to most Partial Equilibrium (PE) models, GTAP assumes that land is heterogeneous. The heterogeneity is introduced by specifying a transformation function, which takes total land as an input and distributes it among various sectors in response to relative rental rates. A Constant Elasticity of Transformation (CET) function is used, where the elasticity of transformation is a synthetic measure of land heterogeneity. 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 labour, capital and land are mobile between sectors but not between regions.

GTAP assumes that products are differentiated by country. This is modelled using the Armington approach, which assumes that imports and domestic commodities are imperfect substitutes in demand. A CES function describes the substitution possibilities between these goods. In this way the bilateral commodity trade is modelled. 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.

The income elasticities in the standard GTAP model are high compared with FAO estimates and do not change with income. Because income may increase enormously, this implies a bias in the results. So, first we estimated a dynamic relationship between PPP-corrected real GDP per capita and income elasticities implicit in GTAP. But this relationship between real income and income elasticities was much higher than the FAO. For that reason we adjusted the relationship for food to have a more consistent behaviour, both with FAO estimates and with the development of the share of food expenses in consumption expenditures in growing economy. In figure 2.2 the blue dots show the original GTAP elasticities, while the red dots in a line show out final estimated relationship, in this case for grain. The other income elasticities are adjusted in a similar way.

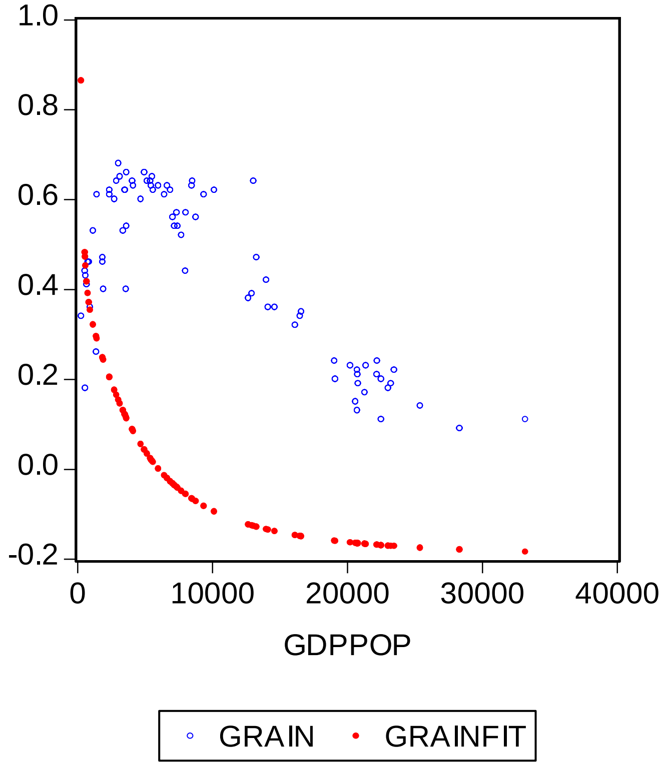

Figure 2.2 *Relationship between GDP per capita (x-axis) and income elasticities (y-axis). Blue dot: original GTAP elasticities, red dots estimated relationship*

2.2.2 Extensions to the standard GTAP model

The base version of GTAP represents land allocation in a CET structure (see left part of figure 2.3). It was assumed that the various types of land use are imperfectly substitutable, but the substitutability is equal among all land use types. The land use allocation structure is extended by taking into account that the degree of substitutability of types of land differs between types (Huang et al., 2004). For this the more detailed OECD's Policy Evaluation Model (OECD, 2003) structure is used. It distinguishes different types of land in a nested

3-level CET structure. The model covers several types of land use more or less suited to various crops (i.e. cereal grains, oilseeds, sugar cane/sugar beet and other agricultural uses). The lower nest assumes a constant elasticity of transformation between 'vegetables, fruit and nuts' (HORT), 'other crops' (e.g. rice, plant based fibres; OCR), the group of 'Field Crops and Pastures' (FCP) and non-agricultural land (NAG). The transformation is governed by the elasticity of transformation σ1. The FCP- group is itself a CET aggregate of Cattle and Raw Milk (both Pasture), 'Sugarcane and Beet' (SUG), and the group of 'Cereal, Oilseed and Protein crops' (COP). Here the elasticity of transformation is σ2. Finally, the transformation of land within the upper nest, the COP-group, is modeled with an elasticity σ3. In this way the degree of substitutability of types of land can be varied between the nests. It captures to some extent agronomic features. In general it is assumed that σ3> σ2 >σ1. This means that it is easier to change the allocation of land within the COP group, while it is more difficult to move land out of COP production into, say, vegetables. The values of the elasticities are taken from PEM (OECD, 2003).

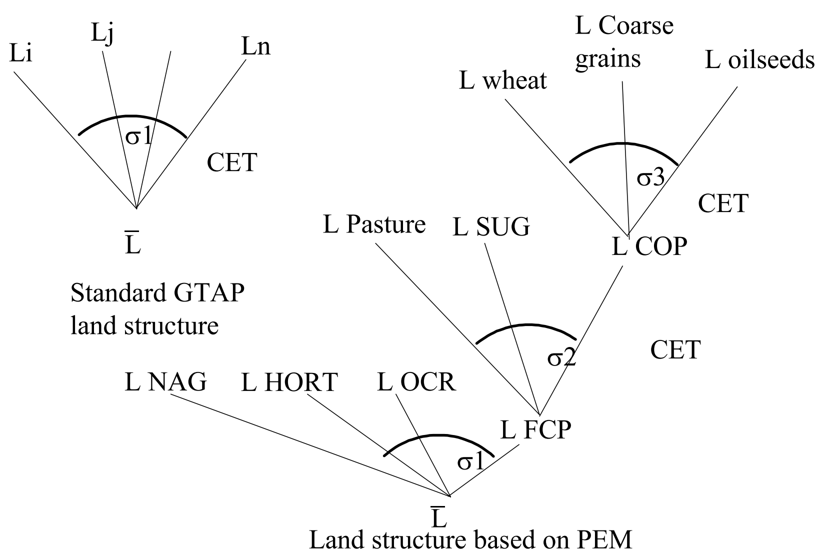

Figure 2.3 Land allocation tree within the extended version of GTAP

Moreover, in the standard GTAP model the total land supply is exogenous. In this extended version of the model the total agricultural land supply is modelled using a land supply curve which specifies the relation between land supply and a land rental rate in each region. Land supply to agriculture can be adjusted as a result of unused agricultural land, conversion of non-agricultural land to agriculture, conversion of agricultural land to urban use and agricultural land abandonment. The concept of a land supply curve has been based on Abler (2003).

The general idea underlying the land supply curve specification is that the most productive land is first taken into production. However, the potential for bringing additional land into agriculture is limited. If the gap between potentially available agricultural land and land used in the agricultural sector is large, the increase in demand for agricultural land will lead to land conversion to agricultural land and a modest increase in rental rates to compensate for the cost to take this land into production (see left part of figure 2.4). Such a situation can be depicted by points situated on the left flat part of the land supply curve.

However, when almost all agricultural land is in use, an increase in demand for agricultural land will mainly lead to high increase of the land rental rates (land becomes scarce, see right part of figure 2.3). In this case land conversion is difficult to achieve and therefore the elasticity of land supply in respect to land rental rates is low as well. This situation is described by points situated on the right steep part of the land supply curve.

We derived and estimated the land supply curve using biophysical data from modelling framework IMAGE (Alcamo et al., 1998). IMAGE takes into account marginal lands and changes in the potential land productivity due to changes in land use and climate change. In the IMAGE model, climate and soil conditions determine the crop productivity on a grid scale of 0.5 by 0.5 degrees, allowing the feedback of heterogeneous information of land productivity to the economic framework.

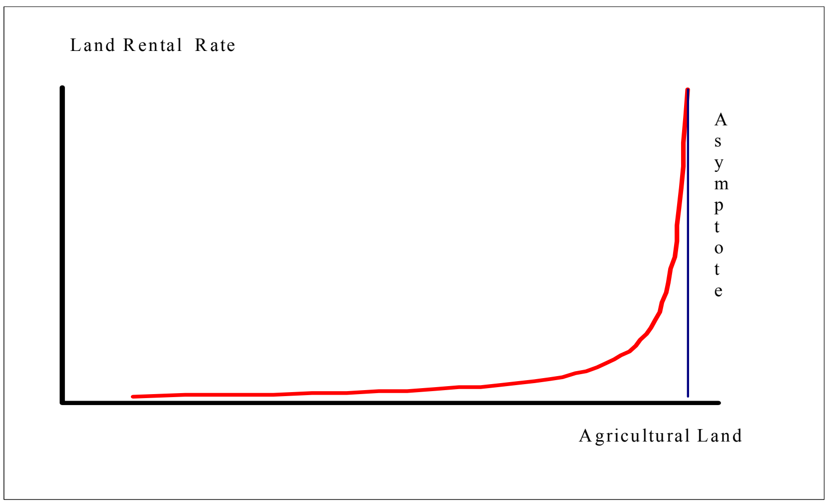

Figure 2.4 Land supply curve determining land conversion and land rental rate

We derive land supply curves using the IMAGE land productivity curves describing the potential crop productivity (for an average crop) as a function of the accumulated land area. This productivity curve can be translated into land supply curve under the assumption that the land price is a function of the inverse of the land productivity. It can be described by the following mathematical equation:

Land supply = a - b/f(1/y)

where, 'a' (>0) is an asymptote interpreted as the maximal potentially available agricultural land and 'b' is a positive parameter and f(1/y) is a non-increasing function of the inverse of land productivity y. Function f(1/y) can be interpreted in two different ways. It can be seen as a function of real land price (p) defined as inverse of yield (i.e.: p = 1/y) or it can be itself interpreted as land price (i.e.: p = f(1/y).

We have assumed that f(1/y) function is defined as follows:

$$f(1/y) = c_o + (1/y)^p + \Sigma_{i=1,\dots,n}\, c_i(1/y)^{p+i}$$

where parameters 'c_i' are estimated parameters, and 'p' and 'i' are set using an iterative estimation procedure.

Asymptote 'a' of the land supply curve is provided by IMAGE and equal to available land per world region minus urban area, protected bio-reserves, ice and tundra and so on. When the potential land productivity is close to the observed land productivity, we estimate the asymptote (simultaneously with other parameters of the land supply curve) using only observations concerning the accumulated land area lower then the currently observed agricultural area. This method was used the EU-15 countries rest of the Western Europe and Japan. The land supply curve was estimated for 25 countries and regions. The estimated land supply function is implemented into GTAP model.

Figure 2.5 shows how the land supply functions can differ per region. For instance, the current position of Africa on their land supply curve indicates that the agricultural land in Africa can still be expanded without a high increase in the rental land price in this region. The opposite situation is observed for EU15. Small expansion in the agricultural land in EU15 will lead to a high increase in real land prices, therefore stimulating intensification processes in agricultural practices.

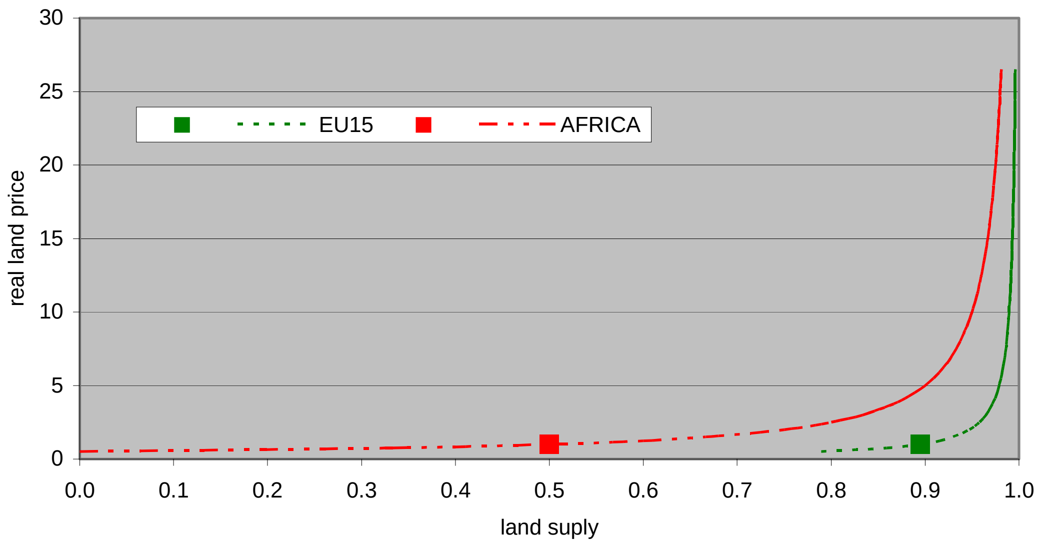

Figure 2.5 Land supply curves (asymptotes scaled to 1) for EU15 and Africa and the current positions of these regions on their land supply curves

2.2.3 Factor market segmentation

If labour were perfectly mobile across domestic sectors, we would observe equalized wages throughout the economy for workers with comparable endowments. This is clearly not supported by evidence. Wage differentials between agriculture and non-agriculture can be sustained in many countries (especially developing countries) through limited off-farm labour migration (De Janvry et al., 1991). Returns to assets invested in agriculture also tend to diverge from returns of investment in other activities.

To capture these stylised facts, we incorporate segmented factor markets for labour and capital by specifying a CET structure that transforms agricultural labour (and capital) into non-agricultural labour (and capital) (Hertel and Keening, 2003). This specification has the advantage that it can be calibrated to available estimates of agricultural labour supply response. In order to have separate market clearing conditions for agriculture and non-agriculture, we need to segment these factor markets, with a finite elasticity of transformation. We also have separate market prices for each of these sets of endowments. The economy-wide endowment of labour (and capital) remains fixed, so that any increase in supply of labour (capital) to manufacturing labour (capital) has to be withdrawn from agriculture, and the economy-wide resources constraint remains satisfied. The elasticities of transformation can be calibrated to fit estimates of the elasticity of labour supply from OECD (2003).

2.2.4 Agricultural production quotas

An output quota places a restriction on the volume of production. If such a supply restriction is binding, it implies that consumers will pay a higher price than they would pay in case of an unrestricted interplay of demand and supply. A wedge is created between the prices that consumers pay and the marginal cost for the producer. The difference between the consumer price and the marginal costs is known as the tax equivalent of the quota rent. 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. If t denotes the tax equivalent of the quota rent, and r denotes the difference between the output quota and output q, then the complementary problem can be written as:

$$r = \bar{q} - q$$

and

either $t > 0$ and $r = 0$ the quota is binding
or $t = 0$ and $r \geq 0$ the quota is not binding

2.3 Coupling of GTAP and IMAGE

Figure 2.6 shows the methodology of iterating the extended version of GTAP with IMAGE. The output of GTAP is, among others, sectoral production growth rates, land use, and a yield factor describing the change in land productivity because of technology improvements and the degree of land intensification. The degree of intensification is modelled endogenously by GTAP, while the technology improvement is assumed exogenously using information from FAO's study 'World Agriculture towards 2015/2030' (Bruinsma, 2003).

The output from GTAP is used by the IMAGE model to calculate change in crop productivity, the demand for land, feed efficiency rates and environmental indicators. This procedure delivers adjustments to the achieved changes in yields and changes in feed conversion, which are given back to GTAP. Through this procedure comparable land foresights are simulated in both models.

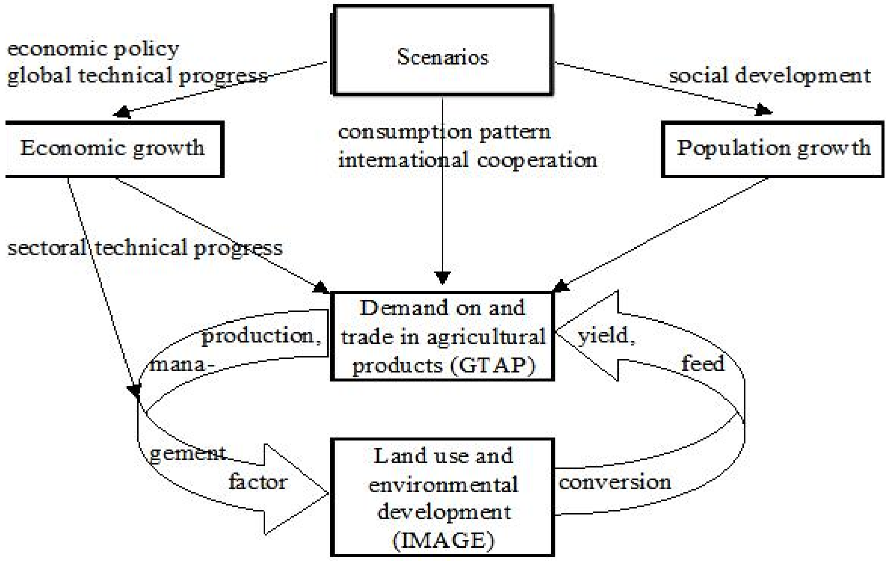

Figure 2.6 The modelling framework of GTAP and IMAGE

2.3.1 Yields

In the adjusted GTAP model yield depends on a trend factor due to technological development and prices. The production structure used in this model implies that there are substitution possibilities among production factors. If land gets more expensive, the producer uses less land and more other production factors such as capital. The impact of a higher land price is that land productivity or yields will increase. Consequently, yield is dependent on an exogenous part - the *trend* component - and on an endogenous part with relative factor prices, which is the *management'* component.

The exogenous trend of the yield is taken from the FAO study 'Agriculture towards 2030' (Bruinsma, 2003) where macro-economic prospects were combined with local expert knowledge. This approach led to best-guesses of the technological change for each country for the coming 30 years. Given the scientific status of the FAO-work these data were used as exogenous input for a first model run with the adjusted GTAP model. However, many studies indicated this change in productivity are enhanced or reduced by other external factors, of which climate change is mentioned most often (Rosenzweig et al., 1995; Parry et al., 2001; Fischer et al., 2002). These studies indicated increasing adverse global impacts because of climate change will be encountered with temperature increases above 3 to 4°C compared to pre-industrial levels. These productivity changes need to be included in a global study. Moreover, the amount of land expansion or land abandonment will have an additional impact on productivity changes, since land productivity is not homogenously distributed over each region.

In our approach, the exogenous part of the yield was updated in an iterative process with the IMAGE model (see figure 2.6). The output of GTAP used for the iteration with IMAGE is sectoral production growth rates and a management factor describing the degree of land intensification. Next, the IMAGE model calculates the yields, the demand for land and the environmental consequences of crop growth productivity. IMAGE simulates global land-use and land-cover changes by reconciling the land-use demand with the land potential. The basic idea 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 and a management factor as computed by 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). This procedure delivers an amount of land needed per world region and the coinciding changes in yields, because of changes in the extent of used land and climate change. Next, these additional changes in crop productivity are given back to GTAP. A general feature is that yields decline if large land expansions occur since marginal lands are taken into production. In the near term, these factors are more important than the effects of climate change.

2.3.2 Feed conversion in livestock

The intensification of livestock production systems also influences the composition of the feed required by livestock production systems. In general, intensification is accompanied by decreasing dependence on open range feeding and increasing use of concentrate feeds, mainly feed grains, to supplement other fodder. At the same time improved and balanced feeding practices and improved breeds in ruminant systems enabled more of the feed to go to meat and milk production rather than to maintenance of the animals. This has led to increasing overall feed conversion efficiency (Seré and Steinfeld, 1996). In the IMAGE model, the production of animal products is used as input to simulate the number of animals required for this production. For this conversion, the animal productivity is taken from Bruinsma (2003) including the future developments until 2030. The calculation of total feed required in dairy and beef production were modified from EPA (1994). In this approach the net energy requirements for dairy cattle are divided into maintenance, feeding, lactation and pregnancy (Bouwman et al., 2004). Based on the animal diets, the intake of crops and grass/fodder are calculated to feed the animals. The feed composition in 2000 is taken from Bruinsma (2003). Future shifts in feed composition were assumed to follow the intensification or extensification coming from GTAP. Intensification will lead to a shift towards more concentrate feeds (maize and soy beans). On the basis of these feed diets the demand for grass and fodder was 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. Hence, 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 were described in Bouwman et al. (2004). This procedure delivers feed conversion or efficiency rates for the livestock sectors that were used as input for the GTAP modelling framework.

2.3.3 Feed demand in food processing industry

As noted above, developments in livestock are important for the demand for feed crops. In many countries feed crops are delivered to the feed-processing industry and this sector adds value and delivers it to the livestock sectors. The feed-processing sector in GTAP is a part of a very heterogeneous food processing sector which causes the problem that feed demand is determined by the growth of this larger food processing sector and only indirectly by the growth of the livestock sectors.[1] Given the importance of crop feed demand for land use we adjust this aggregation issue by creating a direct link between feed demand in agro-food processing sector ('agro') and the growth of the livestock complex. Demand for feed crops in food processing sector is a sales weighted average of growth of livestock sectors:

$$qf(i,"agro"r) = \sum_{k=livestock} \frac{VFA("agro",k,r)}{\sum_{m=livestock} VFA("agro",m,r)} * \left(qo(k,r) - af(i,k,r)\right)$$

where qf (i, 'agro', r) is growth rate of industry demand in food processing sector (agro) for intermediate feed crop input i in region r, VFA ('agro',k,r) is producer expenditure of k industry on sales from food processing industry (agro) in region r, qo(k,r) is production growth in sector k in region r, sector k is a livestock sector, and af(i,k,r) is the feed efficiency rate in livestock sector k in region r. This efficiency rate af(i,k,r) is provided by IMAGE.

2.4 Parameters used in this study

The IMAGE framework makes a distinction between greenhouse gasses emitted by the energy and industry sector and those from land use. In this paper we mainly report emissions of CO_2, CH_4 and N_2O that are associated with land-use (change). Emissions from energy and industry are equal in all scenarios. However, these emissions also drive climate change and therefore crop productivity. Therefore also emissions of all greenhouse gasses of all sectors are given in CO_2 equivalents. This is a measure of the warming potential of all greenhouse gasses. In general, values of CO_2 equivalents are 20-30% higher than for CO_2 alone (Strengers et al. 2004). With regard to the land-use specific emissions the following data are reported:

- for CO_2 values those emitted by land-use are used but not those from natural vegetation. In IMAGE no further distinction of different sources of land-use associated CO_2 emissions are made;
- for land-use associated CH_4 emissions only those from animal waste (manure) and animals (enteric fermentation by ruminants) are presented in the result section. Land-use associated CH_4 emissions in IMAGE also include those from agricultural waste burning, biomass burning, fuel wood burning, landfills, savannah burning, sewage and wetland rice;

[1] In the aggregation used in this paper the problem is more serious because it separates only a very aggregated food-processing sector where the feed processing industry is only a minor part.

- for land-use associated N_2O emissions only those from animal waste and fertiliser are used. In IMAGE land-use associated N_2O emissions also include those from biomass burning, fuel wood burning, agricultural waste burning, savannah burning, land clearing, domestic sewage, crop residues and biological N-fixation.

3. Results

3.1 CO_2 equivalents

Figure 3.1 depicts the total amount of greenhouse gas emissions of all sectors (e.g., industry, energy and land use) under the baseline scenario. In figure 3.2 the difference in greenhouse gas emissions for the periods 2000-2015, 2015-2030 and 2030-2050 is given. In the first temporal census (2000-2015) largest increments are found in China region (CHN), south Asia including India (SOA), North America (NAM), south east Asia including Indonesia (OAS), and Africa (AFR). In the second census (2015-2030) a large increase is found in CHN, AFR and SOA, while the third census (2030-2050) shows the largest increases in SOA and AFR. On a global scale, there is an increase in emissions of all greenhouse gasses, but these increments tend to level off during the successive temporal census periods. While in the first census global emissions increments are found at circa 0.218 Pg/yr, the second census period shows a value of 0.134 Pg/yr and the third census period a value of 0.08 Pg/yr.

Since CO_2 eq. of the sectors energy and industry are in the three liberalisation scenarios not differently from the baseline scenario, the observed deviations in CO_2 eq. are accounted for land use and thus agriculture only (figure 3.3). The full liberalisation scenario shows the largest difference in CO_2 eq. emissions with the baseline scenario by 2015. In this reference year emissions in this scenario are 0.855 Pg C/yr larger than in the baseline scenario which corresponds to a circa 5.9% increase in emissions globally (figure 3.3). This is mostly caused by a strong emission increment in Brazil (BRA, circa 160% increase), other Latin America (OLC, circa 25% increase), south-east Asia (OAS, circa 10% increase) and Africa (AFR, circa 4% increase). By 2030, global emissions in the full liberalisation scenario are lower than in the baseline with respectively values of -0.024 Pg C/yr (circa -0.15%) in 2030, and -0.034 Pg C/yr (circa -0.19%) in 2050. Regional differences are in these census periods smaller with increments in BRA, SOA and OLC and decrements in north America (NAM) and Europe (EUR) in 2030 and additional increments in OECD pacific (ANZ) in 2050.

The removal of trade barriers result in only small differences in CO_2 eq. emissions compared to the baseline scenario on a global scale. In 2015 global emissions are -0.02 Pg C/yr (circa -0.14%) lower, in 2030 0.013 Pg C/yr (circa 0.08%) higher, and in 2050 -0.008 Pg C/yr (circa -0.04%) lower than in the baseline scenario. Differences in regional emissions are small as well. In 2015 largest increments are found in ANZ (circa 3.7%), and BRA (ca. 2.7%), while largest decrements are found in OLC (circa - 12.5%) and OAS (circa- 7%). In 2030 largest increments are found in ANZ (circa 4.7%) and decrements in BRA (circa - 2.9%). In 2050, finally, ANZ shows the largest increment of circa 9.4% while no particular region shows a concomitant decrease in emissions (all decrement are less than -0.5%).

Compared to the previous liberalisation scenarios, the abolition of milk quota leads to smaller (regional) differences in CO_2 eq. emissions compared to the baseline scenario.

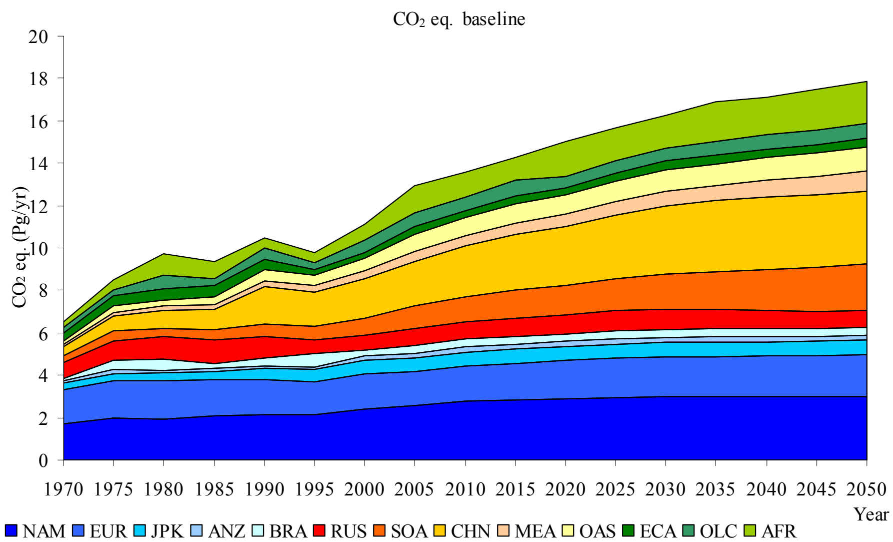

Figure 3.1 Production of all greenhouse gasses (CO_2 equivalents) for the 13 regions under the baseline scenario

Regions: NAM =North America, EUR = Europe, JPK = Japan-Korea, ANZ = Australia - New Zealand, BRA = Brazil, RUS = Russia, SOA = South Asia, including India, CHN = China region, MEA = Middle East, OAS = South East Asia, including Indonesia, ECA = Eastern Europe and Central Asia, OLC =South America and Caribbean excl. Brazil, AFR = Africa.

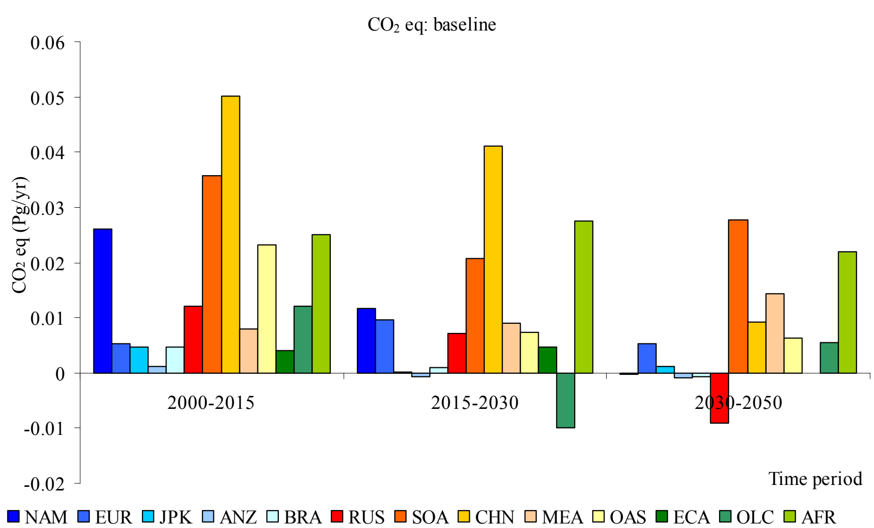

Figure 3.2 Change (in Pg CO_2 eq. per year) in all greenhouse gasses (CO_2 equivalents) for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050

For region abbreviations, see figure A1.1 in appendix 1.

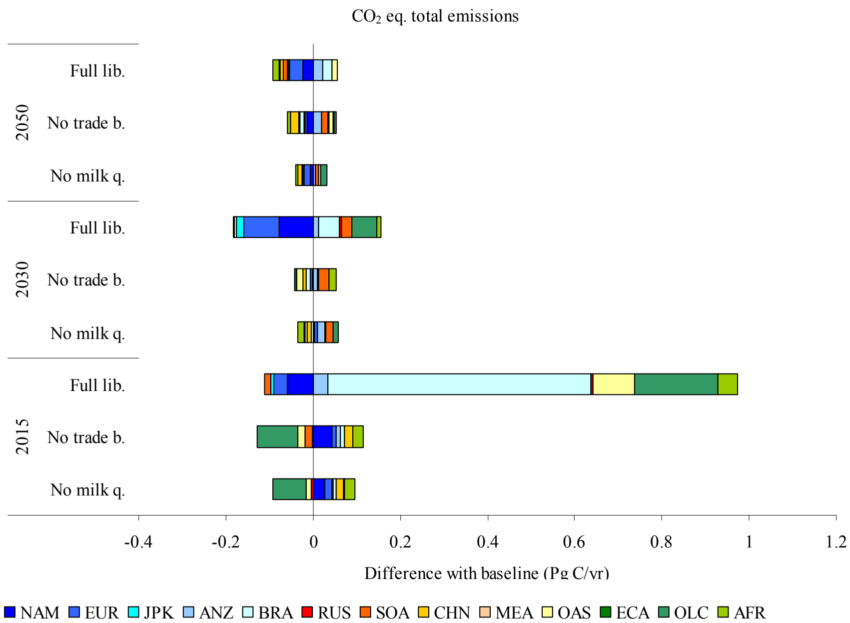

Figure 3.3 A Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for CO_2 equivalents in the 13 regions

Differences are expressed as difference in Pg C/yr (figure 3.3 A), and as percentage difference (figure 3.3 B). For region abbreviations, see figure A1.1 in appendix 1.

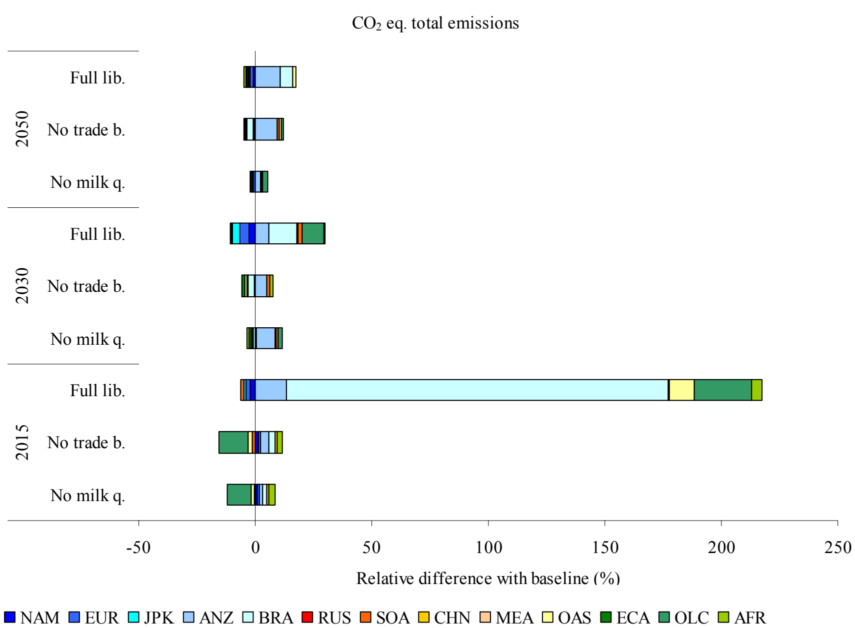

Figure 3.3 B Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for CO_2 equivalents in the 13 regions

Differences are expressed as difference in Pg C/yr (figure 3.3 A), and as percentage difference (figure 3.3 B). For region abbreviations, see figure A1.1 in appendix 1.

In 2015 global emissions in this scenario are almost equal to the baseline, while in 2030 emissions are only 0.16% larger and by 2050 -0.03% lower than in the baseline. In 2015 the largest regional reduction is seen in OLC, while various regions show small increases in emissions. For 2030 and 2050 no particular regional patterns in emissions are found. ANZ shows a small (circa 8% and 2.3%) percentage increase in respectively 2030 and 2050 while in other regions emission differences with the baseline are less than 1%.

3.2 CO_2 land use emissions

Figure 3.4 depicts the increase in CO_2 emissions for the baseline scenario. Land use associated CO_2 emissions are strongly related to land clearing activities. These activities are not gradually implemented in IMAGE but occur when production areas are needed. Hence peak emissions of CO_2 are found. As a result of this implementation only change in emissions are depicted in figure 3.4 and not the amount of CO_2 throughout the simulation period since such a graph will show peak emissions that are difficult to interpret. As can be observed in figure 3.4, in 2015 a strong increase in emissions is found (in descending order) in South East Asia (OAS), South Asia (SOA), Africa, Other Latin America (OLC), and North America (NAM). A decrease in emissions is found in China. In 2030 globally a net decrease in emissions are found with largest decrements in OLC, OAS, SOA, Brazil, China and OECD pacific (ANZ) and increased emissions in Europe, Russia, Africa and North-America. By 2050 all regions have zero or decreasing emissions compared to 2030.

In 2015 the full liberalisation scenario leads to a strong increase in CO_2 emissions in Brazil and rest of Latin America, and to a less strong increase in South East Asia (SOA) and Africa (figure 3.5). Reduction is seen in North America (NAM). The two removal scenarios (trade barrier or milk quota) lead to a small increase in emissions in many regions and a reduction in Latin America (OLC). By 2030 the regional shifts in the full liberalisation scenario leads to a net decrease in CO_2 emissions with reductions found in NAM and Europe. An increase is found in South Asia (SOA) and Latin America. Regional emission differences in the trade barrier and milk quota scenarios are very small by 2030. In many regions small deviations with the baseline scenario can be found. In 2050 only small deviations with the baseline scenario is found for all liberalisation scenarios with a relatively large decrease of emissions in Brazil in the full liberalisation scenario.

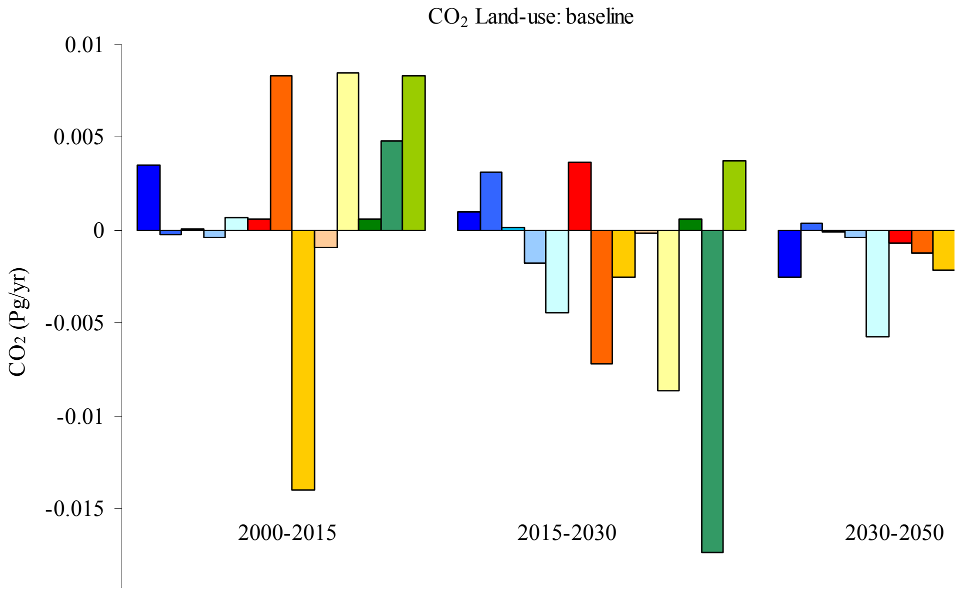

Figure 3.4 *Change (in Pg CO_2 per year) in land use associated CO_2 emissions for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050*

For region abbreviations, see figure A1.1 in appendix 1.

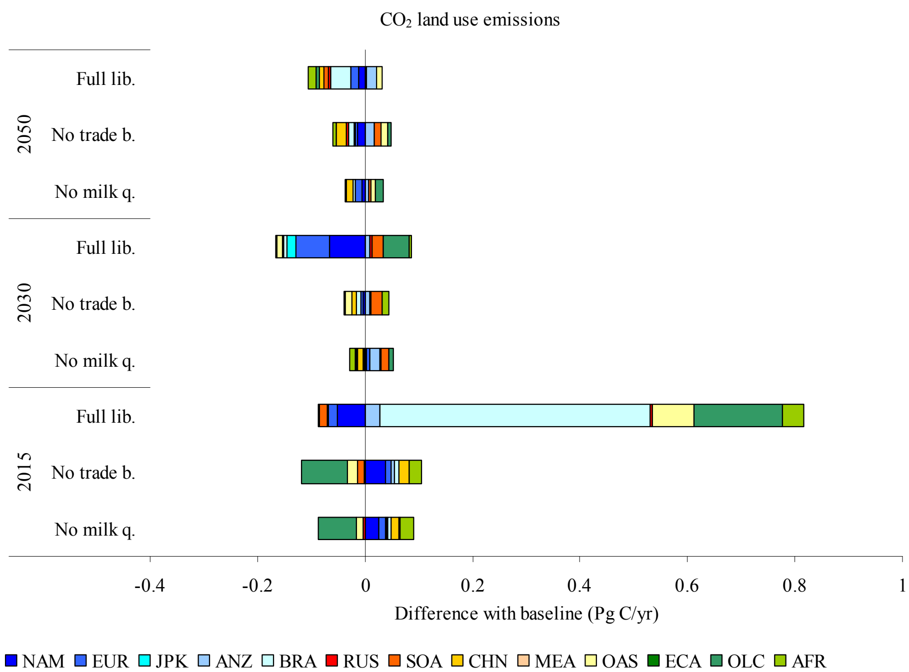

Figure 3.5 *Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for land use associated CO_2 in the 13 regions*

Differences are expressed as difference in Pg CO_2/yr. For region abbreviations, see figure A1.1 in appendix 1.

3.3 CH_4 land-use emissions

Figure 3.6 depicts the methane emissions caused by ruminants and animal waste, hereafter called associated CH_4 land use emissions. The figure shows a further increase in methane emissions under the baseline scenario. In all census periods methane emissions increase in the baseline scenario, and largest regional increments are found in Africa (figure 3.7). During the first (2001-2015) and second (2015-2030) census period large regional increments are also found in SOA, BRA, CHN, and to a lesser extent in OLC. Methane emissions decrease in the EUR region during all census periods, although these decrements are relatively small.

Compared to the baseline scenario, the full liberalisation scenario leads to larger methane emissions. Globally emissions continue to rise from 5.77 Tg CH_4 per year (4.7%) in 2015 to 6.96 Tg CH_4 (4.9%) in 2030 and 7.96 Tg CH_4 (5%) in 2050. In all census periods regional emissions strongly increase in Brazil, both expressed as Tg CH_4 and as percentage differences (figure 3.8). Smaller regional increments are found in SOA, OLC and AFR. During all census periods methane emissions decrease in Europe (-6 to - 10%) in the full liberalisation scenario.

The scenario with removal of trade barriers leads to marginal differences in global emissions. The largest difference with the baseline is found in 2015 where global emissions rise circa 0.1% compared to the baseline. In OECD pacific (ANZ) emissions increase most strongly, based on percentage difference. The largest difference with the baseline scenario is found to be + 6.3% in 2050.

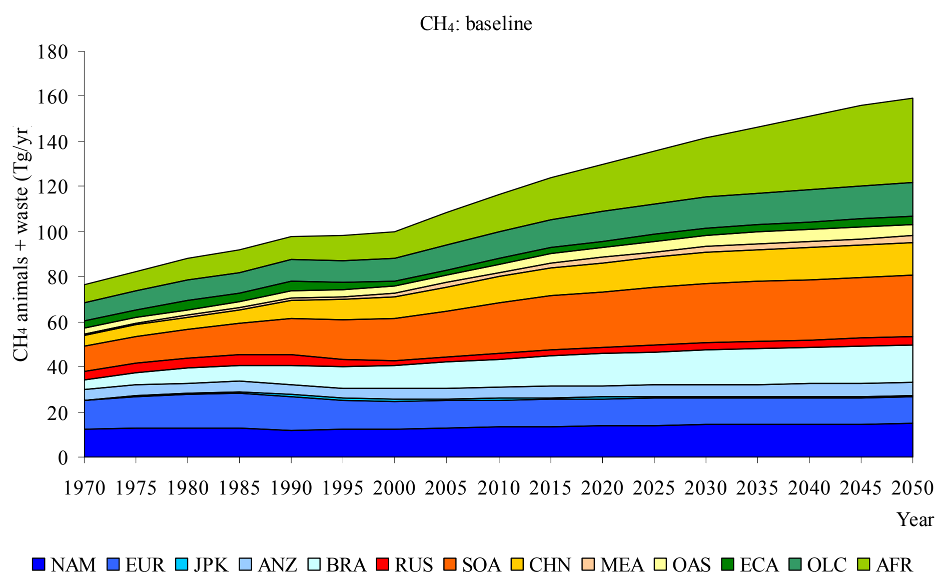

Figure 3.6 Production of land use associated methane emissions (CH_4) for the 13 regions under the baseline scenario

For region abbreviations, see figure A1.1 in appendix 1.

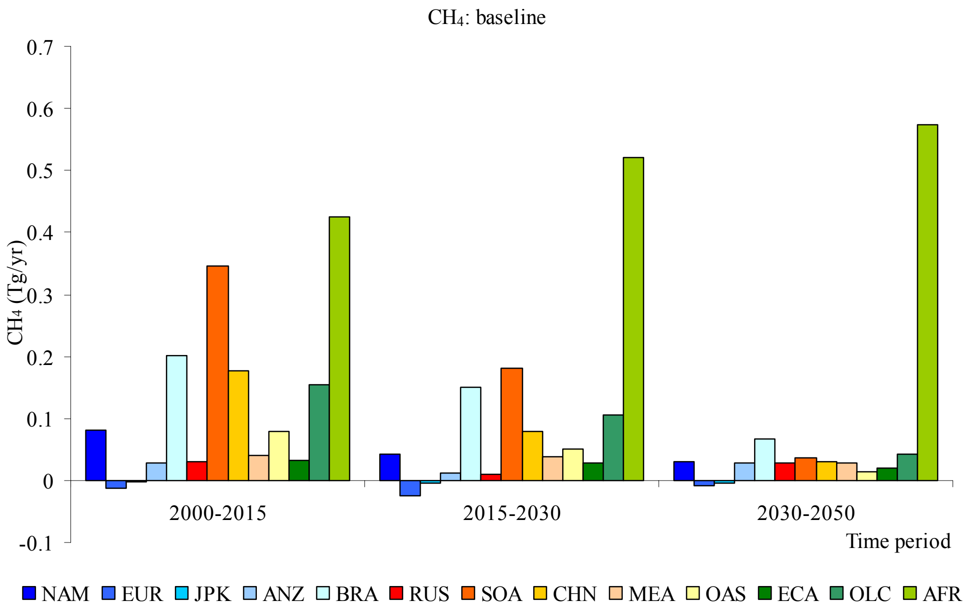

Figure 3.7 Change (in Tg CH_4 per year) in land use associated methane emissions for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050
For region abbreviations, see figure A1.1 in appendix 1.

Regional differences in emissions, compared to the baseline, increase over time, with the relative largest deviations found in 2050. SOA and AFR show the relatively largest decrements in CH_4 emissions in 2030 and 2050, although these differences were less than 1%.

Abolition of milk quota leads to smaller differences in methane emissions than the full liberalisation and removal of trade barrier scenarios. During all census years global emissions are somewhat lower than for the baseline scenario, but differences were always smaller than 0.3%. The same pattern holds for regional differences. In 2015 and 2030 regional differences in methane emissions were found to be smaller than 0.7% compared to the baseline. In 2050 the largest regional increase in methane emissions was found for Russia (+ 1.8%). Abolition of milk quota leads to relatively small emission increases in Europe with + 0.24% in 2015 and + 0.13% in 2030, and a small reduction in 2050 of circa -0.88%.

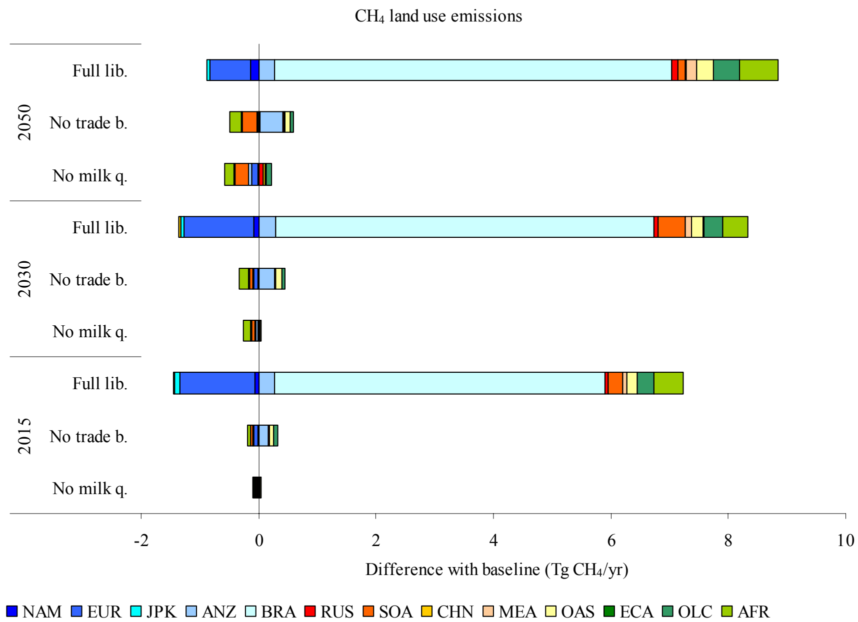

Figure 3.8 A Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for methane (CH_4) in the 13 regions

Differences are expressed as difference in Tg CH_4/yr (figure 3.8 A), and as percentage difference (figure 3.8 B). For region abbreviations, see figure A1.1 in appendix 1.

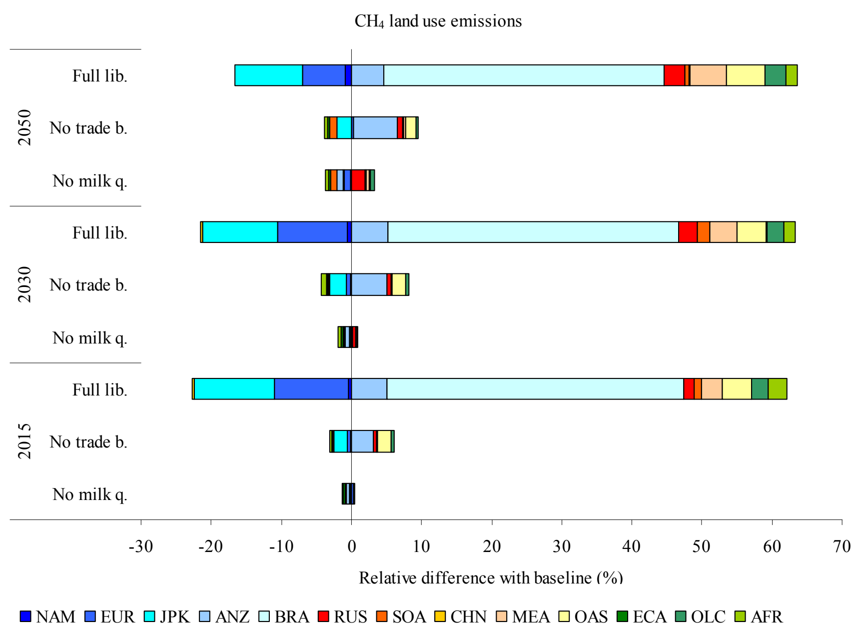

Figure 3.8 B Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for methane (CH_4) in the 13 regions

Differences are expressed as difference in Tg CH_4/yr (figure 3.8 A), and as percentage difference (figure 3.8 B). For region abbreviations, see figure A1.1 in appendix 1.

3.4 N_2O land-use emissions

In figure 3.9 the emissions of nitrous oxide that are associated with land use, i.e. emissions from animal waste and fertiliser application, are depicted for the 13 studied regions under the baseline scenario. Global emissions of nitrous oxide strongly increase over time in the baseline scenario, but large regional differences can be observed. Figure 3.10 depicts the temporal changes in emissions in three successive periods for the different regions. During all successive time slices N_2O emissions strongly increase in Africa. Also for SOA, RUS and OAS emissions strongly increase, but increments become smaller over time. In China and to a lesser extent in NAM, EUR and OLC, emissions increase up to 2015, but from 2030 onwards emissions reduce. In general terms, emissions increase is largest during the first census period (2001-2015) and become smaller over time.

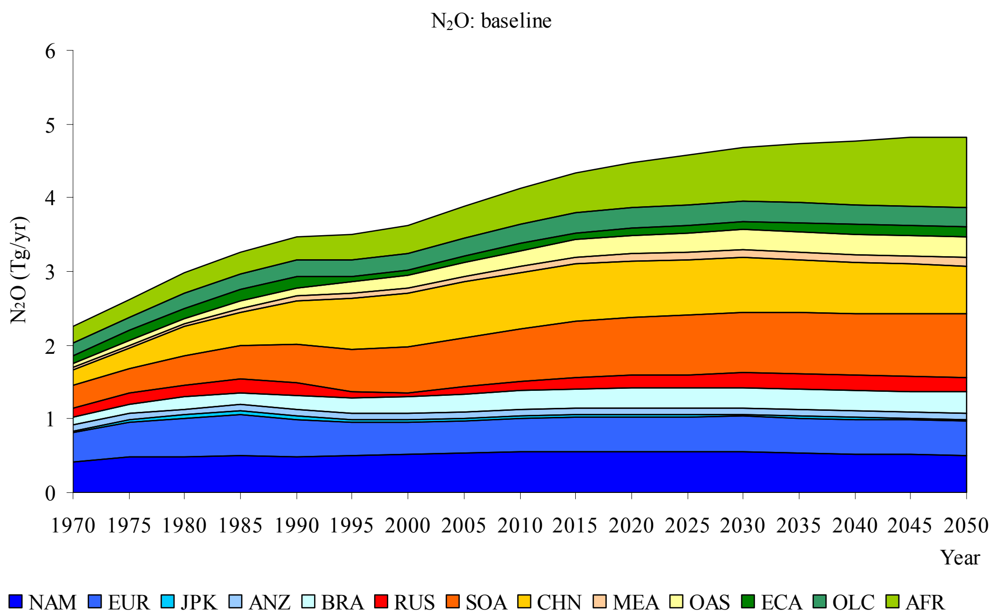

Figure 3.9 Production of land use associated nitrous oxide emissions (N_2O) for the 13 regions under the baseline scenario

For region abbreviations, see figure A1.1 in appendix 1.

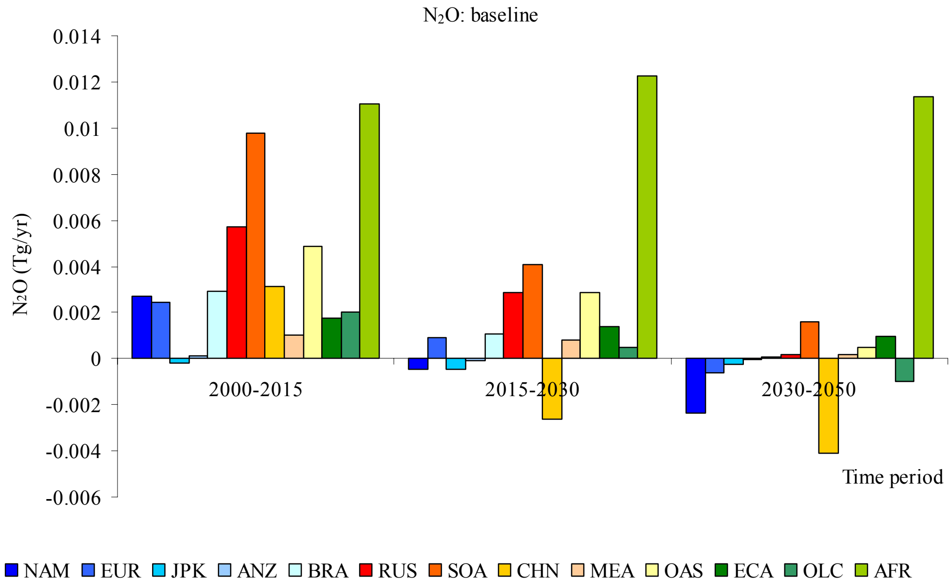

Figure 3.10 Change (in Tg N_2O per year) in land use associated nitrous oxide emissions for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050

For region abbreviations, see figure A1.1 in appendix 1.

Large regional differences in land use N_2O emissions are found in the full liberalisation scenario (figure 3.11). Despite the large regional shifts, global emissions are found to deviate in small percentages compared to the baseline scenario. From 2015 up to 2050 percentage differences in global emissions are found to be 0.07% (2015), -0.7% (2030) and -2.3% (2050). The largest regional increments are found in Brazil (up to +37% in 2050) and other Latin America (OLC, up to 8.7% in 2030). Largest regional reductions are found in NAM, EUR and China region, while also a large percentage reduction is found in Japan region. Separating the emission patterns between those from fertiliser application and from animal waste show a clearer pattern. Under full liberalisation a strong decrease of emissions from fertilisers are found in North America, Europe and to a lesser extent in China and Japan. A small increase is found in Brazil, South and South East Asia and other Latin America. The global effect (summing all regional differences) leads to decreasing emissions from fertiliser application. The opposite can be found for emissions from animal waste. Strong emission increments are found in Brazil, South and South East Asia, Middle East, other Latin America and Africa while emissions decrease in North America and Europe. The net effect is that emissions from animal waste increase globally. The decreasing patterns of emissions from fertiliser application and increasing emissions from animal waste leads to relatively small global differences in N_2O emissions in the full liberalisation scenario compared to the baseline scenario.

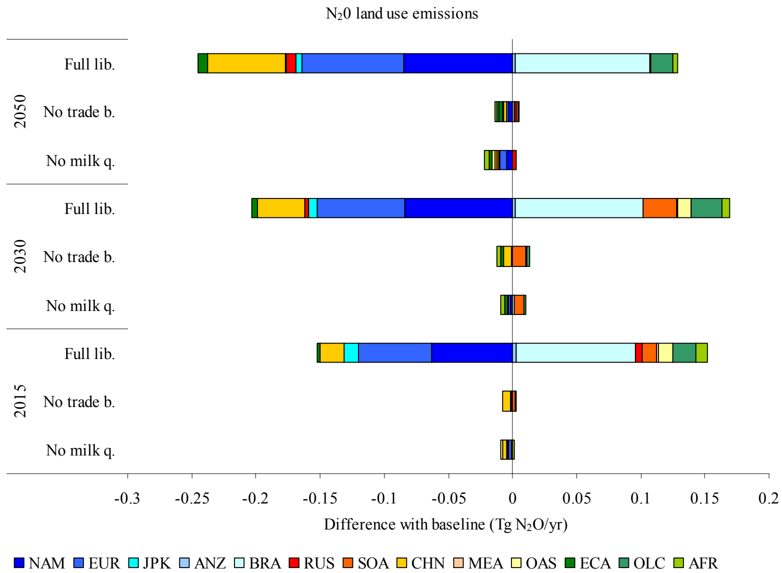

Figure 3.11 A Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for nitrous oxide (N_2O) in the 13 regions
Emission differences calculated for all land use (figures 3.11 A and 3.11 B), emissions from fertilisers (figures 3.11 C and 3.11 D) and emissions from animal waste (figures 3.11 E and 3.11 F). Differences are expressed as difference in Tg N_2O/yr (figures 3.11 B, D and F), and as percentage difference (figures 3.11 A, C, E). For region abbreviations, see figure A1.1 in appendix 1.

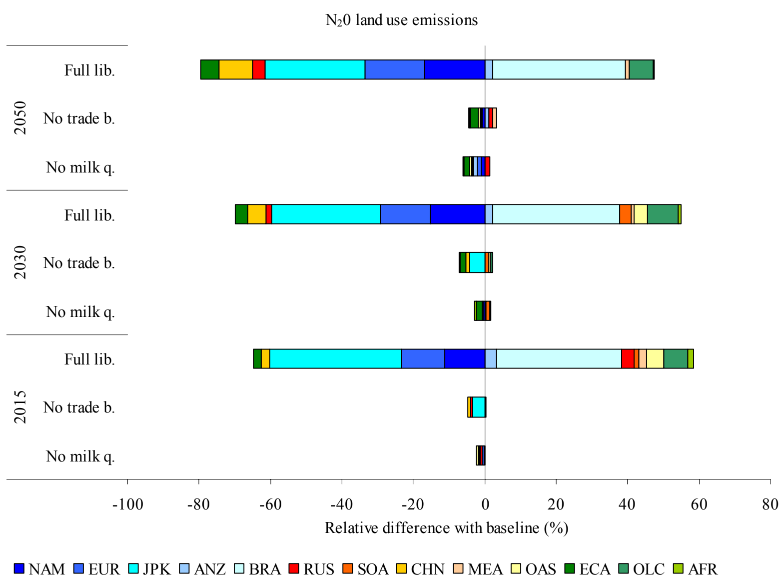

Figure 3.11 B Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for nitrous oxide (N_2O) in the 13 regions
Emission differences calculated for all land use (figures 3.11 A and 3.11 B), emissions from fertilisers (figures 3.11 C and 3.11 D) and emissions from animal waste (figures 3.11 E and 3.11 F). Differences are expressed as difference in Tg N_2O/yr (figures 3.11 B, D and F), and as percentage difference (figures 3.11 A, C, E). For region abbreviations, see figure A1.1 in appendix 1.

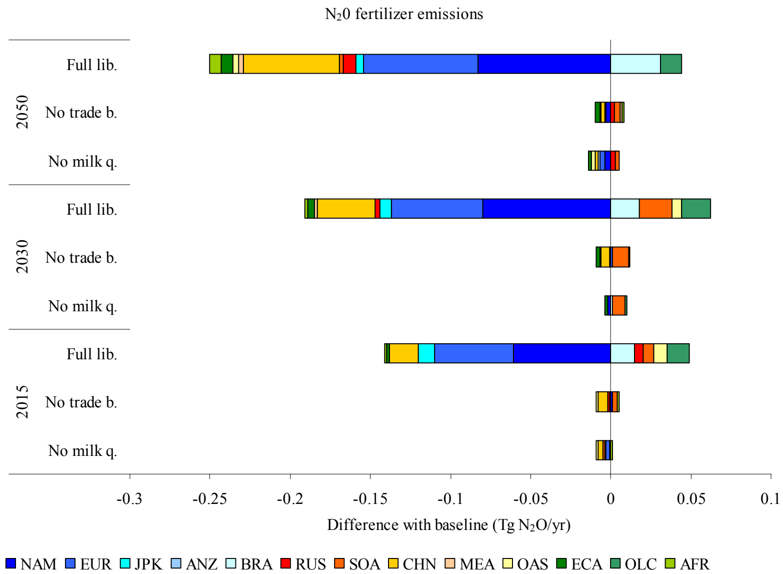

Figure 3.11 C Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for nitrous oxide (N_2O) in the 13 regions

Emission differences calculated for all land use (figures 3.11 A and 3.11 B), emissions from fertilisers (figures 3.11 C and 3.11 D) and emissions from animal waste (figures 3.11 E and 3.11 F). Differences are expressed as difference in Tg N_2O/yr (figures 3.11 B, D and F), and as percentage difference (figures 3.11 A, C, E). For region abbreviations, see figure A1.1 in appendix 1.

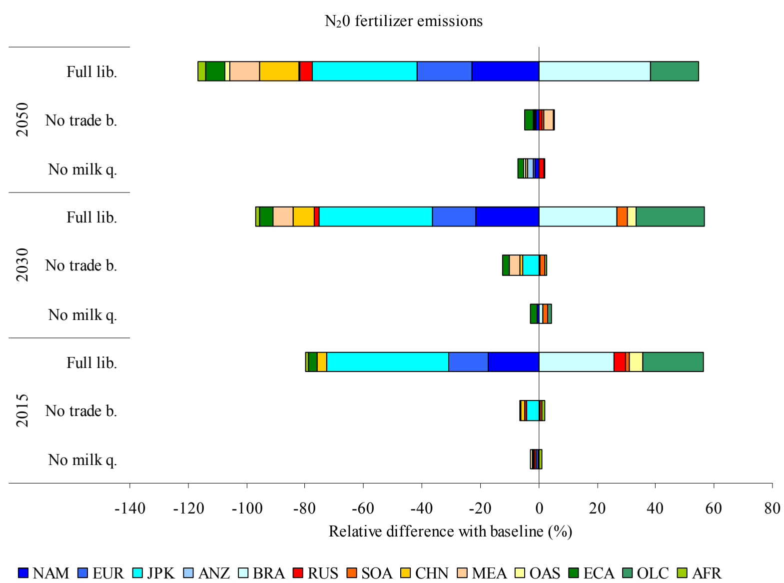

Figure 3.11 D Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for nitrous oxide (N_2O) in the 13 regions

Emission differences calculated for all land use (figures 3.11 A and 3.11 B), emissions from fertilisers (figures 3.11 C and 3.11 D) and emissions from animal waste (figures 3.11 E and 3.11 F). Differences are expressed as difference in Tg N_2O/yr (figures 3.11 B, D and F), and as percentage difference (figures 3.11 A, C, E). For region abbreviations, see figure A1.1 in appendix 1.

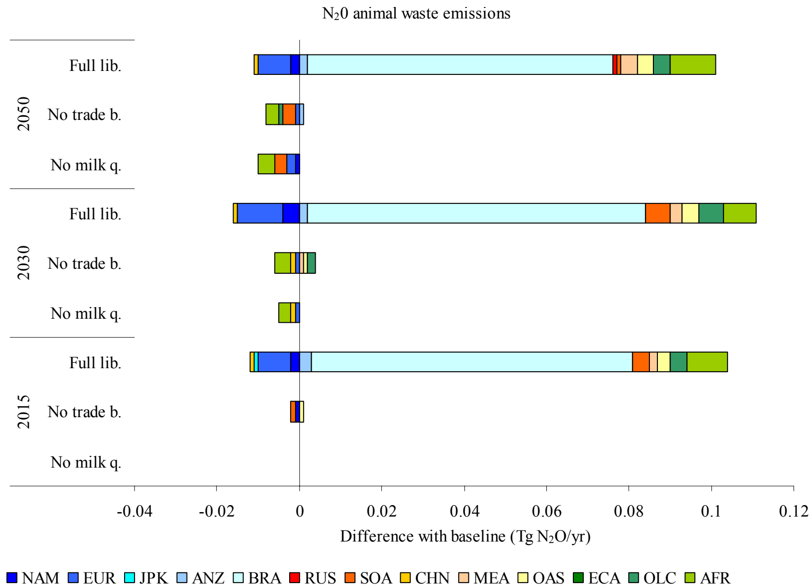

Figure 3.11 E Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for nitrous oxide (N_2O) in the 13 regions

Emission differences calculated for all land use (figures 3.11 A and 3.11 B), emissions from fertilisers (figures 3.11 C and 3.11 D) and emissions from animal waste (figures 3.11 E and 3.11 F). Differences are expressed as difference in Tg N_2O/yr (figures 3.11 B, D and F), and as percentage difference (figures 3.11 A, C, E). For region abbreviations, see figure A1.1 in appendix 1.

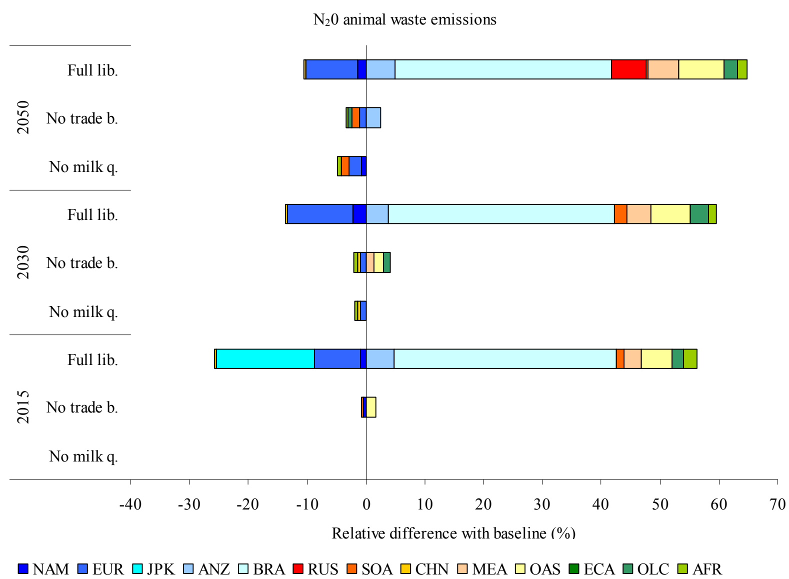

Figure 3.11 F Differences between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota compared to the baseline for nitrous oxide (N_2O) in the 13 regions

Emission differences calculated for all land use (figures 3.11 A and 3.11 B), emissions from fertilisers (figures 3.11 C and 3.11 D) and emissions from animal waste (figures 3.11 E and 3.11 F). Differences are expressed as difference in Tg N_2O/yr (figures 3.11 B, D and F), and as percentage difference (figures 3.11 A, C, E). For region abbreviations, see figure A1.1 in appendix 1.

The abolition of trade barriers leads to very small differences in emissions of nitrous oxide compared to the baseline (figure 3.11). Largest global emission differences are found by 2050, where removal of trade barriers leads to a -0.19% reduction in N_2O emissions. Also regional differences are very small with largest percentage differences compared to the baseline scenario found for JPK (maximum - 4.3%). Separating the emission effects from fertiliser application and animal waste show, in contrast to the full liberalisation scenario, a net increase in emissions from fertiliser globally, but the changes are small. For 2030 and 2050 an increase in fertiliser associated emissions are found in South East Asia. For emissions from animal waste the opposite is found. A net decrease in emissions globally is found with reductions in Africa, South East Asia and Europe. Again, the emission differences with the baseline a relatively small.

Also abolition of milk quota leads to very small differences in nitrous oxide emissions compared to the baseline scenario. Global emissions are reduced -0.3% at maximum by 2050. Also regional differences in emissions are very small. Largest differences are found in ECA (-1.7% in 2030) and +1.5% in RUS by 2050. However the amounts of emission differences are very small. Separating the emission effects from fertiliser and animal waste, show that in 2015 and 2050 a net decrease and in 2030 a net increase in global emissions from fertilisers can be observed. The regional changes in emissions compared to the baseline are very small. Emissions from animal waste decrease globally from 2030 onwards, with most noticeably a decrease in Africa South East Asia and Europe in 2050.

3.5 Animal production

Figure 3.12 depicts the growth for different animal categories in the baseline scenario. For each animal group the breakdown is made for the three census periods 2000-2015, 2015-2030 and 2030-2050. For dairy cattle largest growth is found in SOA and AFR, but after 2030 this large growth is found only in AFR. For non dairy cattle (used for beef production) largest growth is found in AFR, BRA and OLC. For the latter two regions (i.e. Latin America) this growth decreases over time. While for dairy cattle no negative growth was found within the regions, the number of non dairy cattle in SOA shows a decline in all time slices. The number of pigs strongly increases in China region during all time slices while such numbers are somewhat smaller in OAS. The number of poultry shows a mixed picture. Largest growth is found in AFR, SOA and CHN, while also NAM and EUR show large growth. However, for these latter two regions growth is reduced after 2015 and strong negative growth is found after 2030. The number of sheep and goats is largest in AFR and up to 2030 also in China and Middle East (MEA).

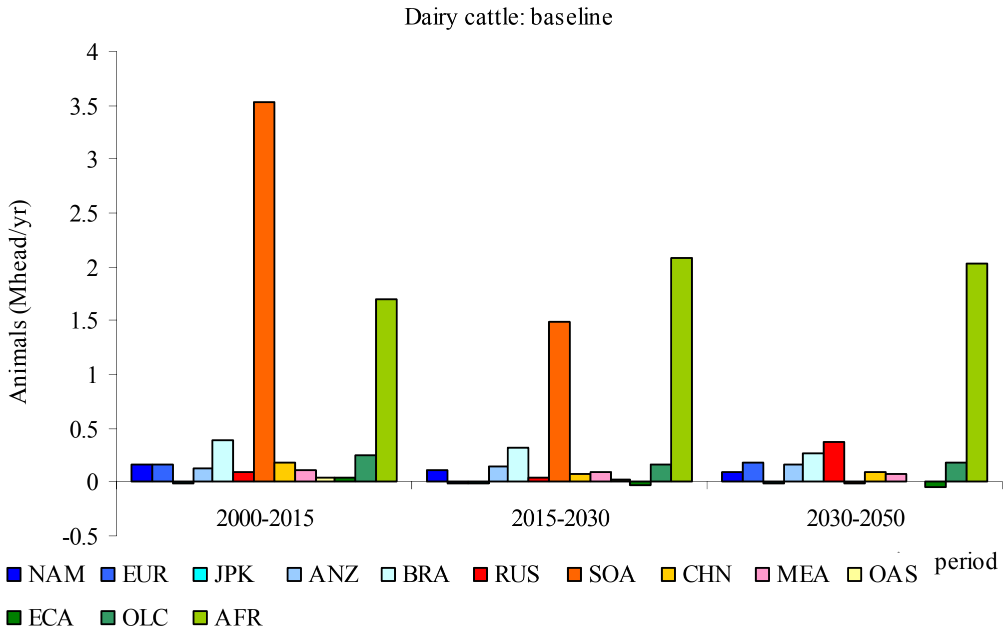

Figure 3.12 A Change (in M head per year) in the number of dairy cattle, beef cattle, pig, poultry, and sheep and goats for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050

For region abbreviations, see figure A1.1 in appendix 1.

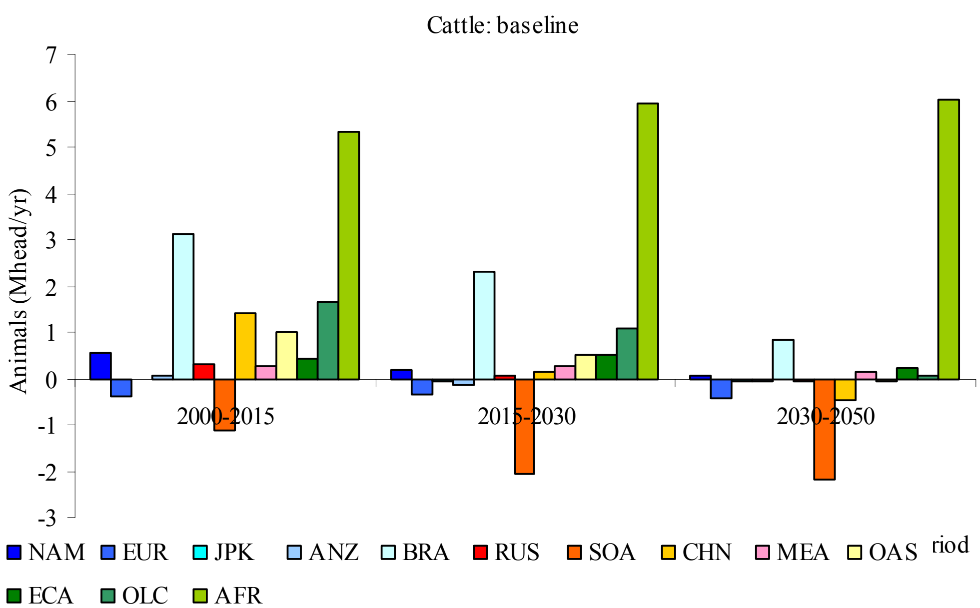

Figure 3.12 B Change (in M head per year) in the number of dairy cattle, beef cattle, pig, poultry, and sheep an goats for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050

For region abbreviations, see figure A1.1 in appendix 1.

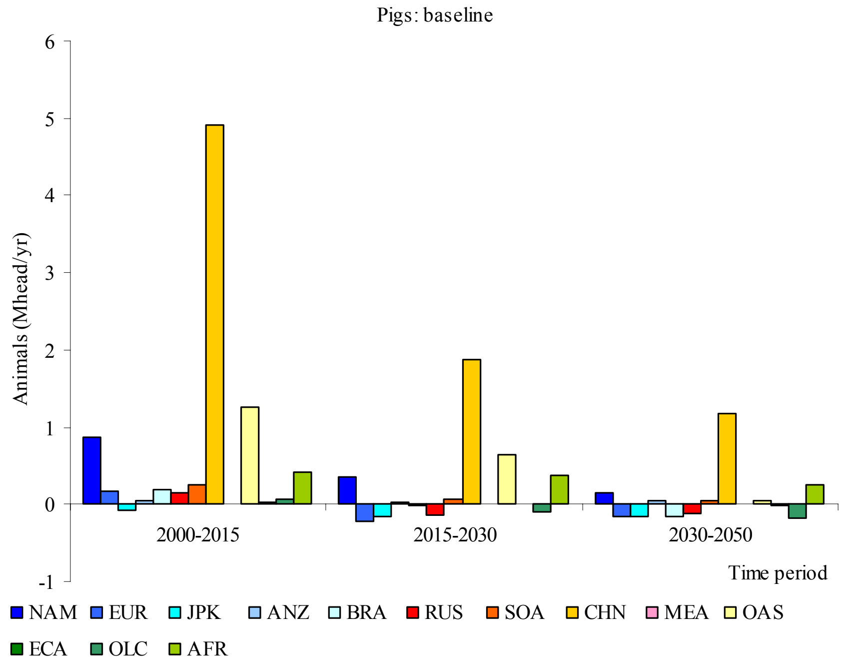

Figure 3.12 C Change (in M head per year) in the number of dairy cattle, beef cattle, pig, poultry, and sheep and goats for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050

For region abbreviations, see figure A1.1 in appendix 1.

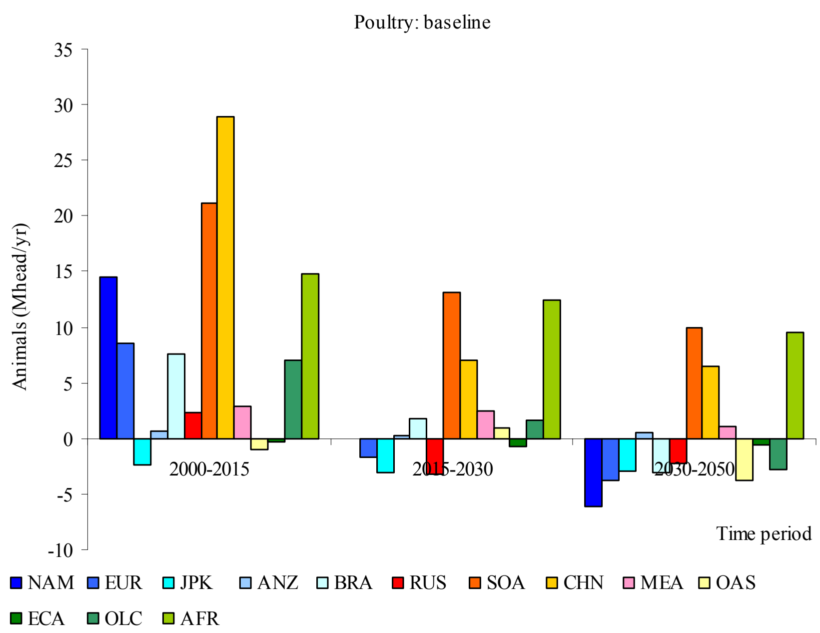

Figure 3.12 D Change (in M head per year) in the number of dairy cattle, beef cattle, pig, poultry, and sheep and goats for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050

For region abbreviations, see figure A1.1 in appendix 1.

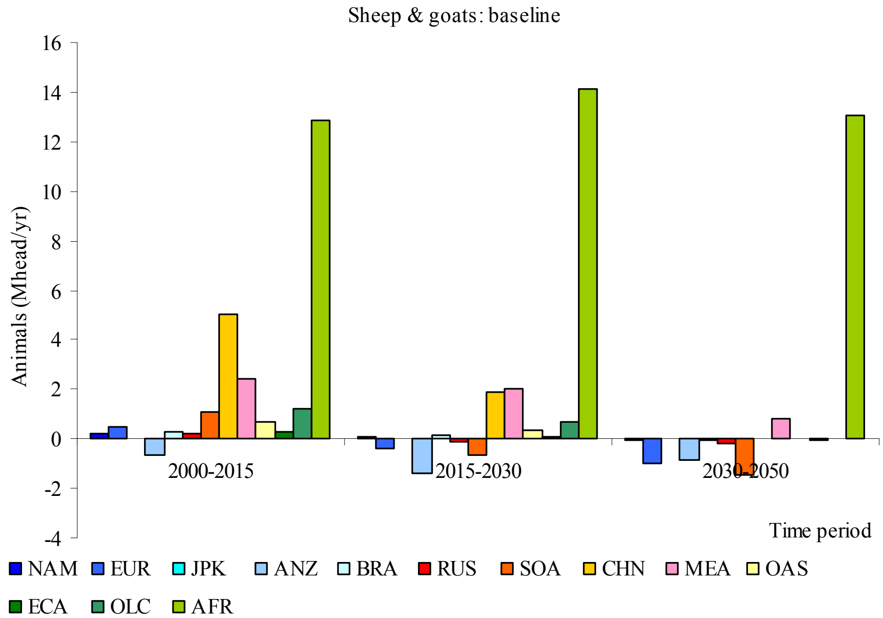

Figure 3.12 E Change (in M head per year) in the number of dairy cattle, beef cattle, pig, poultry, and sheep and goats for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050

For region abbreviations, see figure A1.1 in appendix 1.

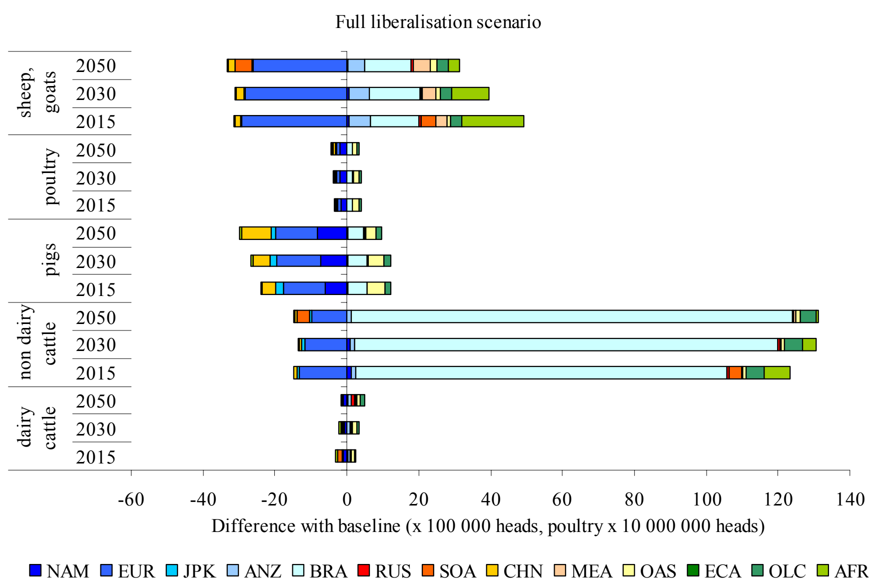

Figure 3.13 A Differences (M heads/yr) between the full liberalisation scenario (figure 3.13 A), scenario with no trade barriers (figure 3.13 B) and scenario with no milk quota (figure 3.13 C) with baseline scenario in the 13 regions

For region abbreviations, see figure A1.1 in appendix 1.

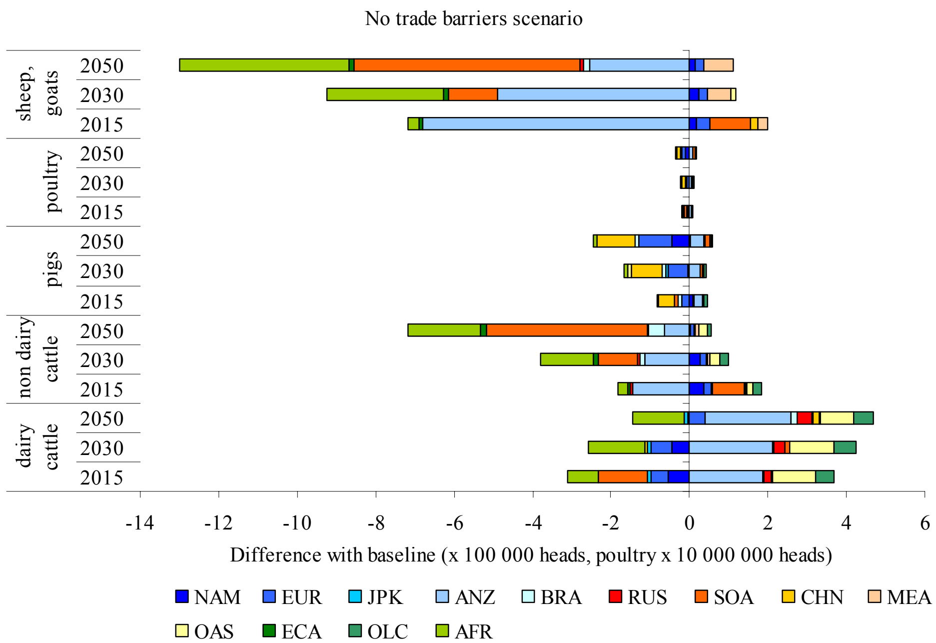

Figure 3.13 B Differences (M heads/yr) between the full liberalisation scenario (figure 3.13 A), scenario with no trade barriers (figure 3.13 B) and scenario with no milk quota (figure 3.13 C) with baseline scenario in the 13 regions

For region abbreviations, see figure A1.1 in appendix 1.

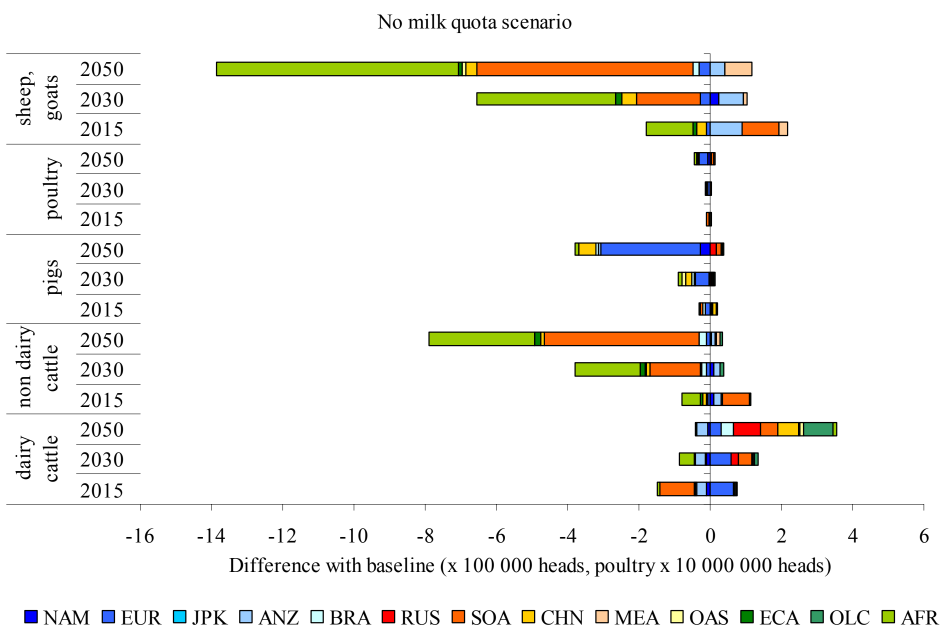

Figure 3.13 C Differences (M heads/yr) between the full liberalisation scenario (figure 3.13 A), scenario with no trade barriers (figure 3.13 B) and scenario with no milk quota (figure 3.13 C) with baseline scenario in the 13 regions

For region abbreviations, see figure A1.1 in appendix 1.

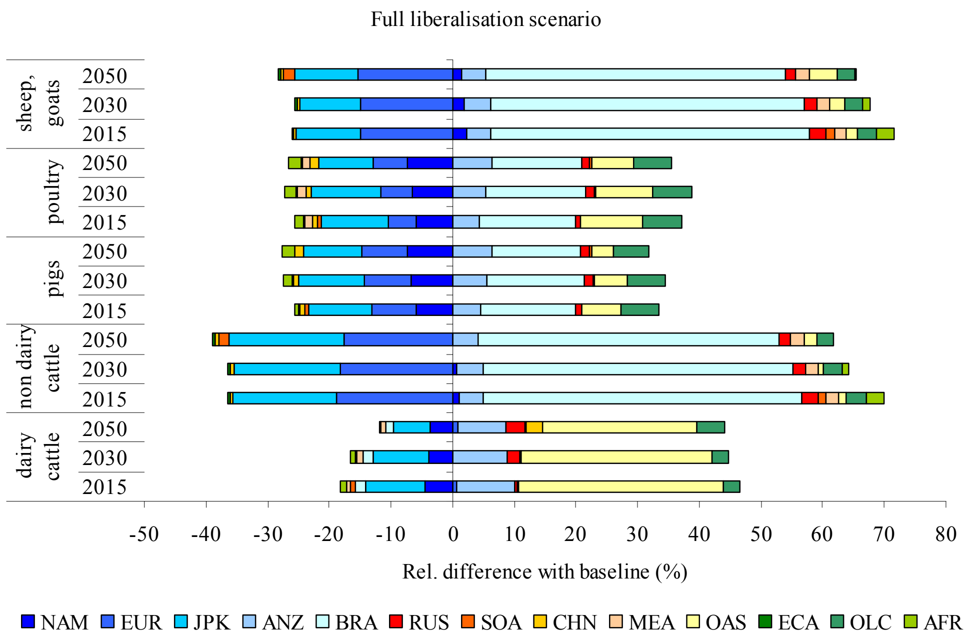

Figure 3.14 A Relative differences (%) between the full liberalisation scenario (figure 3.14 A), scenario with no trade barriers (figure 3.14 B) and scenario with no milk quota (figure 3.14 C) with baseline scenario in the 13 regions

For region abbreviations, see figure A1.1 in appendix 1.

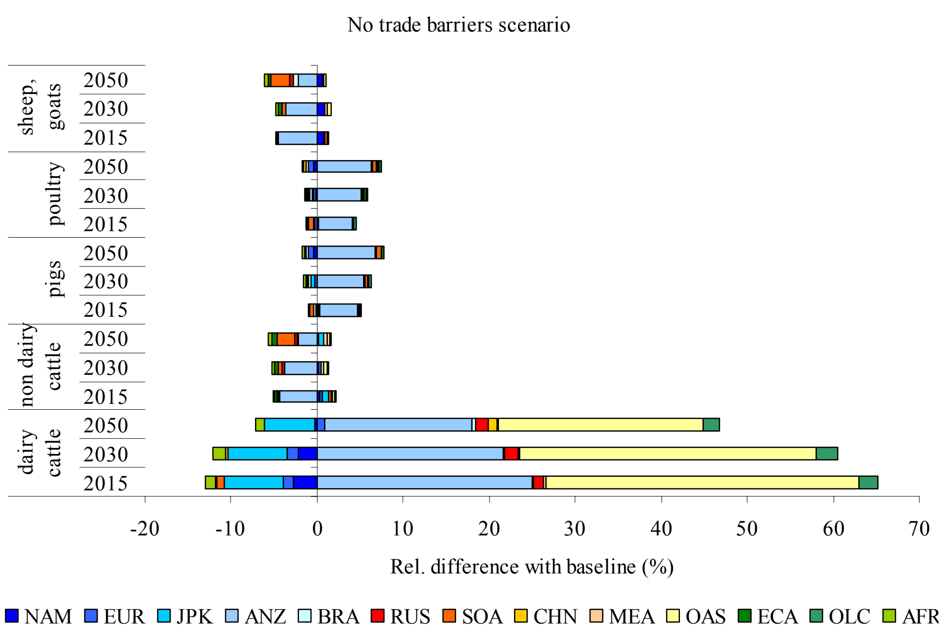

Figure 3.14 B Relative differences (%) between the full liberalisation scenario (figure 3.14 A), scenario with no trade barriers (figure 3.14 B) and scenario with no milk quota (figure 3.14 C) with baseline scenario in the 13 regions

For region abbreviations, see figure A1.1 in appendix 1.

No milk quota scenario

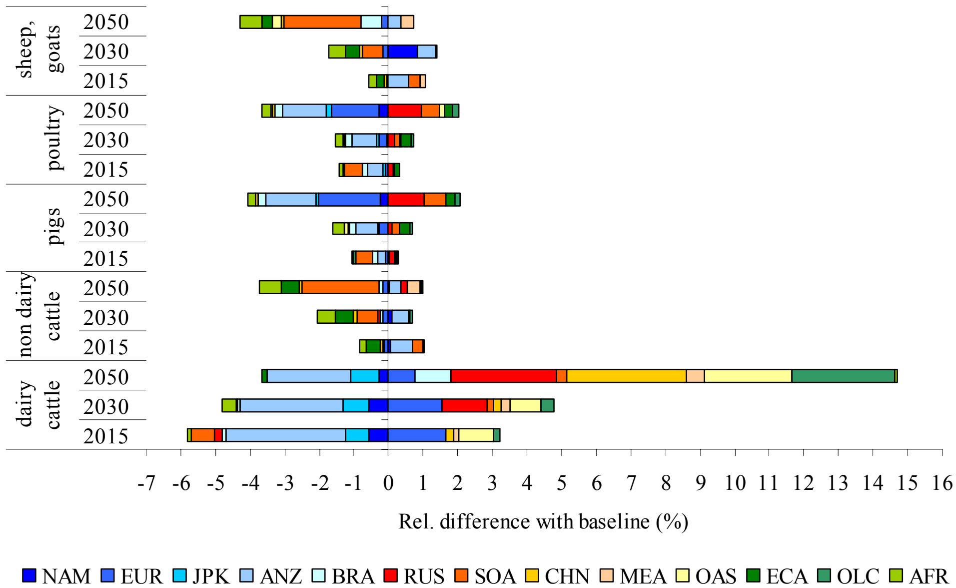

Figure 3.14 C Relative differences (%) between the full liberalisation scenario (figure 3.14 A), scenario with no trade barriers (figure 3.14 B) and scenario with no milk quota (figure 3.14 C) with baseline scenario in the 13 regions

For region abbreviations, see figure A1.1 in appendix 1.

Largest regional shifts of animal production, in terms of number of animals, in the full liberalisation scenario are found for beef and sheep and goats. For non dairy cattle a strong increase is found in Brazil and this difference with the baseline scenario becomes larger over time. Also OLC and to a lesser extent AFR shows an increase in the number of animals, but this increase is much smaller than found in Brazil. Largest decrease in the number of non dairy cattle is found in Europe. For sheep and goats a production shift is found towards OECD pacific (ANZ), Brazil, other Latin America, MEA and AFR. Among these regions the largest increase in found in AFR but this increase becomes much smaller over time. The observed increase in Brazil is more or less constant over time. The largest decrease is found in Europe. The largest percentage differences are found for non dairy cattle and sheep and goats. For all animal categories, except dairy cattle, largest percentage increases are found in Brazil, and to a lesser extent in ANZ, OAS and OLC. NAM, JPK and EUR are regions with overall decreasing percentage production for all animal categories.

The removal of trade barriers scenario shows large regional shifts for dairy cattle, non dairy cattle and sheep and goats. For the other animal categories (i.e. pigs and poultry) the shifts are relatively small. For dairy cattle regional increase are found in ANZ, OAS, OLC, and to a lesser extent in RUS. In 2050 a small increase in Europe is found. Largest decrease is found in AFR and to a lesser extent in SOA. For non dairy cattle the strong reduction in ANZ, SOA and AFR are most noticeable. No clear patterns in regional increases are found, but NAM shows an increase in non dairy cattle for all years, although this increase is relatively small. Also for sheep and goats, a large decrease is found in ANZ, SOA and AFR, while NAM, EUR and MEA show an increased production, but this summed increase is much smaller than the observed decrease in animal numbers. On a percentage base (figure 3.14) largest changes are found for dairy cattle, where ANZ and OAS show the largest percentage increments. For the other animal categories summed regional percentage differences are less then 10%. Compared with the full liberalisation scenario regional shifts in animal numbers are about a factor 10 lower in the trade barrier removal scenario.

The abolition of milk quota leads to an increase of dairy cattle in Europe up to 2030. After 2030 in 2050 also an increase is found in RUS, SOA, CHN and OLC. For non dairy cattle and sheep and goats large reductions are found in AFR and SOA. For both animal groups, reduction in both regions increases over time. There are no clear regions where production increases and production increases of both animal groups are very small compared to the patterns of reduction observed. The regional differences with the baseline scenario based on percentage differences also show no clear patterns. Abolition of milk quota leads to percentage increases in dairy cattle in EUR, but also in RUS OAS and OLC. Abolition of milk quota also leads to small regional differences in other animal categories, but these differences are found between -4% and + 2% compared to the baseline. Here also no clear regional shifts can be observed to what extent some regions show increasing and decreasing patterns. Also for the abolition of milk quota scenario differences with the full liberalisation scenario are a factor ten smaller, except for the reductions found in sheep and goats.

3.6 Agricultural land-use change

Figure 3.15 depicts the land use areas for grass and fodder and food crops in the 13 regions for the reference years 2000, 2015, 2030 and 2050 in the baseline scenario. The figure shows that in ANZ, BRA, CHN, MEA, ECA, OLC and AFR areas for grass and fodder is larger than food crop area during all census periods. Largest absolute growth in grass and fodder area is found in AFR for all time periods. Largest growth in food crop area is found in SOA and AFR. In other regions the agricultural areas are relatively stable over time. Hence production increase is caused by technological developments rather than increasing production areas.

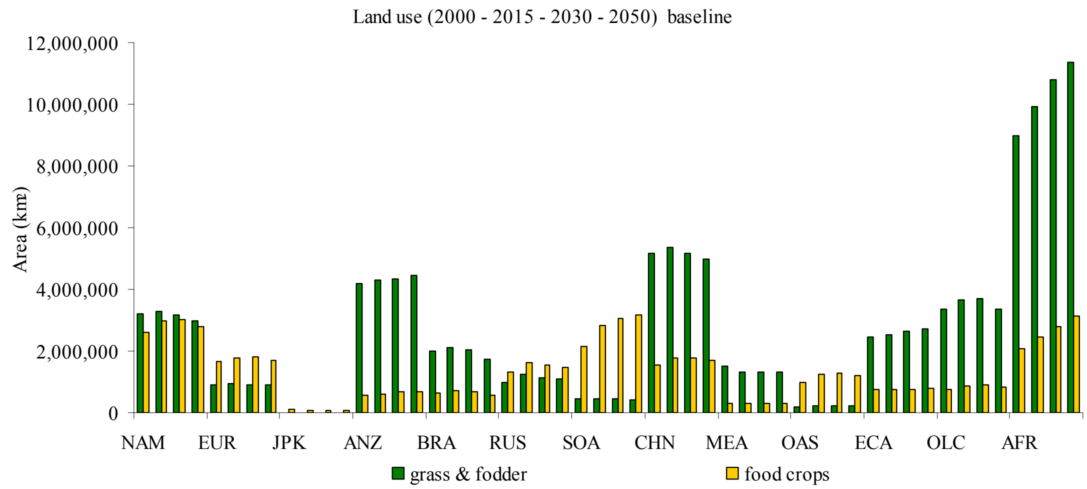

Figure 3.15 Land use area of grass & fodder and food crops in respectively 2000, 2015, 2030 and 2050 in the 13 regions in the baseline scenario

For region abbreviations, see figure A1.1 in appendix 1.

The full liberalisation scenario leads to the largest changes in both grass and fodder areas and food crop areas compared among the three liberalisation scenarios studied (figure 3.16). Grass and fodder area increase largely in Brazil, OLC, and to a lesser extent in ANZ, RUS and AFR. A consistent pattern of area loss is found in NAM and EUR. These patterns are more or less equal in the reference years 2015 and 2030. By 2050 the area increase in Brazil becomes less, but for the other regions area increments remain more or less unchanged compared to the previous time slices. For food crops area increments are found in Brazil, ANZ, Russia, SOA, OAS and OLC. Area increments become smaller by 2050 in Brazil and OLC, while in the other regions mentioned area increase is more or less equal among the three time periods studied. Largest decrements are found in NAM and to a lesser extent in Europe, Japan and China region.

Agricultural area changes in the scenarios removal of trade barriers and abolition of milk quota are very small, both calculated on a km^2 and on a percentage difference basis. The summed regional relative differences all fall between -7% and +7% difference compared to the baseline scenario. Moreover, no clear patterns in regional shifts in agricultural areas can be found for these two scenarios.

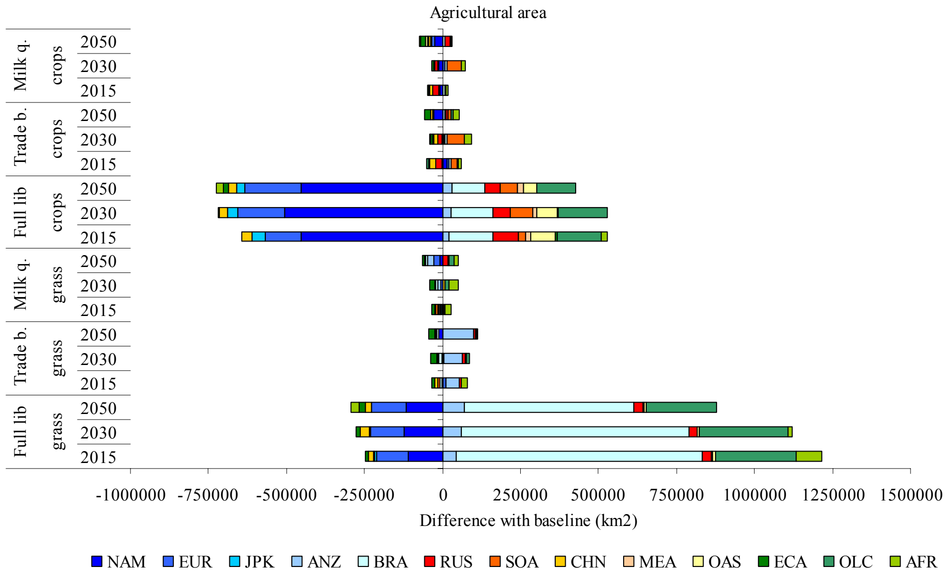

Figure 3.16 A *Difference between the full liberalisation scenario, scenario with no trade barriers and scenario with no milk quota with the baseline scenario for land use grass and fodder and food crops based on km^2 differences (figure 3.16 A) and % differences (figure 3.16 B) in the 13 regions*

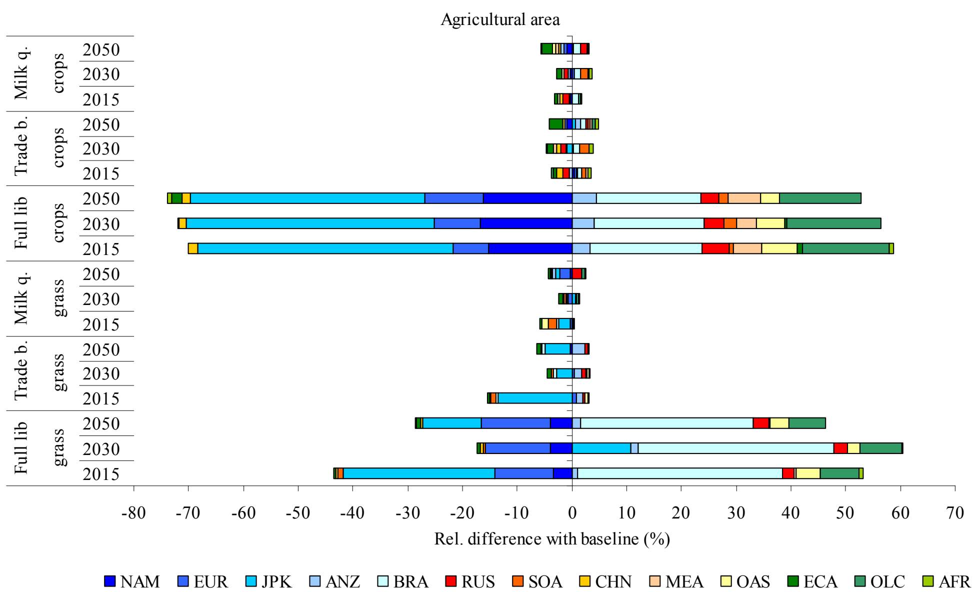

Figure 3.16 B *Difference between the full liberalisation scenario, scenario with no trade barriers and scenario with no milk quota with the baseline scenario for land use grass and fodder and food crops based on km^2 differences (figure 3.16 A) and % differences (figure 3.16 B) in the 13 regions*

3.7 Economic parameters: GDP

In the baseline scenario GDP per capita in especially Asia and Eastern Europe are assumed to grow relatively fast, but the difference with the average growth rate decreases. Latin America is assumed to have a relatively slow growth rate of welfare, implying that they are lagging compared with other regions. Comparing GDP per capita growth in the liberalisation scenario with the baseline, generally a little bit more growth is found, but not for example in ECA (foreign Soviet Union excluding Russia) and not in the first period for SOA, South East Asia. However, these numbers should carefully be interpreted since behind these observed changes a very confuse process of enormous changes in the composition of the economies occur. For example, in SOA in the first period real GDP increases with 89% in the baseline and only 3% less in the liberalisation scenario. The weighting procedure in calculating real GDP may even cause such a small effect. But the main point is that the model catches only switching of production to different countries, and this may imply that some products will get a lower international price, while others a higher one. There is no guarantee that every country benefits from this process. And this process is not the main reason for liberalisation. The main reason is that the increase in competition generates an incentive for higher efficiency and innovation. But this is not included in the model. So, we must be very careful with the interpretation of both the negative and positive aspects of the liberalisation scenario on GDP per capita.

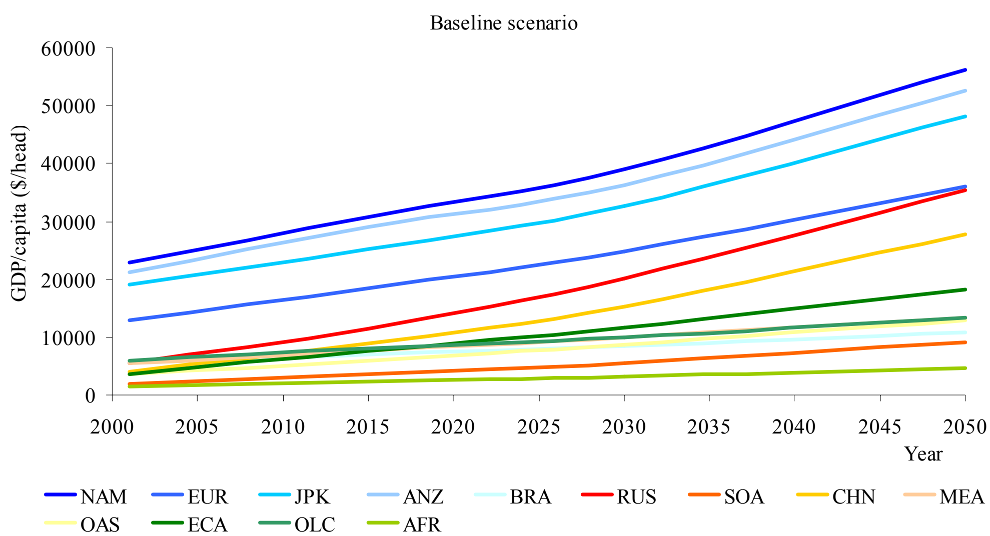

Figure 3.17 Gross Domestic Product (GDP) per capita for the 13 regions in the baseline scenario
For region abbreviations, see figure A1.1 in appendix 1.

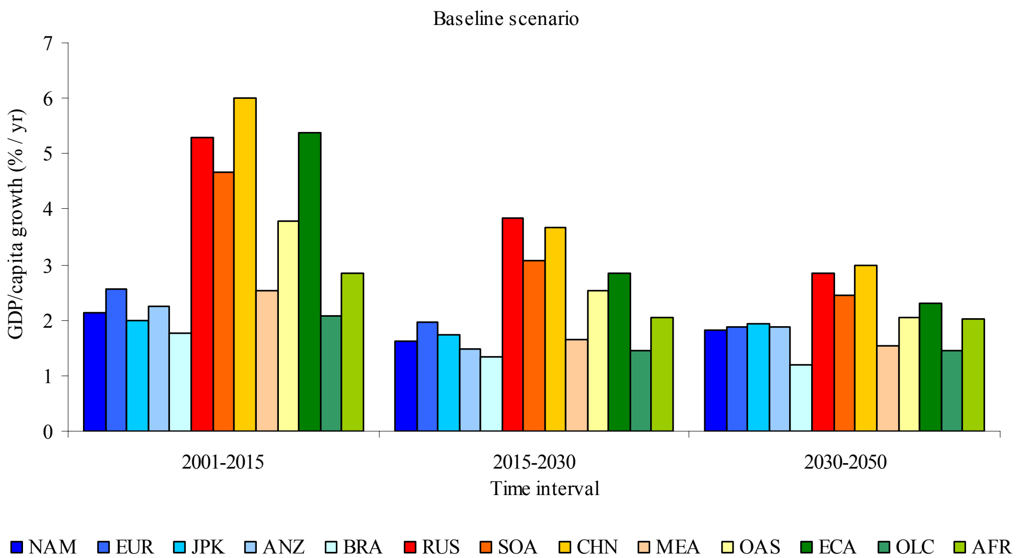

Figure 3.18 Growth of Gross Domestic Product (GDP per capita per year) for the 13 regions under the baseline scenario for the periods 2000-2015, 2015-2030 and 2030-2050
For region abbreviations, see figure A1.1 in appendix 1.

3.8 Economic parameters: production of cattle, raw milk and dairy

Figure 3.19 depict the production of cattle, milk and dairy in the different regions for the three time periods. In the OECD regions NAM, EUR, JPK and ANZ among the three studied commodities the largest production values (in million $) are found for dairy, while in SOA, MEA and ECA milk has the largest production values among the three commodities. In CHN, OLC and AFR cattle production shows the largest values for all time periods. NAM and EUR have also the largest dairy production values among the different regions and these values remain high over time. Up to 2015 milk production in these regions are also the highest, but after this reference year SOA becomes the region with the largest milk production. For cattle the same type of pattern can be observed, although the largest production later in time is found in AFR and to a lesser extent in OLC.

For all three commodities largest growth is found in the first census period (figure 3.20). In all census periods growth in cattle production is largest in AFR, MEA and OAS. JPK shows negative growth of cattle production after 2015, while in Europe such a negative growth is found after 2030. Growth in milk production shows a somewhat fuzzy regional pattern. In all time periods growth is very large in AFR, but in the first period SOA, AFR and OAS show the largest growth, in the second period ANZ, OAS and AFR have the largest growth, and in the last period from 2030 to 2050 ANZ, RUS and AFR have largest growth. Growth in milk production in Europe is very low (< 0.25%) while in JPK negative growth is observed from the second time period onwards. Dairy production growth shows only in the first time period a comparable pattern as found for milk, though some large regional differences are observed where NAM and ANZ have relatively large growth. In the second period ANZ, OAS and AFR have the largest growth, while in JPK and SOA negative growth is found. In the last time period ANZ and to a lesser extent AFR have strong dairy production growth, while in JPK and especially SOA a large reduction is observed. Dairy production growth in Europe is modest with highest value found in the first time period (0.47%).

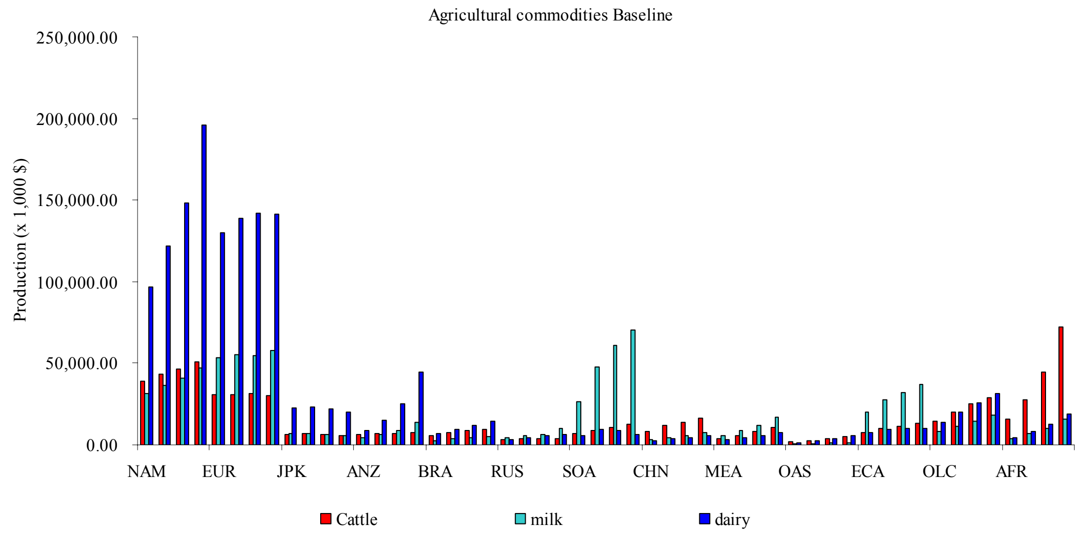

Figure 3.19 Production ($) of cattle (beef) raw milk and dairy products in respectively 2001, 2015, 2030 and 2050 for the 13 regions in the baseline scenario

For region abbreviations, see figure A1.1 in appendix 1.

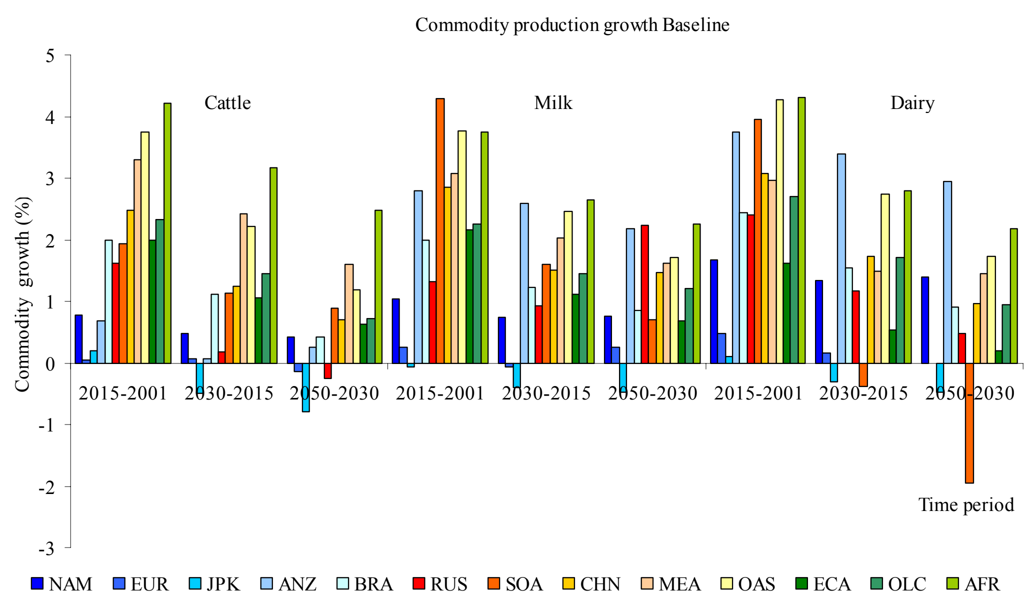

Figure 3.20 Growth of production of cattle, milk, and dairy products for the 13 regions under the baseline scenario for the periods 2001-2015, 2015-2030 and 2030-2050

For region abbreviations, see figure A1.1 in appendix 1.

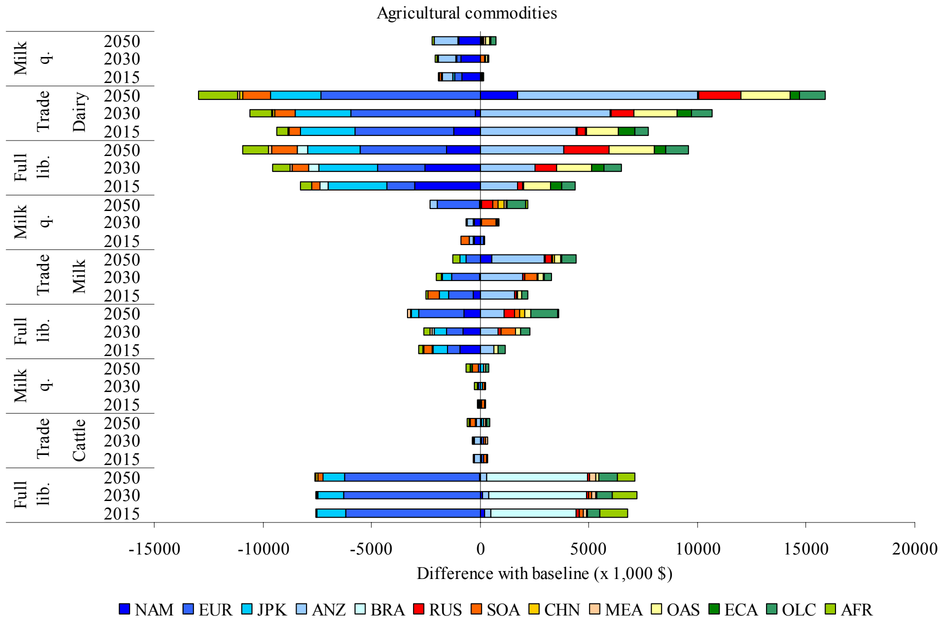

Figure 3.21 A Difference between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota with the baseline scenario for cattle, milk, and dairy production based on $ differences (figure 3.21 A) and % differences (figure 3.21 B) in the 13 regions

For region abbreviations, see figure A1.1 in appendix 1.

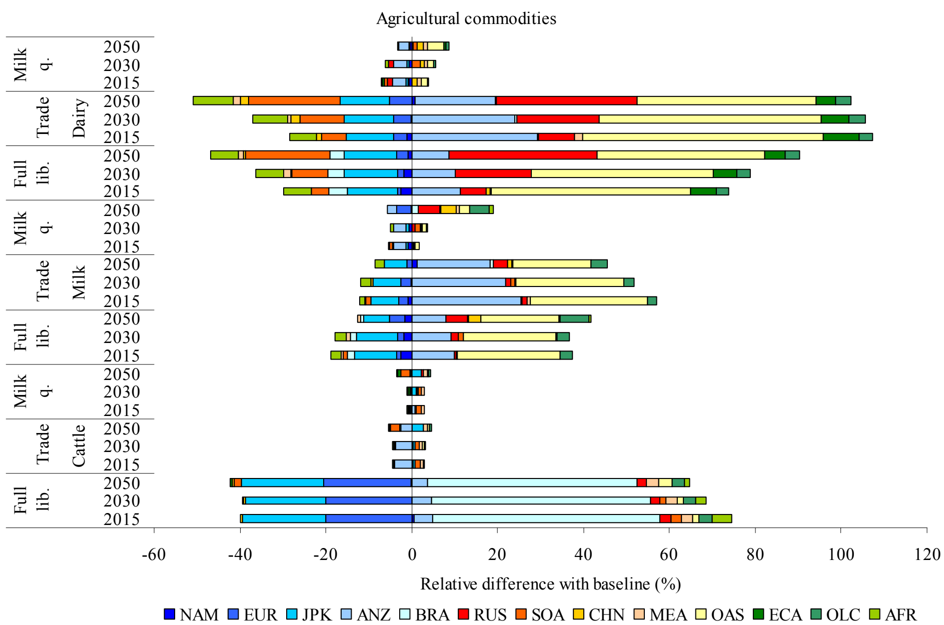

Figure 3.21 B Difference between the full liberalisation scenario, scenario with no trade barriers, and scenario with no milk quota with the baseline scenario for cattle, milk, and dairy production based on $ differences (figure 3.21 A) and % differences (figure 3.21 B) in the 13 regions

For region abbreviations, see figure A1.1 in appendix 1.

Full liberalisation and removal of trade barriers have the largest effects on regional shifts in commodity production both expressed on $ and percentage base (figure 3.21). For cattle the effect of full liberalisation is much larger than for the other two liberalisation scenarios, and a strong regional increase of cattle production is found in Brazil, OLC and AFR. A concomitant decrease in cattle production is observed in Europe and to a much lesser extent in JPK. For the scenarios of abolition of trade barriers and milk quota the effects on cattle production is marginal. For milk production the effects of full liberalisation and removal of trade barriers are very similar with respect to the regional shifts in production values. An increased production is found in ANZ, OLC, RUS, and SOA and for the first three regions this increase becomes larger over time. Negative effects, i.e. reduced growth, are less similar between both liberalisation scenarios (i.e. full liberalisation and trade barrier removal scenario). In the full liberalisation NAM, EUR and JPK show decreasing production values compared to the baseline, but for EUR this reduction becomes larger over time. In the trade barrier scenario the negative effects on production EUR are noticeable. Remarkably, in the milk quota scenario negative effects for EUR are observed only in the last time slice. Dairy production shows the largest regional shifts compared among the three commodities studied while the effects of full liberalisation and trade barrier scenario are comparable where it is remarkable to find that the effects in the trade barrier scenario are somewhat larger than in the full liberalisation scenario. In both scenarios production increments are found in ANZ, RUS, OAS, ECA and OLC and the increments become larger over time. Decrements are found for both scenarios in NAM, EUR, JPK, BRA and SOA, where NAM decrements become smaller over time and in the trade liberalisation scenario become positive in the last time slice. Reductions become larger over time in EUR, SOA and AFR and this pattern is consistent for the two scenarios. Abolition of milk quota, finally leads to modest regional shifts in dairy production, where in NAM and ANZ negative growth is found, but no noticeable growth increments in EUR. are found.

3.9 Values within EU

Table 3.1 shows the GDP per capita and growth in GDP per capita in the baseline scenario within the European community. In all EU country regions growth in GDP/capita is lowest in the 2015-2030 time period. The largest reduction in GDP growth is found in EU-12 (new member states) where after a circa 4.9% growth in the first census period (2001-2015) a growth of 2.1% is observed in the successive time period.

Table 3.1 GDP per capita (in $) in the baseline scenario and GDP growth (% per year) in new EU member states (EU-12), EU member states without the Netherlands (EU-14) and for the Netherlands (NL)

	GDP/capita				GDP growth (%)		
Region	2001	2,015	2030	2050	2001-2015	2015-2030	2030-2050
EU-12	6,901	11,613	15,237	22,290	4.88	2.08	2.31
EU-14	19,339	24,652	31,481	44,745	1.96	1.85	2.11
NL	22,203	28,302	36,143	51,370	1.96	1.85	2.11

Table 3.2 shows the economic production values of milk, dairy and cattle for the baseline scenario and the relative differences of the liberalisation scenarios with this baseline. For all production values full liberalisation has the largest effect. For milk and dairy strong positive effects are found in EU-12 and the Netherlands. For milk in both region/country an increased production difference is found over time, while for dairy this is only found in the Netherlands. In EU-14 full liberalisation leads to decreasing production values. Removal of trade barriers has no effect on milk production in EU-12 and the Netherlands and has a negative effect in EU-14. Abolition of milk quota leads to a stable increase of milk production in EU-12, a larger production in the Netherlands and a decreasing production in EU-14. For dairy production trade barrier removal has negative production effects in EU-12 and abolition of milk quota a positive effect. In the Netherlands removal of trade barriers has a very small, but negative effect on dairy production values while for milk quota abolition dairy production increase strongly. For EU-14 both scenarios leads to a reduction in dairy production values. The liberalisation scenarios have very small (zero) or strong negative effects on the cattle production values in the three studied EU regions. The strongest reductions are found in the full liberalisation scenario and largest decrements are found in EU-14 and the Netherlands. The effects on cattle production in EU-12 are, compared to EU-14 and the Netherlands, relatively small. In the Netherlands, abolition of milk quota leads to a reduction of beef production. This can be explained by the change in competition between dairy and beef cattle for land. Both sectors use grasslands and the observed increase in dairy production is at the expense of beef production in this scenario in the Netherlands.

Table 3.2 Production of raw milk, dairy and cattle (in $) under the baseline scenario and the differences (in %) of the full liberalisation scenario, abolition of trade barriers scenario and abolition of milk quota scenario compared with the baseline for new EU member states (EU-12), EU member states without the Netherlands (EU-14) and for the Netherlands (NL)

Region	Scenario	Milk				Dairy			
		2001	2015	2030	2050	2001	2015	2030	2050
EU-12	Baseline	9845	10,364	10,364	10,364	9,371	9,592	9,404	9,246
EU-12	Full lib.		5.91	5.82	8.20		22.77	22.25	17.06
EU-12	Trade b.		0.00	0.00	0.00		-2.52	-3.06	-2.91
EU-12	Milk q.		5.85	5.85	5.85		20.67	19.72	12.59
EU-14	Baseline	34882	34,900	33,805	33,982	103,513	108,206	110,420	109,215
EU-14	Full lib.		-4.15	-5.94	-10.62		-3.67	-5.49	-7.42
EU-14	Trade b.		-2.81	-3.35	-0.93		-3.90	-4.94	-5.98
EU-14	Milk q.		-2.99	-3.96	-8.51		-2.93	-3.10	-2.55
NL	Baseline	3655	3,710	3,710	3,710	7,019	7,625	8,271	9,267
NL	Full lib.		25.77	37.55	44.02		25.73	37.40	43.60
NL	Trade b.		0.00	0.00	0.00		-0.03	-0.08	-0.15
NL	Milk q.		22.35	26.04	23.99		22.33	25.96	23.85

Table 3.2 Production of raw milk, dairy and cattle (in USD) under the baseline scenario and the differences (in %) of the full liberalisation scenario, abolition of trade barriers scenario and abolition of milk quota scenario compared with the baseline for new EU member states (EU-12), EU member states without the Netherlands (EU-14) and for the Netherlands (NL) (continue)

Region	Scenario	Cattle			
		2001	2015	2030	2050
EU-12	Baseline	3,726	4,789	4,813	4,453
EU-12	Full lib.		-6.47	-5.88	-5.70
EU-12	Trade b.		0.00	-0.02	0.38
EU-12	Milk q.		-0.13	0.00	0.47
EU-14	Baseline	22,763	20,918	20,634	19,924
EU-14	Full lib.		-23.19	-23.48	-23.12
EU-14	Trade b.		0.35	0.31	0.22
EU-14	Milk q.		0.22	0.12	0.20
NL	Baseline	1,343	1,262	1,405	1,578
NL	Full lib.		-55.07	-57.15	-57.22
NL	Trade b.		-0.16	-0.07	-0.13
NL	Milk q.		-4.36	-4.63	-3.87

3.10 Global patterns in economic production and greenhouse gas emissions

The figures 3.22 and 3.23 depict global patterns in trade and emissions as predicted under the baseline scenario. World GDP per capita almost linearly grows with circa 3% per year up to a 190% increase in 2050 compared to 2001. Global production values of raw milk, dairy and cattle have lower growth than world GDP. Milk and cattle production growth is up to 2030 circa 1.9% per year. After 2030 growth decreases to circa 1.4% per year reaching a value of 78% increase by 2050 for both cattle and milk. Dairy growth is somewhat lower than found for cattle and milk. Up to 2030 yearly growth is about 1.4% and after 2030 circa 1.3% per year, reaching an increase of 66% by 2050.

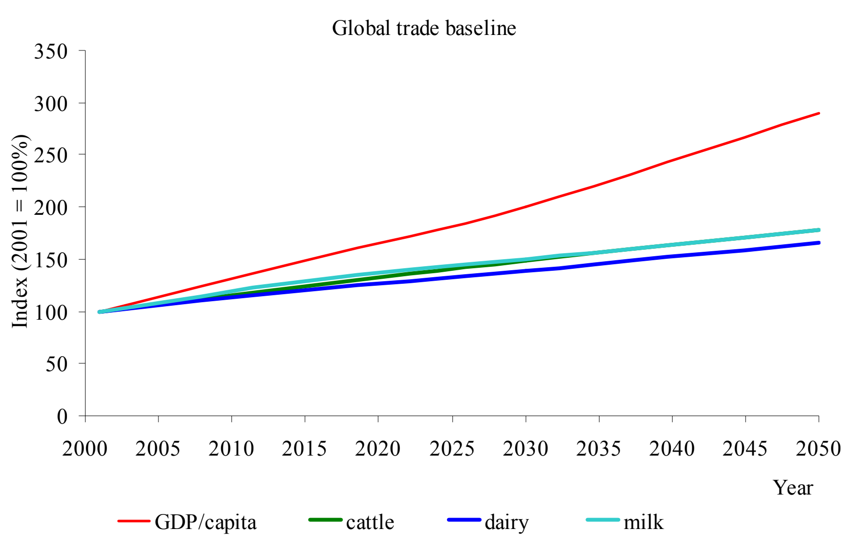

Figure 3.22 World trade (GDP/capita, cattle, raw milk and dairy products) in the baseline scenario. Values are indexed on values of 2001

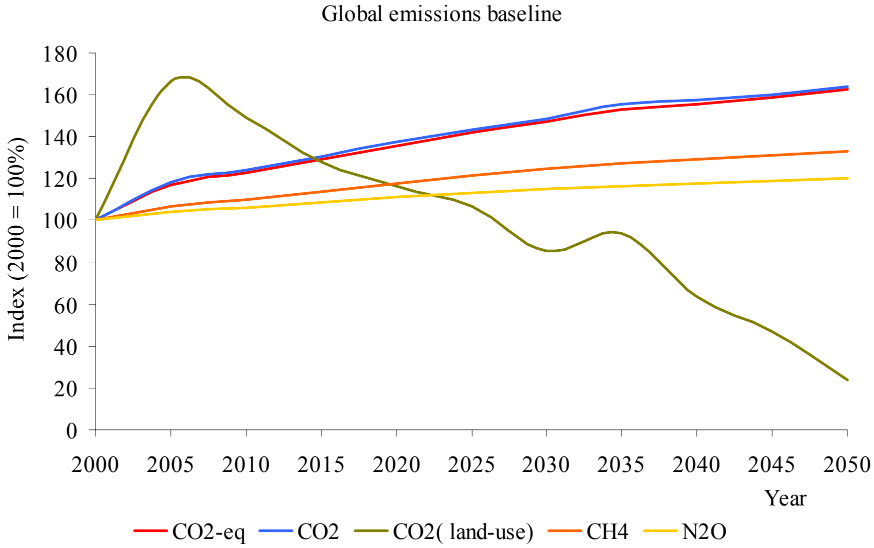

Figure 3.23 World emissions (total N_2O, CH_4, CO_2, CO_2 equivalents, and land use associated CO_2) in the baseline scenario. Values are indexed on values of 2000

Figure 3.23 depicts the total emissions of methane, nitrous oxide, carbon dioxide and CO_2 equivalents of all sectors (i.e., industry, energy, agriculture etc.) and carbon dioxide emissions that are associated with land use only. For the greenhouse gasses summed over all sectors emissions continue to rise after 2000. For total CO_2 and CO_2 equivalents the steepest increment is found between 2000 and 2010. After that year emissions increase linearly and after 2035 the emissions are levelled off. By 2050 emissions of total CO_2 and equivalents are circa 63% higher than in 2000. Emissions of methane and nitrous oxide that are summed for all sectors more or less linearly rise up to 2035 after which these emissions level off. By 2050 emissions are 33% and 20% higher for respectively methane and nitrous oxide. Emissions of CO_2 that is solely associated with land use show a remarkable pattern over time. Up to 2010 a strong increase in land use associated CO_2 emissions are found. After that year a gradual decline of emissions are found up to a reduction of 75% by 2050 compared to 2000. This rise and fall of emissions are the result of land clearing for agriculture. Natural vegetation (i.e., savannah and tropical forests) is cleared for agriculture (crops and grassland) for new production areas. By 2010 these new agricultural areas reaches a maximum after which emissions drop.

4. Discussion

4.1 Baseline scenario: regional patterns

As MNP (2006) has pointed out, the baseline scenario is not necessarily the most plausible scenario for future developments. The baseline scenario assumes no new policies in the direction of trade liberalisation or reform of the agricultural sector beyond what has been agreed today. One other important assumption in this scenario is that the model framework does not include direct feedbacks of environmental stresses on economic or demographic indicators. Within the baseline scenario it is implicitly assumed that such feedbacks will not lead to noticeable effects.

In the baseline scenario world population is assumed to grow from circa 6.1 billion people in 2000 up to 8.3 billion by 2030 and 9.4 billion by 2050. Largest population growth is found in Africa and South Asia (India). As a corollary, agricultural production and demand will increase as well. Agricultural land use (i.e. grass and fodder and cropland area in this study) increases in those regions where land is available. Such an increase is found in OECD pacific, Brazil, and most noticeable in Africa. In other regions the agricultural area does not increase much over time but agricultural productivity increases. In all five studied animal categories (i.e., dairy cattle, beef cattle, pigs, poultry, and sheep and goats) a global increase in the number of animals is found with strong regional differences. For dairy cattle strong regional increments are found in South Asia (mostly India) and Africa, while the number of beef cattle most strongly increases in Brazil, Latin America and Africa. Pig production strongly rises in China while for sheep and goats the largest regional increments are found in Africa. For poultry the pattern is much more diffuse, as increments are found across different regions. The greenhouse gas that is mostly associated with ruminants, CH_4, strongly increases in the regions Brazil, South Asia, Africa, and to a lesser extent in China and Latin America. Nitrous oxide, the greenhouse gas with the relatively largest warming potential and mostly associated with manure and fertiliser, most strongly increases in Africa and to a lesser extent in South Asia, Russia and South East Asia. Effects of land clearing are most noticeable from land use associated CO_2 emissions. Regions with more than 0.1 Pg CO_2 increase from 2000 to 2015 are Brazil, Latin America, South Asia and South East Asia, China and Africa. The observed strong increase of global land use associated CO_2 emissions mostly occur in these regions. In Africa land use associated emissions continue to rise after 2015 with a peak at 2030 after which a decline is found to circa 0.194 Pg CO_2 per year.

The strong demand for animal products is caused both by an increasing population as well as changing food consumption patterns. Moreover, because a relation between income (GDP/capita) and animal food consumption (kg food intake per person per year) is assumed, animal consumption patterns change strongly in the baseline scenario. Although this relation differs between regions, caused by amongst others cultural differences, in all regions this relation shows an increasing pattern. Because GDP increases over time in all regions, the demand for animal food increases as well. Hence production of all animal categories increases over time with a concomitant increase in greenhouse gasses.

4.2 Full liberalisation scenario: regional patterns

In the full liberalisation scenario trade barriers and quota were phased out for all agricultural sectors by 2015. After that year no trade distorting policy was operating under this scenario and only macro economic effects are operational. Unlike the world scenarios developed by the IPCC, such as the global market scenario A1, and regional community scenario B2, the full liberalisation scenario does not have different assumptions on population growth, consumption patterns and technological development within sectors compared to the baseline scenario. Thus, the removal of trade barriers and quota in all agricultural sectors in the full liberalisation scenario and the resulting GDP effects that feed back to the consumption patterns are the only differences with the baseline scenario.

Full liberalisation leads to large regional differences in the numbers of cattle (non-dairy), pigs and sheep and goats. In all years largest increments in the number of non-dairy cattle are found in Brazil. In Europe a consistent decrease in this number is found. The regional shifts in animal numbers, however, are not balanced. The observed increase in the number of non-dairy cattle in Brazil is much larger than the observed decrease in Europe, leading to a net global increase of circa 116 million animals in 2050. Comparing the shifts in the number of non-dairy cattle with production values (in USD) for beef, it becomes clear that the production decline in Europe and Japan that shifted towards Brazil, Other Latin America, Africa, and OECD pacific is almost at equal extent. Globally this shift leads to a reduction in production of circa USD500 million in 2050. This inequality is caused by the large productivity differences between Europe and Brazil. In Europe, animals are larger and produce more beef per head, while in Brazil animal husbandry is much more extensive.

Compared to non-dairy cattle, which are used for beef production, shifts in the number of dairy cattle is relatively small in the full liberalisation scenario. Both milk and dairy production decreases in North America, Japan, and Europe and for the latter region this decrease becomes larger over time. Milk production increases in OECD pacific, Russia, South Asia and Other Latin America, while dairy production increments are also found in these regions with the addition of South East Asia. Compared to the baseline scenario the production of milk in the full liberalisation leads worldwide to a decline of USD1,670 million in 2015 but to an increased production of USD275 million by 2050. Dairy production in the full liberalisation scenario is globally lower than in the baseline for all periods in the scenarios. Values differ from a production decline of circa USD4,000 million in 2015 to USD1,400 million in 2050.

After the implementation of the full liberalisation scenario by 2015, global emissions of land use associated CO_2, CH_4 and N_2O emissions rise more than in the baseline scenario (see figure 4.1). The strong increments in CO_2 and CH_4 emissions are caused by two different mechanisms. First, full liberalisation results in production shifts to areas with low labour costs, namely South Asia, Africa and Latin America. In these regions natural vegetation is cleared for agricultural production, leading to a strong increase in CO_2 emissions caused by vegetation burning. In these areas agricultural production is strongly oriented to ruminants (cows for milk or beef). In IMAGE it is assumed that the cattle husbandry is more intensive in Europe than in the regions mentioned above. Hence more cows are needed per unit milk or beef produced than was in Europe, and therefore CH_4 emissions more strongly increase in the full liberalisation scenario than in the baseline. CH_4 emissions remain high due to the mechanisms described above. A comparable pattern can also be applied for the increase in N_2O emissions globally. Globally a strong and net increase in the number of non-dairy cattle is observed, while for all other animal categories (i.e., dairy cattle, pigs, poultry, sheep and goats) a small decrease or no change is found. Nitrous oxide emission differences between full liberalisation and the baseline scenario are determined by two factors, those emitted from fertiliser application and those emitted from animal waste. It is the latter emission factor that strongly increases in the full liberalisation, while emissions from fertiliser decrease in the full liberalisation scenario. Nonetheless, a net increase in N_2O emissions is observed in 2015 and 2030 globally.

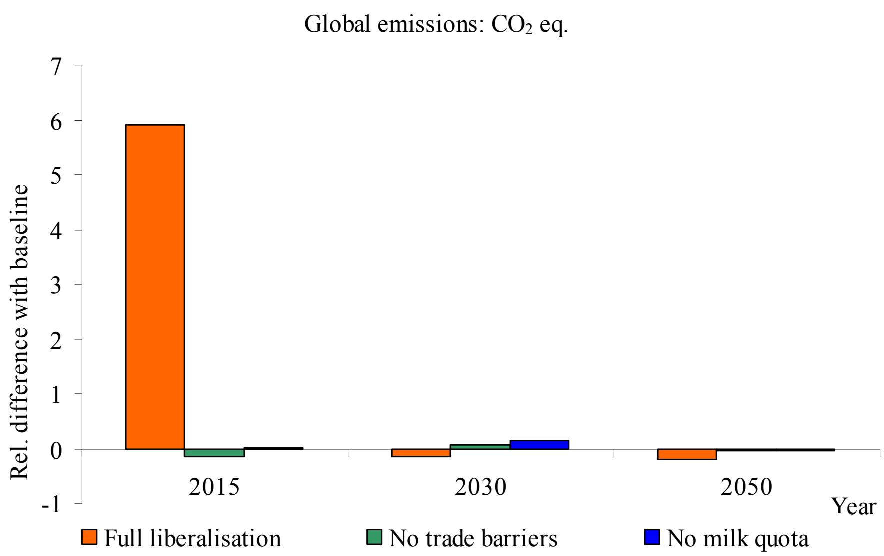

Figure 4.1 A Relative differences (in %) of the three liberalisation scenarios compared to the baseline scenario in global emissions (CO_2 equivalents, land use associated CO_2, CH_4, and N_2O) for the reference year 2015, 2030 and 2050

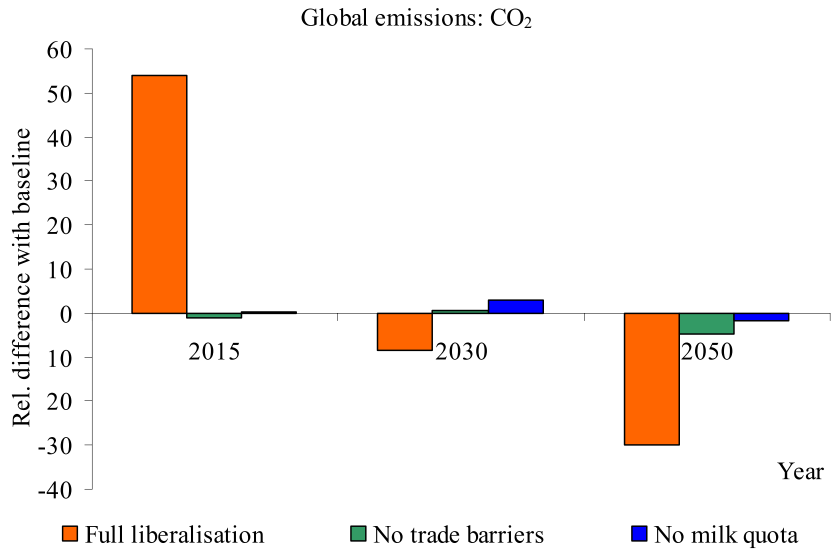

Figure 4.1 B *Relative differences (in %) of the three liberalisation scenarios compared to the baseline scenario in global emissions (CO_2 equivalents, land use associated CO_2, CH_4, and N_2O) for the reference year 2015, 2030 and 2050*

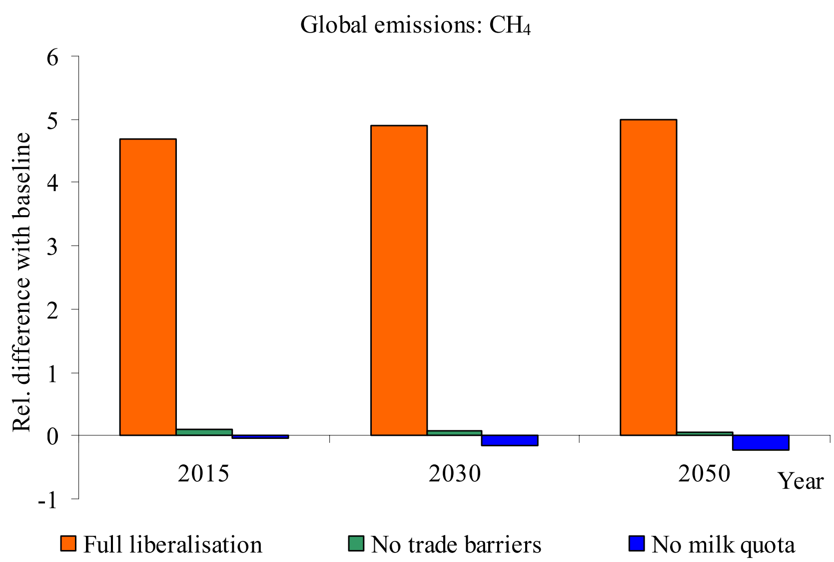

Figure 4.1 C *Relative differences (in %) of the three liberalisation scenarios compared to the baseline scenario in global emissions (CO_2 equivalents, land use associated CO_2, CH_4, and N_2O) for the reference year 2015, 2030 and 2050*

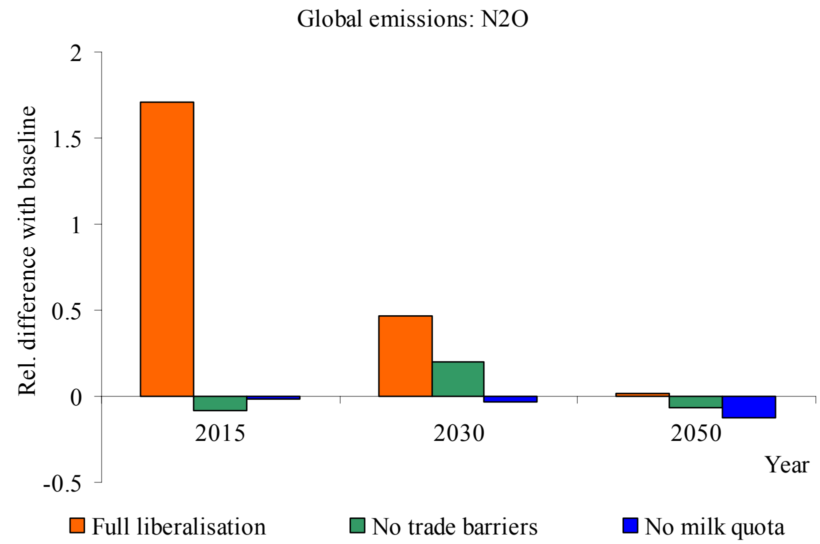

Figure 4.1 D Relative differences (in %) of the three liberalisation scenarios compared to the baseline scenario in global emissions (CO_2 equivalents, land use associated CO_2, CH_4, and N_2O) for the reference year 2015, 2030 and 2050

4.3 Abolition of trade barriers scenario: regional patterns

In the abolition of trade barriers scenario a partial agricultural trade liberalisation is implemented. In this scenario the import and export taxes and subsidies for the milk and dairy sector is removed by 2015 while all other trade mechanisms were kept equal to that of the baseline. Moreover, after 2015 only macro economic effects of trade barrier removal are seen in this scenario. In other words, this scenario assumes a partial liberalisation of the milk sector by the removal of trade barriers, but with continued milk quota in Europe.

As expected the various effects on trade, land use, livestock and emissions of this scenario are located between the two 'extreme' scenarios of the baseline and the full liberalisation scenario. Thus the trade barrier abolition scenario gives insight in the repercussions of keeping or removing trade barriers on agricultural productivity and the environment. Removal of trade barriers only leads to small regional differences in agricultural area (small change in both grassland and cropland) compared both to the full liberalisation and baseline scenarios. Shifts in animal numbers are comparable to, but generally smaller than the full liberalisation scenario but some remarkable regional differences were found. Removal of trade barriers leads to an increase in dairy cattle numbers in OECD pacific. This is at the expense of decreasing non-dairy cattle and sheep and goats in this region. In Africa a reduction in the numbers of all animal categories is found. In South Asia this is the case for non-dairy cattle and sheep and goats, but not in each reference year. In Europe and North America trade barrier removal leads to a reduction in the number of dairy cattle. As a result land is available for other animal types and a (small) increase in non-dairy cattle and sheep and goats is found in these two regions. Overall, the effect of trade barrier removal on cattle numbers is very small however, compared to the baseline scenario. Effects on milk and dairy production on the other hand are large and the global differences are comparable to the full liberalisation scenario. Removal of trade barriers only leads to a shift of milk production towards OECD pacific, South East Asia, other Latin America and in some years to South Asia (in 2030), North America and Russia (in 2050). This production shift is at the expense of Europe, Japan and Africa where milk production declines. For dairy comparable production shifts are found, like increased production values in OECD pacific and Latin America with the addition of consistent production increases in Russia, South Asia and Central Asia. Consistent production declines are found in Europe, Japan and Korea, Africa and South East Asia.

Because large regional shifts in animal numbers and agricultural areas do not occur in this scenario, the global emissions of all greenhouse gasses are more or less equal to the baseline scenario. For each greenhouse gas studied (i.e. CO_2, CH_4 and N_2O) no remarkable regional shifts are found. Thus where full liberalisation leads to large changes in both regional and global emission patterns, the trade barrier scenario does not.

4.4 Abolition of milk quota scenario: regional patterns

The abolition of milk quota scenario assumes a policy towards a gradual decline of all EU milk quota by 2015. After 2015 no new policies are added to this scenario, thus leading only to macro economic effects of milk quota abolition up to 2050. Trade barriers like import and export subsidies are maintained however. As in the full liberalisation and no trade barrier scenarios population growth and consumption patterns are kept equal to that in the baseline scenario.

Abolition of milk quota leads to marginal shifts in agricultural production area, as also seen in the trade barrier scenario. As could expect the milk quota scenario mostly affects the number of dairy cows. Indeed, Europe profit most from this scenario with an increasing amount of dairy cattle, but after 2030 also in Russia, South East Asia (SOA), China and Other Latin America such an increase is found. Unexpected, however, is the relatively strong decline of beef cattle and sheep and goats in Africa and South East Asia. A clear explanation for this shift cannot be made. Milk quota removal does not lead to large changes in the regional production of dairy and milk compared to the baseline scenario. Global emissions of the greenhouse gas studied do not differ much with the patterns found for the trade barrier removal scenario. Small differences for each greenhouse gas are found, when comparing to the trade barrier scenario (see figure 4.1) but the differences are less than 1-4%. Also regional shifts in emissions compared to the baseline scenario are the smallest amongst the tree trade liberalisation scenarios.

4.5 Trade effects in the EU

In GTAP trade movements are studied between countries and country aggregations (i.e. regions) and therefore trade effects of the different liberalisation scenarios can be studied on EU specific countries. In this study three different country aggregations were made; the Netherlands, EU-14 ('old' member states excluding the Netherlands) and EU-12 ('new' member states). The Netherlands profited mostly from full liberalisation for milk and dairy production. During all years production was highest among the three EU regions studied with the largest values found in 2050 for both milk and dairy. On the other hand, production of beef also declined most strongly in the Netherlands, and this decline was more or less equal throughout the years (ca. 56% reduction). The strong increase in milk and dairy production in the full liberalisation scenario in the Netherlands is almost solely based on the removal of milk quota. Both scenarios (i.e. full liberalisation and milk quota) show almost equal production values, while trade barrier removal had no effect on the production values. This pattern is also found in EU-12, but much less in EU-14. This picture cannot be applied to beef production. Generally speaking, the scenario of milk quota removal had a larger effect on beef production than the scenario of trade barrier removal. However, these differences are small, since the effect of the milk quota scenario is a factor 10 lower than found in the full liberalisation scenario. This pattern also holds for EU-12 and EU14, but the reduction in beef production is much less in these EU regions compared to the Netherlands.

Since IMAGE is a global emission model with a specific spatial resolution, predictions on emissions on a country base and on a small regional base cannot be made. Therefore, effects of trade liberalisation on greenhouse gas emissions in different EU countries are very hard, if not impossible, to tackle in IMAGE.

4.6 Trade liberalisation and production

The OECD published a report on the developments of the dairy sector as affected by forthcoming trade liberalisation (OECD, 2004). In a GTAP study two liberalisation scenarios were developed in which the level of tariff reduction varied. Both liberalisation scenarios showed very little increase (less than 1%) in the level of world milk production (OECD, 2004). However, large regional productivity shifts were found with most notably production increments in New Zealand and Australia. Little effects were found for the Netherlands (OECD, 2004). Also Saunders et al. (2006) found increasing productions values in New Zealand but also declining production values of raw milk and dairy products in the EU under two liberalisation scenarios for 2010. These latter findings are partially in contrast to the findings in our study. The full liberalisation scenario led in the GTAP-IMAGE framework indeed to a decreased production of both milk and dairy in Europe, but this is mainly caused by a reduction in the EU-14. For both EU-12 (new member states) and the Netherlands production of both commodities increases under full trade liberalisation. For the Netherlands, this increase is mostly determined by the abolition of EU milk quota. As van Berkum and Helming (2006) pointed out, abolition of milk quota will lead to a reduction of EU milk price by 15%. A similar reduction of producer milk price is also predicted by Saunders et al. (2006).

It is commonly acknowledged that three mechanisms are associated with trade liberalisation; the composition effect, the scale effect and the technique effect (e.g. Cole et al., 1998). Trade liberalisation is likely to change the composition of industries as countries tend to specialise, while the scale effect stems from the expansion in the scale of production which is likely to change when markets expand due to liberalisation. It is commonly assumed that open markets will lead to a stronger technological development than when markets are closed. (e.g. Aldcroft, 2001). This technological development can boost productivity by innovative measures. Hence, open markets that are caused by trade liberalisation should increase their productivity. Some liberalisation scenarios like the Standardised Reference Emissions Scenarios (SRES) developed by The Intergovernmental Panel on Climate Change (IPCC) have incorporated differences in technological development. The global market A1 scenario, for example, has a stronger technological development than the regional community B2 scenario. The liberalisation scenarios in our study, as well as those developed by the OECD (2004) and by Saunders et al. (2006) lack this possible mechanism. In other words, these liberalisation scenarios only differ in access to world markets and as a result regional shifts in scale and composition of productivity occurs. To be more realistic, effects on technological development should also be implemented in such liberalisation scenarios since they might play a crucial role when markets get gradually more open.

4.7 Trade liberalisation and greenhouse gas emissions

Within the IPCC programme the SRES scenarios forecast future greenhouse gas emissions from all sectors, without considering specific climate policies and their impact on emission reductions (e.g., Strengers et al. 2004). Strengers et al. (2004) modelled future emissions of greenhouse gasses using the IMAGE 2.2 framework. This study included the SRES scenarios A1, A2, B1 and B2, while emphasis was given on the land-use associated emissions. Their results show that the global market scenario A1 had much larger emissions of CO_2, CH_4 and N_2O than under the regional community (B2) scenario. These results are comparable with the results presented in our study. In addition, the SRES scenarios not only differ in the degree of open markets but also in population growth, consumption patterns etc. Therefore increased greenhouse gas emissions in the global market scenario might be attributed to a larger world population and a changed consumption pattern. Our results show that also without assuming larger population growth and a changed consumption pattern liberalisation will lead to increased emissions of greenhouse gasses.

The OECD studied the effects of two liberalisation scenarios on the dairy sector using the GTAP model (OECD, 2004). The two scenarios reflect some of the elements of various proposals submitted to the WTO, such as market access, export competition and domestic support. Comparable to the full liberalisation scenario presented in our study, the OECD scenarios included a liberalisation that is limited to all agricultural sectors, where tariffs are reduced but those on industrial products remained fixed. Increased emissions that were associated with an increasing density of dairy cattle were found in OECD pacific (New Zealand, Australia) and to a lesser extent in Central and South Asia in the OECD study (OECD, 2004). Reductions in CO_2 equivalents were found in Japan, United States and Middle East incl. Turkey, Northern and Southern Africa (OECD, 2004). Despite the large regional differences in greenhouse gas emissions, the OECD report also estimates that the global greenhouse gas emissions from milk production are expected to increase only slightly as a result of further trade liberalisation.

Saunders et al. (2006) used the Lincoln Trade and Environment Model LTEM to study the effects of agricultural trade liberalisation on production and greenhouse gas emissions both in the EU and New Zealand for the year 2010. Unlike GTAP, LTEM is a partial equilibrium model where only supply and demand of the agricultural sector is balanced, keeping everything else equal. Saunders et al. (2006) found that for both liberalisation scenarios, i.e. EU liberalisation and liberalisation within the whole OECD, a 12 - 20% drop in greenhouse gasses in Europe can be expected and a concomitant increase of 7 to 40% of emissions in New Zealand. These shifts are clearly the results of changing production values of raw milk and dairy in EU and New Zealand caused by the liberalisation scenarios.

As Ervin (1997) pointed out, the possible negative environmental effects from trade liberalisation may also result from pollution caused by increased international transport. While in the analysis of the dairy sector by the OECD (2004) emissions of greenhouse gasses by transport are only briefly touched upon, the GTAP-IMAGE framework in this study even ignores the effects of altered transport movements caused by a global market completely. As shown both in our study as in the OECD report of 2004, liberalisation causes large regional shifts in production areas. It can be expected that such shifts will also lead to altered transport movements. Emissions from transport depend on the type of transport as well as the distance taken. Thus production shifts caused by liberalisation can have a large effect on the total amount of greenhouse gasses when (altered) transport movements are taken into account as well. Effects of altered transport movements should therefore be incorporated when liberalisation scenarios are implemented. Currently it is not possible to model correctly all associated transport movements due to liberalisation in the GTAP-IMAGE framework.

The studies of OECD (2004), Saunders et al. (2006) and MNP (2006) used baseline scenarios to compare effects of liberalisation. In all these baseline scenarios no new policies were implemented, and as shown in our study, greenhouse gas emissions continued to rise. CO_2 equivalents grow circa 1.8% annually between 2000 and 2015 leading to a total increment of circa 30% by 2015 compared to 2000. Thus, without flanking policy measures to reduce greenhouse gas emissions, global greenhouse gas emissions will also *strongly* increase both in the baseline as in the different liberalisation scenarios. Due to the spatial resolution the IMAGE framework could not predict future emissions in small countries like the Netherlands. Based on the predicted increase in milk and dairy productivity in the Netherlands under the full liberalisation and the abolition of milk quota scenarios a concomitant increase in methane and nitrous oxide emissions are foreseen. To meet the Kyoto targets in the forthcoming years, additional policy is needed to reduce emissions when reform of the CAP is negotiated.

4.8 Conclusions

4.8.1 Baseline scenario

- With no new policies added, the emissions of greenhouse gasses (CO_2 equivalents) will rise globally up to 63% in 2050 compared to the year 2000 in the baseline scenario.
- The increase in greenhouse gas emissions by 2015 is strongest in respectively China, South Asia including India, South East Asia including Indonesia, Africa and North America. By 2030 increases in emissions are strongest in China, Africa, and South Asia including India, and by 2050 in respectively South Asia including India, Africa, and Middle East.
- Considering the different greenhouse gasses (CO_2, CH_4 and N_2O) studied, the emissions of CO_2 decrease on the long term, the emissions of CH_4 (methane) strongly increase up to 2050, and the emissions of N_2O (nitrous oxide) show a relative small increase over time.
- Up to 2020 a strong increase of CO_2 emissions is found caused by land clearing of natural vegetation for agricultural land use in Africa, Latin America, South East Asia including Indonesia, and South Asia including India.
- The continued increase of methane emissions are caused by increasing cattle density in the different regions.
- Increased beef production contributes more to the observed methane emissions than milk and dairy production.
- The increased emissions are due to increasing population density and a stronger demand for animal food caused by increased income.
- World GDP increases with circa 3% per year, adding up to a 179% increase by 2050.
- Global production of milk and beef increases with 1.9% per year up tot 2030, and with 1.4% per year from 2030 to 2050.
- Global increased production of dairy is smaller than milk and beef and increases with 1.4% to 1.3% per year up tot 2050.

4.8.2 Liberalisation scenarios

- Among the three liberalisation scenarios studied, the full liberalisation scenario has the largest effects on greenhouse gas emissions.
- Full liberalisation adds an extra 50% of CO_2 emissions from agriculture by 2015, followed bye a reduction of 30% in 2050 compared to the baseline scenario.
- Both removal of trade barriers and removal of milk quota seem to have very small extra emission effects on CO_2.
- The increased CO_2 emissions in the full liberalisation scenario is caused by land clearing for agriculture in Brazil and Latin America, South East Asia including Indonesia, and Africa.
- Full liberalisation adds an extra 5% of methane emissions up to 2050, while both the removal of trade barriers and milk quota scenarios had hardly any additional effect.

- The strongest increase in methane emissions in the full liberalisation scenario is found in Brazil, and to a lesser extent in other Latin America, Africa, OECD pacific, South Asia and South East Asia.
- These regional emission increments are mostly caused by increased numbers of beef cattle and sheep and goats.
- Full liberalisation adds an extra 1.7% of nitrous oxide emissions in 2015, but this emission increment becomes smaller over time. By 2030 an extra of 0.47% is found while by 2050 emissions are equal to the baseline scenario.
- Trade barrier removal leads only in 2030 to an extra 0.2% of nitrous oxide. In 2015 and 2050 global emissions are very comparable to the baseline.
- In general milk quota abolition does not lead to different global N_2O emissions.
- Increased global emissions of N_2O in the full liberalisation and trade barrier removal scenarios are only the result of increasing emissions from animal waste. In these scenarios N_2O emissions from fertiliser application are lower than in the baseline.
- Largest regional differences in production of dairy are found in the full liberalisation and removal of trade barriers scenario, while for beef production these large differences are found in the full liberalisation scenario only.
- For dairy largest production decline is found in North America, Europe and Japan, while increments are found in OECD pacific, South Asia, Russia, Eastern Europe and Central Asia, and Latin America.
- For beef a strong production decline is found in Europe and a concomitant increase in Brazil and rest of Latin America, and Africa.
- For milk production the regional shifts are fuzzier, but a decrease is found in North America and Europe and an increase in OECD pacific, Latin America and South Asia.
- Within the EU, full liberalisation and abolition of milk quota leads to a strong increase of dairy and milk production in the Netherlands and new member states (EU-12) while trade barrier removal had negative or no effect on production.
- With full liberalisation beef production most strongly reduces in EU-15, including the Netherlands.

4.8.3 Concluding remarks and policy recommendations

Shifts in agricultural commodity production may give insight to what extent liberalisation will add to the poverty alleviation target. According to FAO (2003) the regions that are most dependent on agriculture, both in terms of share of GDP as on the share of population dependent on agriculture, are South (East) Asia, China and Africa. Their agricultural GDP ranges from 16% in Africa to 24% in South Asia while the population depending on agriculture ranges from 56% in Africa to 60% in South East Asia. However, in South America, including Brazil the share of agricultural GDP in total GDP and the share of the population depending on agriculture is only 6.7% and 18.7% respectively. Adding the three calculated commodities (beef, milk and dairy in GTAP) show that OECD pacific, Russia, Brazil and the rest of Latin America and South East Asia including Indonesia profit most from liberalisation. Especially beef production will move to Brazil. In contrast, Africa does not show an increased production of the three added commodities. This pattern becomes even worse for Africa with trade barrier removal. Here the net production of the three commodities decline.

The production shifts of liberalisation towards South America will result in a strong increment of CO_2 emissions caused by land clearing. Clearing of natural vegetation is needed to expand new agricultural areas. Such clearing is also found in the baseline scenario but this process is strongly accelerated with liberalisation. This response can solely be attributed to production shifts caused by liberalisation and are not the result of differences in human population density. In both scenarios human population is kept equal and thus food demand is equal as well. Clearing of natural vegetation not only increase CO_2 emissions, but may also have strong negative effects on the world biodiversity since large natural areas in South America are also hot spots of biodiversity. In addition, cattle farming in South America are much more extensive and less productive than in Europe and North America. With increasing cattle numbers methane emissions increase more than proportionally in South America than emissions decline in Europe. As a net result, global methane emissions will rise with liberalisation.

Milk quota and manure policy set limits on methane emissions in the Netherlands. Removal of milk quota will result in an increased number of dairy cattle and a concomitant decrease in beef cattle. The observed small change in methane emissions in Europe and the Netherlands is caused mainly by the reduction in beef production. If trade liberalisation is negotiated with continued high beef production, methane emissions are expected to increase as well. Given the ambitious climate policy of the Netherlands and the EU, additional emissions through shifts in agricultural production would increase the problem. It should be acknowledged that agricultural liberalisation can have a significant impact or side-effects on greenhouse gas emissions and the climate policy arena. At the moment intense activities are going on to reduce deforestation rates or to compensate countries for conserving biodiversity. Appropriate policies should therefore be in place or should be tightly coordinated with a potential liberalisation of agricultural trade.

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Appendix 1. Regional breakdown by countries used in the GTAP-IMAGE framework

Countries	Region	acronym
Egypt, Burkina Faso, Central African Republic, Sao Tome and Principe, Eritrea, Ethiopia, Nigeria, Gabon, Comoros, Mauritania, Lesotho, Swaziland, Mayotte, Algeria, Angola, Benin, Botswana, Burundi, Cameroon, Cape Verde, Chad, Côte d'Ivoire, Djibouti, Equatorial Guinea, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar. Malawi, Mali, Mauritius, Mozambique, Namibia, Senegal, Seychelles, Sierra Leone, South Africa, Congo, Gambia, Niger, Sudan, Tunisia, Uganda, Zambia, Zimbabwe, Réunion, Rwanda, Saint Helena, Lybia, Somalia, Togo, Tanzania	North, East, West and South Africa	AFR
American Samoa, Australia, Christmas Islands, Cocos, Commonwealth of the Northern Mariana Islands, Cook Islands, Micronesia, French Polynesia, French Southern Territories, Guam, Heard & McDonald Islands, Western Samoa, Tonga, Kiribati, New Caledonia, New Zealand, Niue, Norfolk Islands, Pitcairn, Fiji, Nauru, Palau, Marshall Islands, Vanuatu, Solomon Islands, Tokelau, Tuvalu, Wallis & Futuna	Oceania	ANZ
Brazil	Brazil	BRA
People's Republic of China, Taiwan, Hong Kong, Macau, Mongolia	China Region	CHN
Belarus, Kyrgyz, Kazakhstan, Moldova, Tajikistan, Uzbekistan, Turkmenistan, Ukraine	Eastern Europe and Central Asia	ECA
Czech Republic, Faeroe Islands, Germany, Serbia, Montenegro, Bosnia H., Croatia, Macedonia, France, Luxemburg, Greece, Ireland, Italy, Belgium, Denmark, Norway, Spain, Sweden, Netherlands, Portugal, Albania, Austria, Bulgaria, Cyprus, Estonia, Finland, Hungary, Iceland, Latvia, Lithuania, Malta, Poland, Slovenia, Slovakia, Turkey, Romania, UK, Switzerland	Western and Central Europe	EUR
Japan, Korea	Japan region	JPK
Jordan, Iran, Iraq, Saudi Arabia, Lebanon, Yemen, Bahrain, Israel, Kuwait, Qatar, Oman, Syria, United Arab Emirates	Middle East	MEA
Canada, USA, Mexico	North America	NAM
Brunei Darussalam, East Timor, Indonesia, Cambodia, Thailand, Laos, Malaysia, Papua New Guinea, Singapore, Philippines, Vietnam, Myanmar	South East Asia	OAS
Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad & Tobago, Venezuela, Antigua and Barbuda, Argentina, Netherlands Antilles, Barbados, Belize, Bermuda, Cayman Islands, Falklands, French Guiana, Grenada, Guadeloupe, Jamaica, Martinique, Montserrat, Puerto Rico, Bolivia	Other Latin America and Caribbean	OLC
Azerbaijan, Georgia, Armenia, Russia	Russia and Caucasus	RUS
India, Sri Lanka, Pakistan, Afghanistan, Bhutan, Nepal, Bangladesh, Maldives	South Asia	SOA
Antarctica		
Greenland		

Figure A1.1 Regional breakdown by countries used in the GTAP-IMAGE framework

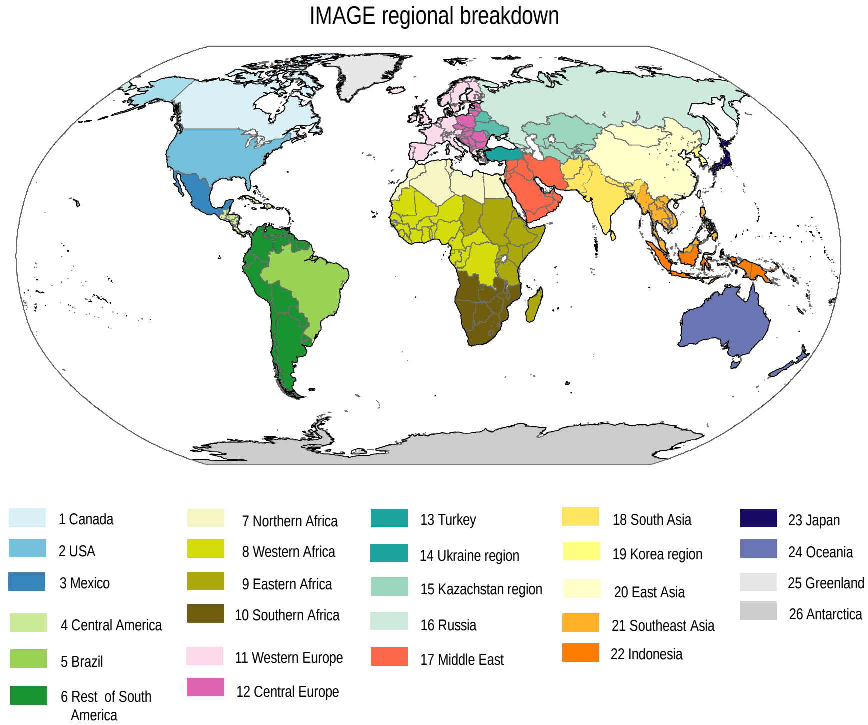

Figure A1.2 A The 24 world regions in the IMAGE model (figure A1.2 A) and the aggregated 13 world regions (figure A1.2 B) used in this study. See figure A1.1 in appendix 1 for a full list of country aggregations for each region

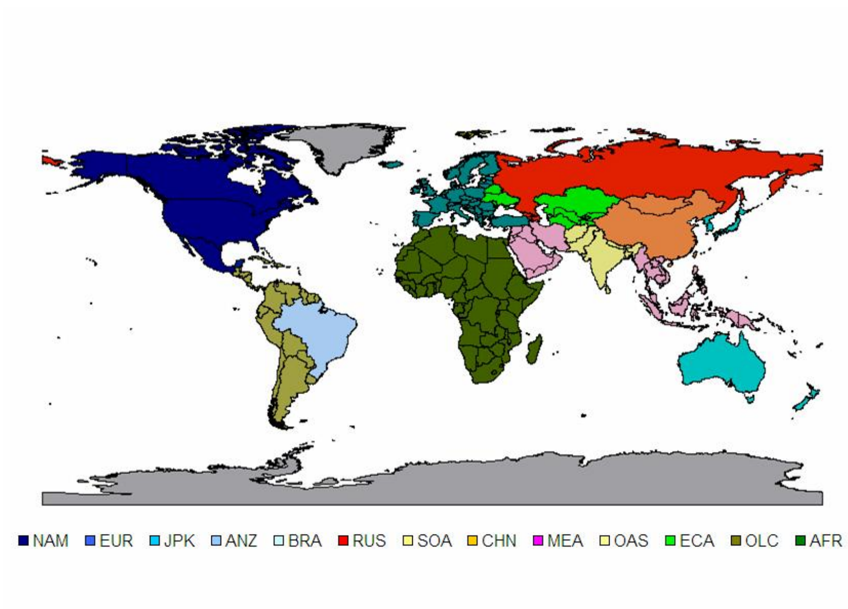

Figure A1.2 B The 24 world regions in the IMAGE model (figure A1.2 A) and the aggregated 13 world regions (figure A1.2 B) used in this study. See figure A1.1 in appendix 1 for a full list of country aggregations for each region

Appendix 2. Animal feed conversion factors used in IMAGE

Table A2.1 The fraction of animal feed of dairy cows from food products (crops) (%)

Year	1970	1980	1990	2000	2050
Region					
NAM	0.58	0.58	0.58	0.58	0.58
EUR	0.63	0.65	0.68	0.68	0.68
JPK	0.65	0.65	0.65	0.68	0.68
ANZ	0.40	0.40	0.40	0.40	0.40
BRA	0.55	0.55	0.55	0.55	0.55
RUS	0.50	0.50	0.50	0.50	0.50
SOA	0.90	0.90	0.90	0.90	0.90
CHN	0.60	0.60	0.60	0.55	0.55
MEA	0.70	0.75	0.80	0.85	0.85
OAS	0.20	0.45	0.70	0.55	0.55
ECA	0.60	0.63	0.65	0.68	0.68
OLC	0.55	0.55	0.55	0.55	0.55
AFR	0.54	0.55	0.56	0.58	0.58

Table A2.2 The fraction of animal feed of dairy cows from residues in total fraction of animal feed from food products (%)

Year	1970	1980	1990	2000	2050
Region					
NAM	0.64	0.60	0.47	0.42	0.42
EUR	0.71	0.71	0.69	0.64	0.64
JPK	0.69	0.54	0.48	0.64	0.64
ANZ	0.94	0.97	0.89	0.56	0.56
BRA	0.59	0.71	0.83	0.85	0.85
RUS	0.53	0.43	0.45	0.53	0.53
SOA	0.41	0.42	0.41	0.40	0.40
CHN	0.86	0.86	0.81	0.67	0.67
MEA	0.78	0.65	0.37	0.36	0.36
OAS	0.43	0.49	0.62	0.51	0.51
ECA	0.55	0.48	0.53	0.59	0.59
OLC	0.74	0.75	0.71	0.65	0.65
AFR	0.76	0.75	0.74	0.71	0.71

Appendix 3. Population growth and consumption patterns in the baseline scenario

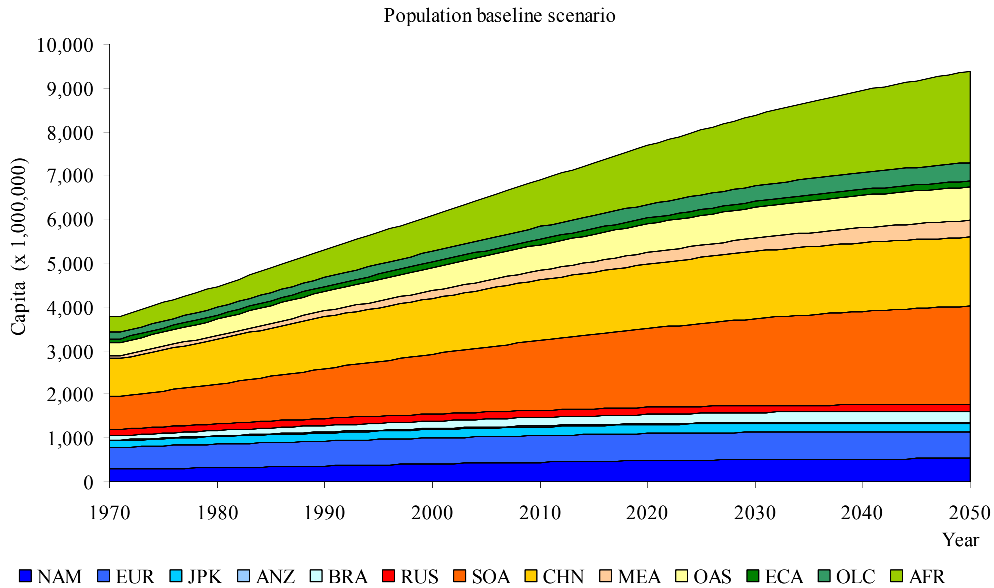

Figure A3.1 Population growth in the 13 regions as modelled in the baseline scenario. The same values are used for the three liberalisation scenarios

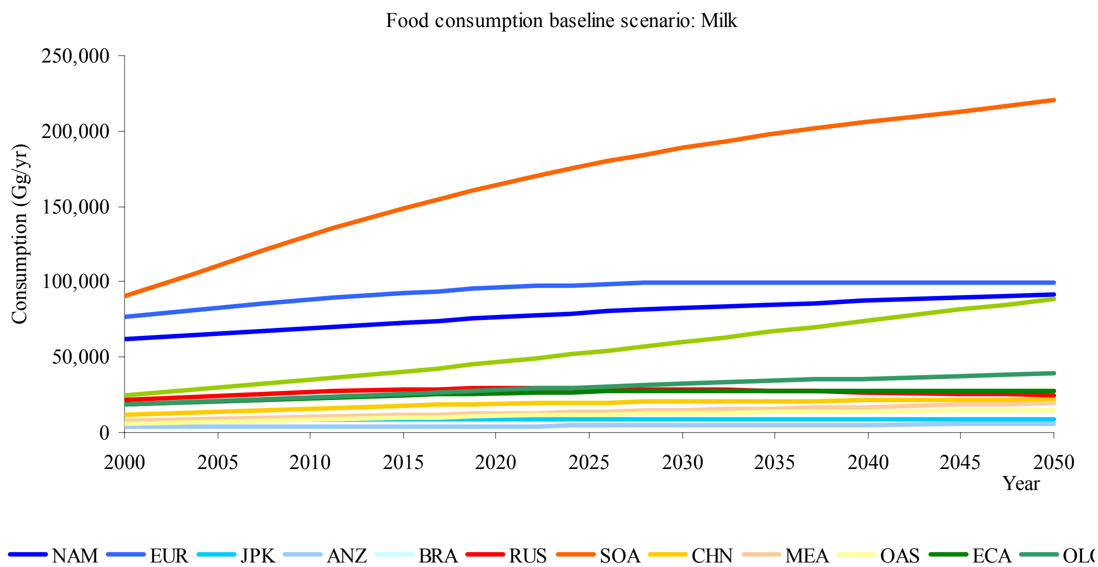

Figure A3.2 Regional consumption patterns of milk in the baseline scenario. The same values are used for the three liberalisation scenarios

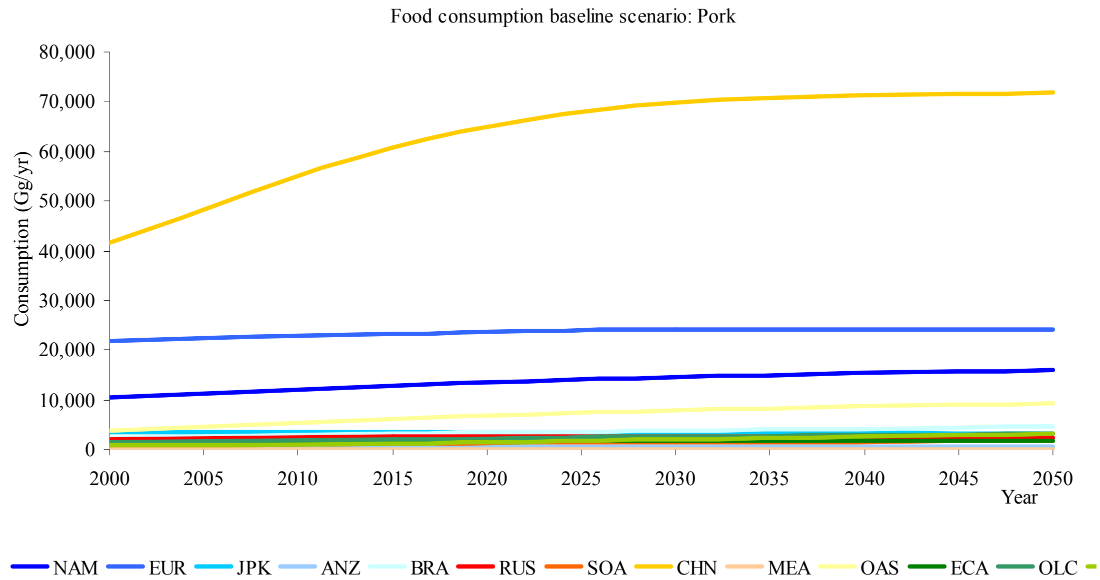

Figure A3.3 Regional consumption patterns of pork meat in the baseline scenario. The same values are used for the three liberalisation scenarios

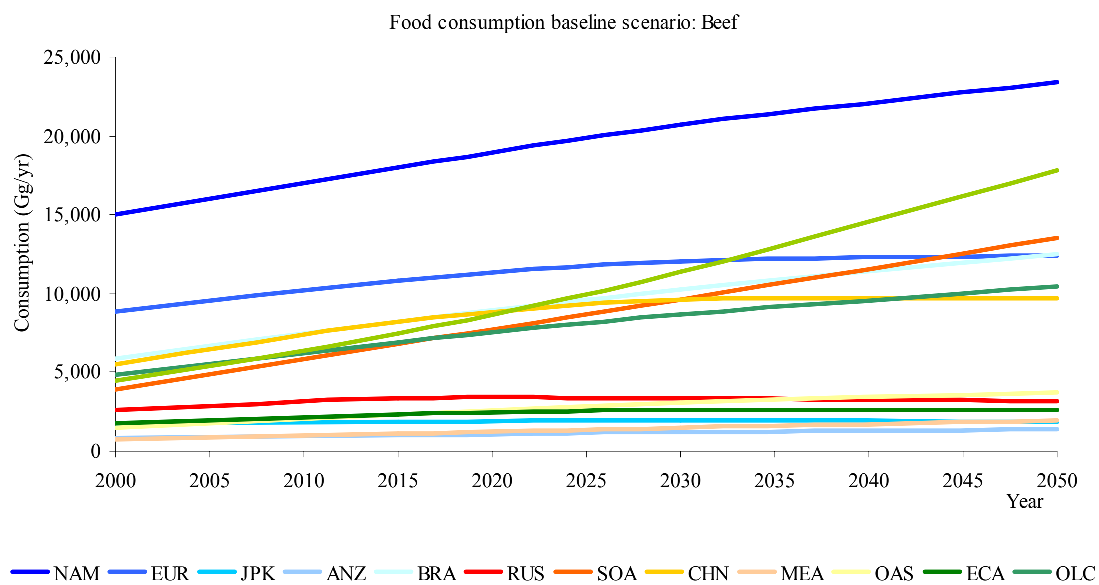

Figure A3.4 Regional consumption patterns of beef in the baseline scenario. The same values are used for the three liberalisation scenarios

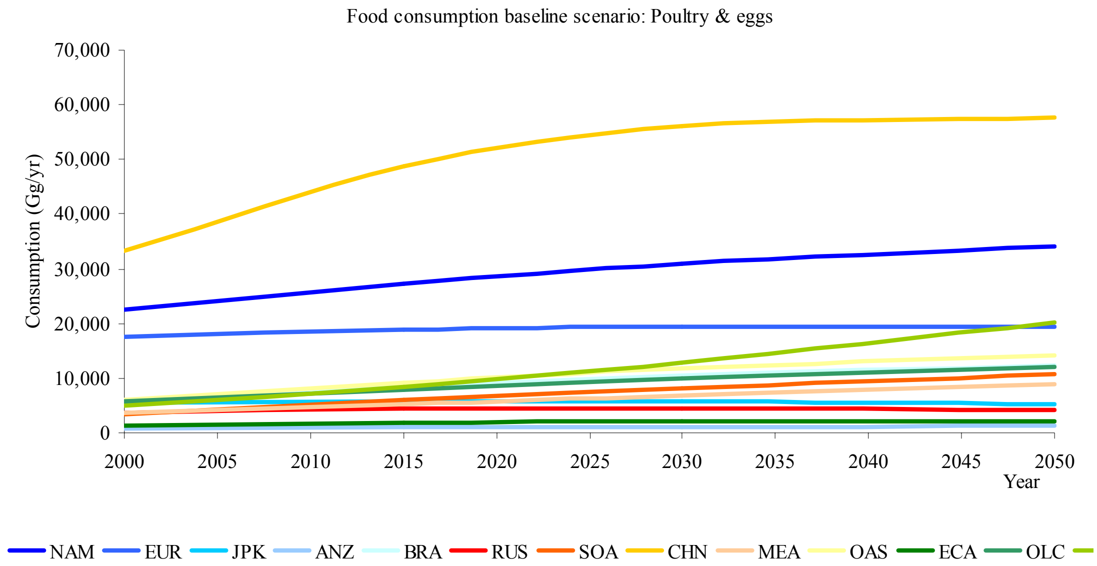

Figure A3.5 Regional consumption patterns of poultry and eggs in the baseline scenario. The same values are used for the three liberalisation scenarios