

Author

Martin Banse

LEI (Agricultural Economics Research Institute)

PO Box 29703

2502 LS The Hague

The Netherlands

Website: www.lei.nl

PREFACE

The Bio-based Raw Materials Platform (known as PGG), which is part of the Energy Transition programme in the Netherlands, commissioned the Agricultural Economics Research Institute (LEI) and the Copernicus Institute of Utrecht University to study the macro-economic impact of large-scale deployment of biomass for energy and materials in the Netherlands. Two model approaches were applied based on a consistent set of scenario assumptions: a bottom-up study including techno-economic projections of fossil and bio-based conversion technologies and a top-down study including macro-economic modelling of (global) trade of biomass and fossil resources. The results of the top-down study (part II) including macro-economic modelling of (global) trade of biomass and fossil resources, are presented in this report.

BACKGROUND

Under the framework of previous studies, e.g. EUruralis and Matisse, 1st-generation (and in a rudimentary way also 2nd-generation) biomass have already been implemented in the quantitative tool the general equilibrium model GTAP at the LEI institute, covering the currently available technologies to use food and feed crops to produce bio-fuels for the transport sector to substitute for common oil products. This study focuses on the macro-economic consequences on the Dutch economy of the large-scale use of biomass resources for transportation fuel, bio-electricity and chemicals¹. For the set-up of the various scenarios for biomass uses, a link has been developed between the uses of biomass inputs estimated in the bottom-up approach and the quantitative modelling approach.

Previous studies on increased use of 1st-generation biomass focused on achieving specific targets and subsequently analysing macro-economic implications (e.g. for food and land prices). In this study, the combination of bottom-up scenarios (with a range of selected bio-based value chains) has been 'enforced' onto the macro-economic model, i.e. the estimated quantities of biomass utilisation in various sectors in the bio-based economy have been translated into blending targets to be applied in the macro-economic model.

However, there are also clear limitations to this link between the bottom-up and the top-down approach: one is the lower level of detail of the economic model in comparison to the bottom-up system calculations. Another element is that the macro-economic model does not take into account key (macro) trends on aspects such as productivity changes, economic growth and sectoral shifts at large and that, as a consequence, impacts for specific sectors may appear as relatively minor because they are 'overruled' by such macro trends. The work focuses on delivering results for bio-based oriented scenarios compared to a baseline to circumvent this problem, but it should be noted that results obtained at sectoral level are sensitive to the underlying macro trends.

1 Methodological Approach

The quantitative analysis of this study is based on an extended version of the LEITAP model, where previous model versions have been applied in the EUruralis project (Version 2.0) and in the MATISSE project (coordinated by PBL, the Netherlands Environment Assessment Agency).

LEITAP is a global computable general equilibrium model that covers the entire economy, including factor markets and is often used in WTO analyses and CAP analyses. More specifically, LEITAP is a modified version of the global general equilibrium model GTAP (Global Trade Analysis Project). The model, and its

¹ The use of biomass inputs in the fine or bulk chemical sector is dependent on the different technology assumption in the scenarios.

underlying database, describes production, use and international trade flows of commodities, services and inputs between regions of the world. Assumptions about population growth, technological progress, and policy framework are the main drivers behind the model's results. Based on such assumptions, the model determines production, use and trade flows as a result of market clearing on all commodity and input markets in all countries/regions of the world. Agricultural policies are treated explicitly (e.g. production quotas, intervention prices, tariff rate quotas, (de)coupled payments.²

In previous projects the LEITAP model has been extended to include 1st-generation biomass production. For this extension the approach separates energy from non-energy intermediate inputs and presents energy inputs in a capital-energy composite [Burniaux and Truong, 2002]. It extends this methodology by explicitly depicting the use of cereals, vegetable oils and sugar-beet or sugar-cane as inputs in the production of biofuels in a multi-level structure in the petroleum activity. This extension enables researchers to analyse the impact of targeted policies such as tax exemptions and obligatory blending for the petroleum sector for individual regions and countries.

In addition to the extensions directly related to modelling biofuels, the extended version of LEITAP includes some key characteristics of related markets. The functioning of the land market is particularly crucial. Therefore we included a new demand structure to reflect that the degree of substitutability of types of land differs between land types [Huang, et al., 2004] and we included a land supply curve to include the process of land conversion and land abandonment [Meijl et al., 2006]. Furthermore, in the new LEITAP version, agricultural labour and capital markets are modelled as segmented from the non-agricultural factor markets.

The LEITAP model has been extended for this project:

- for nested input structure, which separates energy from non-energy intermediates in the bio-based sectors, i.e. petrol, electricity as well as bulk and specialty chemicals
- for 2nd-generation bio-energy crops ('woody crops') which are used in the petroleum sector, in the electricity sector, in the gas sector³ and, depending on the scenario, also in the chemical sector
- for an implementation of policy instruments which allow for a separate treatment of mandatory blending targets in the petrol, the electricity and the fine chemical sectors.

The demand structure of the **petroleum industry** has been extended to include the use of woody crops in the similar nest as other bio-based inputs for an ethanol composite (see Figure 1).

² A full description of LEITAP is presented in the annex of this report.

³ Woody crops in the gas sector are used as an intermediate for syngas production.

The model allows for energy and capital substitution in the petroleum and the electricity sector. Compared to the standard presentation of production technology the extended LEITAP model aggregates all energy-related inputs for the petrol sector, such as crude oil, gas, electricity, coal, petrol products, under the nested structure under the added-value side. At the highest level the energy-related inputs and the capital inputs are modelled as an aggregated 'capital-energy' composite (Figure 1).

To introduce the demand for bio-energy inputs, the nested CES function has been adjusted and extended to model the substitution between different categories of oil (oil from bio-energy and crude-oil), ethanol and petroleum products and in the added-value nest of the petroleum sector. The non-solid aggregate is modelled the following way: 1) the non-solid aggregate consists of two sub-aggregates, fuel and gas. 2) Fuel combines oil seeds, crude oil, petroleum products and ethanol.⁴ 3) Ethanol is made out of sugar-beet/cane, cereals and woody crops.

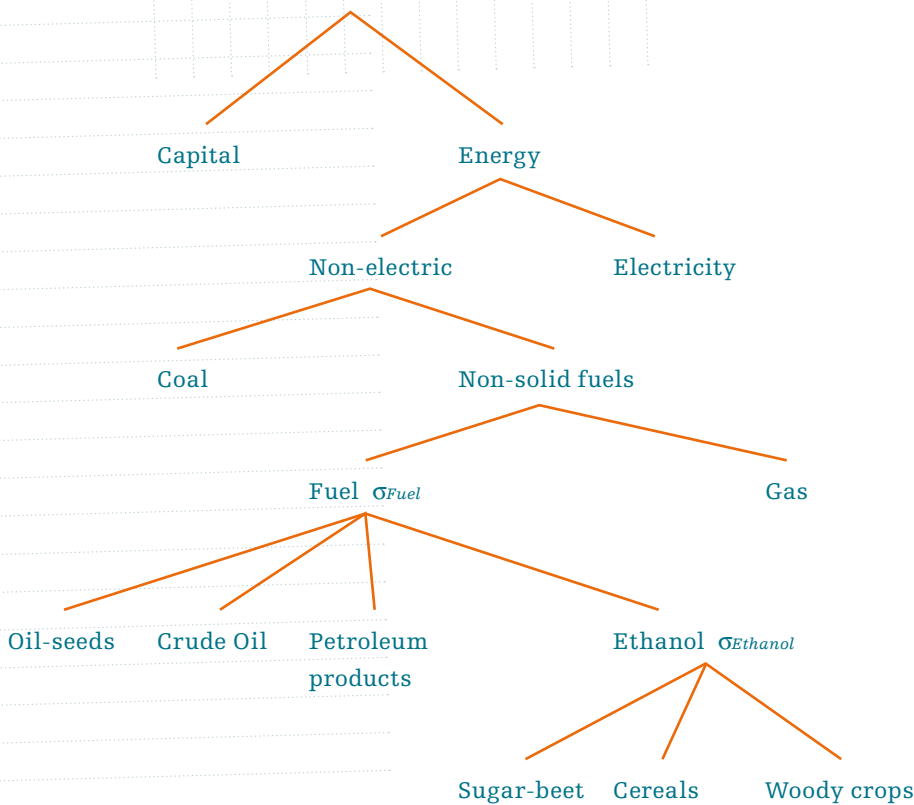


Figure 1: Capital-energy composite in the Extended LEITAP in the Petroleum Sector

4 Ethanol is not modelled as a product for final demand but only as an aggregated composite input in the bio-based industries. As a part of the composite intermediate input ethanol woody crop is also an 'indirect' substitute in the biodiesel production.

This approach is able to present an energy sector where industry's demand of intermediates strongly depends on cross-price relation of fossil energy and biomass-based energy. Therefore, the output prices of the petrol-industry will be (amongst others) a function of fossil energy and biomass prices. The nested CES structure implies that crucial variables for the demand for biomass are the relative price developments of crude oil versus the development of the agricultural prices. Also important is the initial share of bioenergy inputs in the production of fuel. A higher share implies a lower elasticity and greater impact on the oil markets. Finally, the substitution possibilities between crude oil and biomass (represented by the substitution elasticities σ_{Fuel} and $\sigma_{Ethanol}$) are crucial. These represent the degree of substitutability between crude oil and bio-energy crops. The values of the elasticity of substitution are taken from Birur *et al.* [2007], who – based on a historical simulation of the period 2001-2006 – obtained for σ_{Fuel} a value of 3.0 for the US, 2.75 for the EU, and 1.0 for Brazil.⁵ These values are applied here and are kept constant under the LowTech scenarios. Under the HighTech scenarios 2nd-generation biomass technologies are assumed to be available. Therefore, the elasticities of substitution between fossil energy and biomass inputs are increased by 50% for the period 2010-2020, and are set at 100% higher values for the years 2020-2030. As technology progresses over time it might be expected that biomass and fossil fuels become closer substitutes.

Biomass inputs in the **fine chemical industries** are mainly used as a substitute for fossil energy inputs. Therefore, we model the demand for biomass inputs in the fine chemical industries similar to the approach applied for the petroleum industries. There are two exceptions: in the chemical sector the demand of ethylene is modelled via the demand for petroleum products and the demand of hydrogen from biomass via the demand for gas inputs.

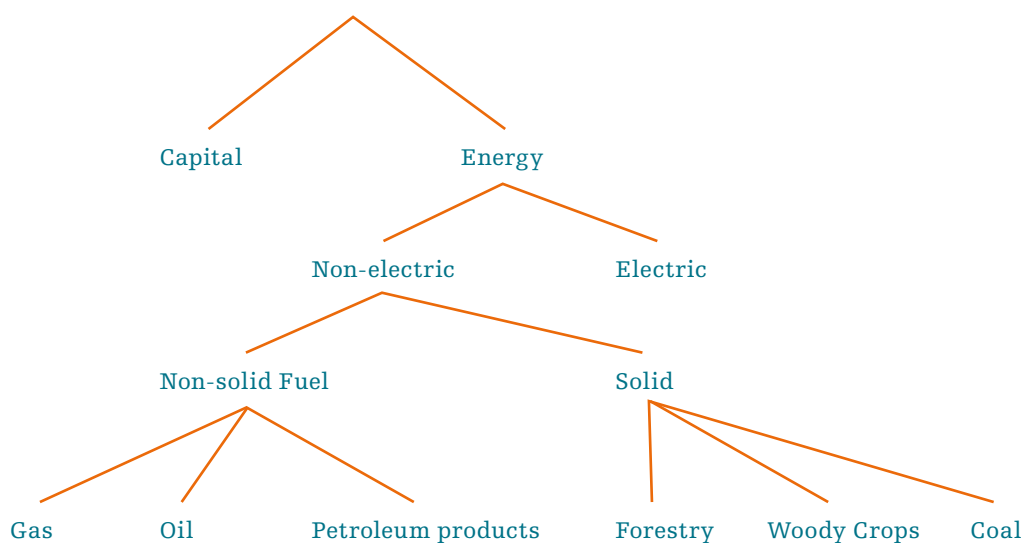
The demand structure of the **electricity industry** differs from the input demand structure of the petroleum and fine chemical industries. The model also allows for energy and capital substitution in the electricity sector. Compared to the standard presentation of production technology the extended LEITAP model aggregates all energy-related inputs for the electricity sector, such as crude oil, gas, electricity, coal, petrol products, under the nested structure under the added-value side.

To introduce the demand for bio-energy inputs the nested CES function in the electricity sector has been adjusted and extended to model the substitution between different categories in the composite of non-electric inputs in the following way: 1) the non-electric aggregate consists of two sub-aggregates, solid and non-solid inputs, 2) non-solid combines gas, crude oil and petroleum products and 3) the solid composite is made out of forestry, woody crops and coal, see Figure 2.

5 For the parameter $\sigma_{Ethanol}$ a 50% higher elasticity is applied than for σ_{Fuel} . For a discussion on these technical parameters see also Banse *et al.* 2008 and Birur *et al.* 2008.

In the scenarios calculated for this study we apply the estimated biomass volumes in the bio-based industries as blending targets which have to be implemented by the fuel, electricity or fine chemical sectors. Depending on the technology and the ratio between fossil and biomass input prices, the estimated amount of biomass could differ from that which would have been applied by the three sectors in a situation without these blending targets, i.e. it might be simply unprofitable for these sectors to apply the estimated amount of biomass.

Figure 2: Capital-energy composite in the Extended LEITAP in the Electricity Sector



Implementation of scenarios with an increased use of biomass inputs

If the estimated amount of biomass utilisation is smaller than the optimal amount based on cost-minimising behaviour of the industries, a subsidy is given to the bio-based industries to achieve the specified biomass shares. This has also been implemented for the modelling of the EU Biofuels Directive, which fixes the share of biofuels in transport fuel. It should be mentioned that the payment of subsidies on biomass inputs in the bio-based industries are modelled as so-called 'budget neutral' from a government point of view. To achieve this in our model two policies were implemented: first, the biomass share in transport fuel, the bioenergy share in electricity and the biomass share in the fine chemicals are made exogenous and second, a subsidy on biomass inputs is made endogenous to achieve the specified biofuel share.

In the case of low technologies and moderate fossil energy prices, the subsidies in the bio-based sectors are necessary to make the biomass inputs competitive with fossil energy. These policy instruments (input subsidies in the bio-based sectors on

bioenergy inputs)⁶ are implemented as 'budget-neutral' subsidies that are counter-financed by an end-user tax on petrol and electricity consumption.

Budget equations are introduced in the model in which end-user tax receipts provide the income and the input subsidies provide the spending. In the case of a mandatory blending, the budget surpluses are made exogenous and considered equal to zero. The end-user tax on petrol and electricity are made endogenous to generate the necessary budget to finance the subsidy on inputs necessary to fulfil the mandatory blending. Due to the end-user tax, consumers pay for the mandatory blending as end-user prices of blended petrol and electricity increase. The higher prices are the result of the use of more expensive bioenergy inputs relative to fossil energy inputs in the production of fuel and electricity.

It should, however, be mentioned that the LEITAP model is based on the assumption that technical changes do not occur in a sudden shift from one technology to another, i.e. even under the HighTech scenario 2nd- and 1st-generation biomass inputs will be used in the bio-based industries. Substitution between one input (1st-generation biomass) with another input (2nd-generation biomass) is modelled as a continuous function. This approach differs from most analyses based on linear-programming or technology approaches with thresholds, and sudden and drastic shifts in different technology options.

GTAP data used

Version 6 of the GTAP data was used for simulation experiments. The GTAP database contains detailed bilateral trade, transport and protection data characterising economic linkages among regions, linked together with individual country input-output databases which account for intersectoral linkages. All monetary values for the data are in \$US millions and the base year for version 6 is 2001. This version of the database divides the world into 88 regions. An additional interesting feature of version 6 is the distinction of the 25 individual EU Member States. The database distinguishes 57 sectors in each of the regions; i.e. for each of the 65 regions there are input-output tables with 57 sectors that depict the backward and forward linkages amongst activities. The database provides considerable detail on agriculture, with 14 primary agricultural sectors and seven agricultural processing sectors (such as dairy, meat products and further processing sectors).

The social accounting data was aggregated to 37 regions and 13 sectors (see Annex Tables A1 and A2, respectively). The sectoral aggregation distinguishes agricultural

6 Please note that input subsidies are granted for cereals, oilseeds, woody crops and sugar-beets/cane in the petrol and the fine chemical sectors. In the electricity sector forestry inputs are assumed not to be eligible for subsidies, while the woody crops inputs are eligible for subsidies. The use of forestry, however, is taken into account for the calculation of the bioenergy shares in the electricity sector.

sectors that can be used for producing bioenergy crops (e.g. grains, wheat, oilseeds, and sugar cane/beet) and that use land, and bio-based industries that demand biomass (crude oil, petroleum, gas, coal and electricity). The regional aggregation includes all EU-15 countries (with Belgium and Luxembourg as one region) and all EU-12 countries (with Baltic regions aggregated to one region, with Malta and Cyprus included in one region, and Bulgaria and Romania aggregated to one region) and the most important countries and regions outside EU, from an agricultural production and demand point of view.

Adjustment of the GTAP 6 database towards biomass production and bio-based industries

Developments in the biofuel sector are extremely fast, so we updated the GTAP database to include the latest developments. The calibration of the utilisation of biomass in LEITAP is based mainly on sources published in F.O. Licht's World Ethanol and Biofuel Reports as well as the F.O. Licht Interactive Database for Ethanol and Biofuels [F.O. Licht, 2007]. Current uses of biomass for liquid biofuel production at EU Member State level are derived from Eurostat and publications by the European Commission. For implementing 1st-generation biomass crops the GTAP database has been adjusted to include the input demand for grain, sugar and oilseeds in the petroleum industry. Under the adjustment process the total intermediate use of these three agricultural products at national level has been kept constant, while the input use in non-petroleum sectors has been adjusted in an endogenous procedure to reproduce 2005 biofuels shares in the petroleum sector (corrected for their energy contents).

For the extension of 2nd-generation bio-energy crops the production and consumption data of the GTAP sector 'other crops' has been adjusted by the so-called 'splitcom' program, which allows us to divide the production and consumption data in GTAP according to defined shares. Here the information of the production of bioelectricity in the EU Member States and the use of wood and wood wastes, as published in the European Biomass Statistics 2007 [Kopetz et al., 2007].

In the original database the chemical industry is presented as a single sector. To show the impact of growing biomass utilisation in the fine chemical industry we also applied the Splitcom program to separate the fine chemical industries from the rest of the chemical sector. Due to the limited information about the composition of the Dutch chemical industry (in value terms), we based our assumption for the disaggregation of the chemical sector on the quantity shares in the chemical industries.⁷

7 Due to the lack of data we applied a share of 20% for fine and 80% for bulk chemicals similar to Wielen et al. [2006].

2 SCENARIO DESCRIPTION AND MODEL RESULTS

2.1 Scenario description

To assess the impact of an increasing use of biomass in the bio-based industries, i.e. liquid petrol, chemicals, gas and electricity, we applied the estimated biomass blending shares as presented in Tables 5-7 in Part I of the report describing the bottom-up scenarios. As outlined in Part I of the report, in addition to the four main scenarios that include single chemical representatives, an additional scenario (IntHighTechAC) was created that includes bio-based production of natural gas and petroleum products in both the specialty and bulk chemical industries. The same assumptions on GDP and population growth have been applied to all five scenarios in this study. Apart from those coefficients that define the differences between the HighTech and the LowTech, as well as the differences between the National and the International scenarios, all other parameters are kept constant over the scenarios.

The main difference between the HighTech and the LowTech scenarios is the different degree of the substitutability between biomass and fossil inputs in the bio-based industries. We assume that under the LowTech scenario production of the bio-based industries is mainly based on current (1st-generation biomass) technologies. Therefore, 1st-generation biofuels can be substituted for fossil fuels. However, especially under the LowTech scenarios, the efficiency of biomass conversion is assumed to be low, i.e. at current level, which leads to a relative low elasticity between fossil and biomass energy inputs. The values of the elasticity of substitution are taken from Birur *et al.* [2007].

To identify the effect of an enhanced use of biomass inputs we also ran all four main scenarios without a mandatory blending obligation for biomass use in the bio-based industries, i.e. petrochemicals, electricity and chemicals. It should be mentioned that even without a mandatory blending, the use of biomass inputs changes due to changes in relative prices (biomass crops vs. fossil fuel). Especially in the HighTech scenarios, it can be assumed that the required subsidies for the biomass use will strongly decline due to the high technological progress we assume for these scenarios.

To illustrate the long-term development the results are presented for the initial period, for 2010, 2020 and 2030.

2.2 Scenario results

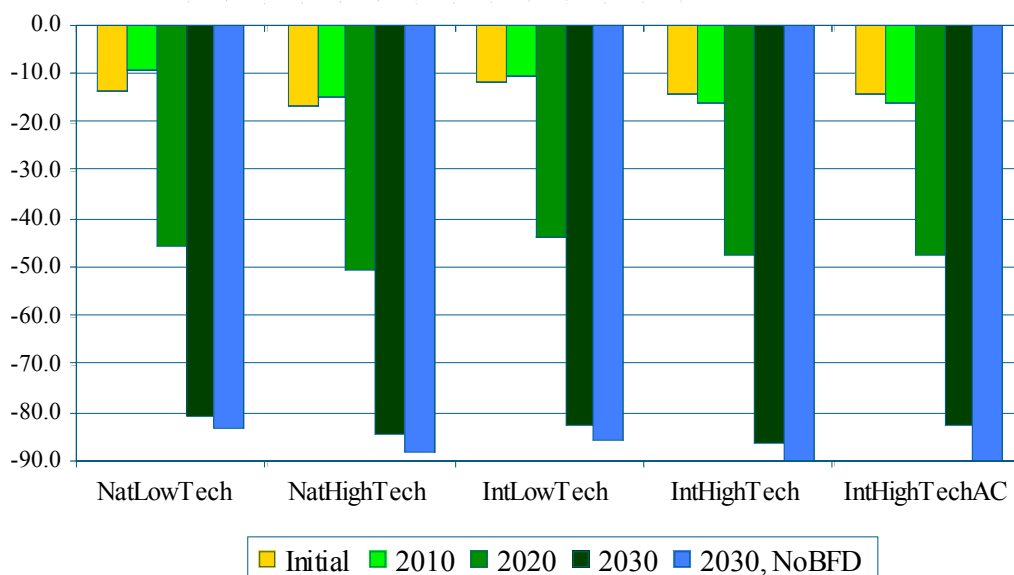
Under all scenarios calculated for this study, the Dutch trade balance deteriorates significantly, see Figure 3. This decline is triggered by a strong increase in GDP and private income. In all scenarios Dutch GDP is projected to increase by around 60% between the initial period (2006) and the final projection year, 2030. Imports increase at a similar rate while overall exports increase by just 12%. As a

consequence of this general macro-economic development, which is not related to any specific tendency of the 'bio-based economy', the Dutch trade balance becomes increasingly negative.

However, with an enhanced biomass utilisation, the increasing trade deficit is partly compensated due to a substitution of fossil energy imports by the increasing use of biomass in the bio-based industries. Under the IntHighTechAC scenario this effect is most visible. Under the scenarios where the use of biomass is not enforced (NoBFD), the resulting trade balance is projected to be more negative compared to the scenarios where biomass use is implemented as mandatory.

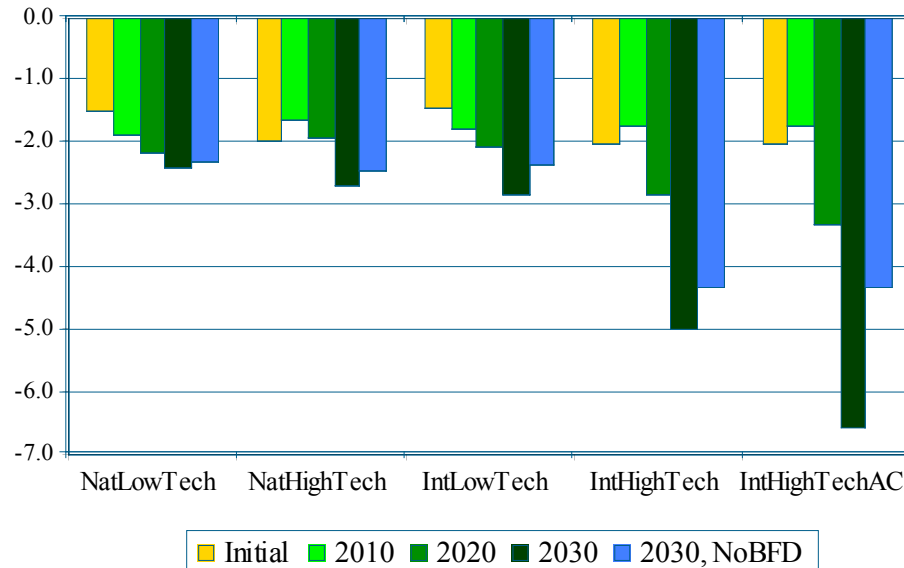
It should be mentioned that, even without an enforced use of bio-energy crops through a mandatory blending, the shares of bio-energy inputs increase in fuel consumption for transportation purposes and in electricity.

Figure 3: Balance in total trade, in bln €, the Netherlands



The Dutch balance in trade with biomass crops also declines, see Figure 4, which presents the development of the aggregated Dutch trade balance in biomass crops, regardless of whether these products are used for food, feed purposes or as inputs in the bio-based industries. Under the two 'Int' scenarios (with open trade with all trading partners), Dutch biomass imports increase and the trade balance becomes more negative, especially in the IntHighTech scenario, where biomass use is high. This strong increase is also due to relative high biomass blending shares modelled especially under the IntHighTech and IntHighTechAC scenarios. With the lower trade deficit under the 'NoBFD', where biomass use is not modelled as mandatory, the imports are projected to be lower in all scenarios, see Figure 4.

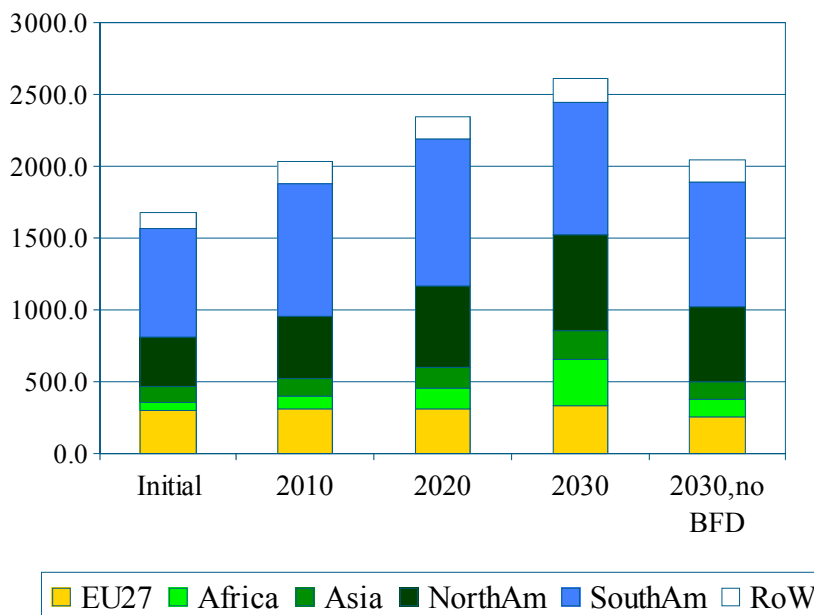
Figure 4: Trade balance in biomass crops, in bln €, the Netherlands



The regional composition of trade in biomass crops is depicted in Figures 5 and 6. Figure 5 presents the development under the NatLowTech scenario, which serves as a kind of reference scenario between the initial period and 2030. The projection indicates that the majority of biomass crop imports is coming from the other EU Member States as well as from North and South America. With an increase in imports of biomass crops, the additional demand for biomass will come mainly from those regions with a relative large land reserve. Under all model scenarios the land reserve in EU-15 countries is rather limited, while in the North American countries land reserves are higher compared to the EU-15 Member States. The largest reserve in agricultural land is projected for the countries in South America. Consequently, additional demand for biomass crops imported to the Netherlands is projected to come from South American countries, especially Brazil.

Under the 'International' scenario it is assumed that biomass imports come particularly from the non-EU countries. Technically this assumption is implemented with higher trade elasticities for the 'International' scenarios than for the 'National' scenarios. Therefore, imports from outside EU are not restricted under the 'National' scenarios. Due to high trade elasticities under the 'International' scenarios producers strongly react to relative changes in domestic vs. world prices. This set-up also explains the strong increase in non-EU imports under the IntHighTech scenario.

Figure 5: Imports of biomass crops under NatLowTech, in mln €, the Netherlands



While Figure 5 shows the development of total biomass crop imports, the composition of the utilisation of these crops within the Dutch economy significantly changes over time. In the initial situation biomass imports, as an input to the bio-based economy, contribute only around 3% of total imports of these products. In 2030, however, almost half of the total biomass imports are used as an input to the bio-based sectors in the Netherlands.

The differences in biomass imports between the different scenarios, presented in Figure 6, are due to the different blending shares in the scenarios calculated for this study. In the IntHighTech and IntHighTechAC scenarios, with blending shares of 60% and 75%⁸ in transportation fuels, respectively, imports of biomass are projected to increase to more than 5 billion €. Most of this additional import is coming from South American countries, see Figure 6.

8 The GTAP-based model aggregates all petroleum products in one sector (Petrol). Because both transport fuels as chemical feedstocks are aggregated to one commodity, replacement of naphtha for ethylene production by biomass implies a higher biomass blending share in the Petrol sector. This is translated in an additional bio-based blending share (15% points), i.e. demand for ethanol for transport fuels in the LEITAP model.

Figure 6: Imports of biomass crops in 2030 under different scenarios, in mln €, the Netherlands

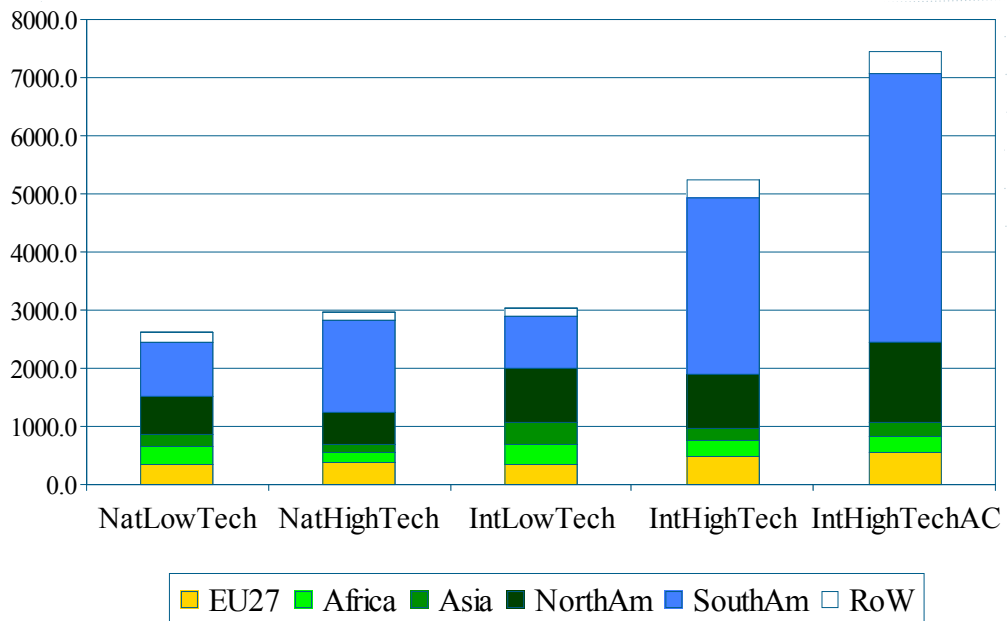


Figure 7a shows the development of the total production of biomass crops (grain, oil-seeds and woody crops) regardless of final uses (food, feed, and biomass) under the four main scenarios. It becomes clear that even under high blending rates – projected under the IntHighTech scenarios, Dutch agriculture does not expand production at a high rate. This small expansion is due to restrictions on agricultural land-use in the Netherlands. The higher biomass use under mandatory blending will lead to an additional crop production of around 150 million €. As already mentioned for the development of imports of biomass crops, the use of biomass crops in the bio-based industries increases even without mandatory blending. This endogenous development is due to the fact that, until 2030, the development of *relative* prices is in favour for biomass crops, i.e. prices for biomass crops are projected to decline *relative* to fossil energy prices. Therefore, the use of biomass inputs as a substitute for fossil energy becomes more and more profitable.

Figure 7b – the right-hand graph – presents the share of domestic crops used in the bio-based industry in total domestic crops production. It should be mentioned that these numbers are relative to initial 2006 values. Showing the development relative to the initial situation presents both the autonomous trend to use more biomass and the enforced biomass use due to mandatory blending targets. As a general result: 2/3 of the biomass crop demand is related to mandatory targets, while 1/3 is related to autonomous trends which occur also without mandatory blending targets.

Figure 7a: Production of biomass crops, in bln €, the Netherlands

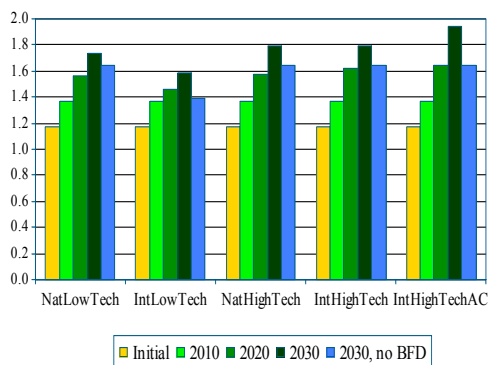
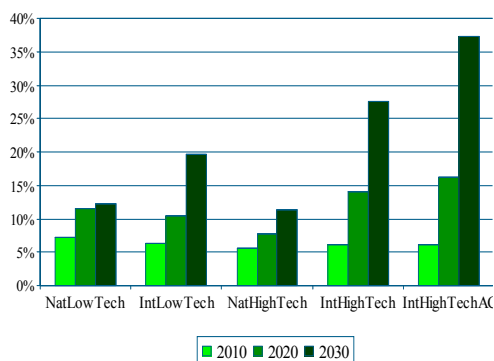


Figure 7b: Share of biomass crops use for bio-based Industries, in %



The share of domestically produced biomass crops in total biomass crop production strongly depends on the assumed blending target. Under the IntHighTechAC scenario around 37% of total Dutch biomass crop production is projected to be used as inputs to the bio-based industry, Figure 7b.

Figure 8a: Income in bio-based industries, in mln €, the Netherlands

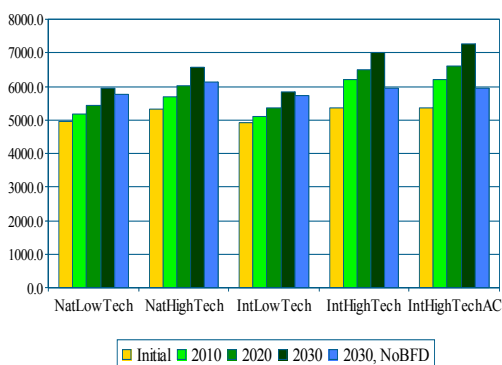
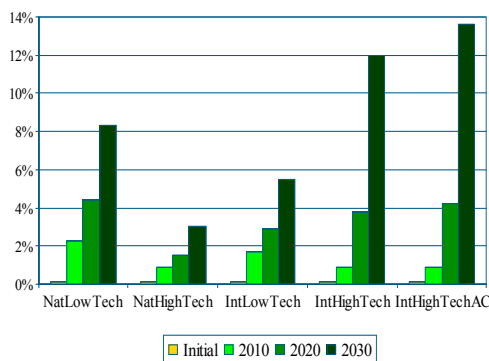


Figure 8b: Share of employment in bio-based industries, in %



Under all scenarios the aggregated income in the petrol, electricity and the fine chemical industries is projected to increase, see Figure 8a. This figure includes the income generated in both the ‘non bio-based’ and the bio-based part of the respective industries.⁹ Amongst the three bio-based sectors covered in this study, under the IntHighTech scenario 75% of the total income presented in Figure 8a is allocated to the electricity sector, 24% for the petrol and 1% to the fine chemicals

⁹ Sectoral income is defined as the sum of all payments to factors employed in each sector. These payments include salaries, capital user costs and land rents which occur in agriculture only. Please note that installation and investments costs of new technologies are not included in these income figures, displayed here.

sector.¹⁰ In the IntHighTechAC scenario these shares change and only 60% of total income is generated in the electricity sector, 30% in the petrol sector and 10% in the chemical sector.

Higher blending rates will lead to an increase in biomass inputs at the expense of fossil energy inputs. The question remains: Will this development towards a more bio-based economy also lead to an increased income in the bio-based industries? The scenario results indicate that, with a shift towards a more bio-based economy, total income in the bio-based sectors might be up to 1 billion € higher compared to scenarios without an enforced use of biomass, see Figure 8a. This strong income effect is projected only for the IntHighTech scenario, which assumes very high utilisation of biomass in 2030 under very favourable conditions. Under a more conservative scenario, assuming a low rate of technology development, such as the IntLowTech scenario, the projected additional income is only 100 million €. Although, depending on the scenario, 60-75% of total income is allocated to electricity, the additional income from enhanced bio-based activities industries is projected to be allocated differently. Of the 1 billion € additional income under the IntHighTech scenario, 19% is created in the electricity production, 78.5% in petrol production and 2.5% in the (fine) chemicals industries. Under the IntHighTechAC scenario the shares are 11% in electricity, 76% in the petrol and 14% in the chemical sectors.¹¹ These numbers are different to the bottom-up analysis conducted in Part I of this report. The structure of employment in the bio-based sectors is also affected by the shift towards a more bio-based oriented economy. With high blending shares under the IntHighTech scenario, almost 12% of total employment in the petrol, fine chemical and electricity sector is working in the bio-based part of these industries, see Figure 8b. With 13.8% under the IntHighTechAC scenario, this share is even higher.

Similar developments are projected for the additional income for Dutch agriculture. Compared to the scenarios without enforced biomass use (NoBFD scenario), the enhanced biomass use generates an additional income between 50 and 140 million € in Dutch farming, see Figure 9a. This development is also mirrored by the share of agricultural employment in the production of biomass crops, see Figure 9b. Depending on the projected scenario, between 3% and 5% of agricultural employment will be related to the production of biomass crops used in the bio-based sectors.

It is important to mention that total agricultural employment is projected to decline

10 The high share in electricity is due to the fact that the electricity sector in the top-down model includes both electricity production and distribution.

11 This lower share in the IntHighTechAC scenario (compared to the IntHighTech scenario) is related to the fact that the substitution of natural gas by syngas mainly affects the gas sector and not the chemical industries. Biobased synthesis gas requires high capital investments and skilled labour similar to 2nd generation biofuels. These results indicate that further research is required in order to address for these factors in the macro-economic model.

strongly in all scenarios. Compared to current levels, employment in Dutch agriculture in 2030 is projected to be half the current level. This strong decline is mainly due to a high growth in labour productivity, which boosts the structural change in Dutch farming. The projected increasing share of employment for biomass crops the bio-based economy is not able to alter this trend, but it will ease the burden of structural changes in Dutch agriculture.

Figure 9a: Agricultural income in biomass production, in mill. €, Netherlands

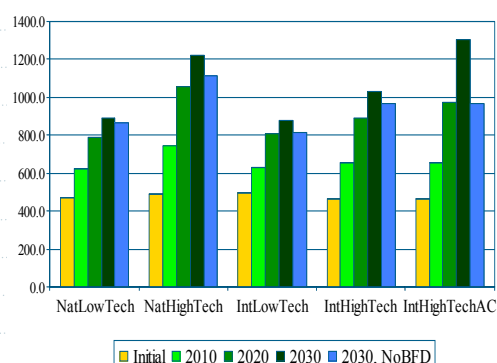
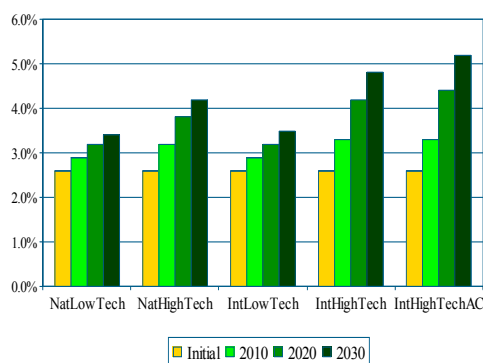


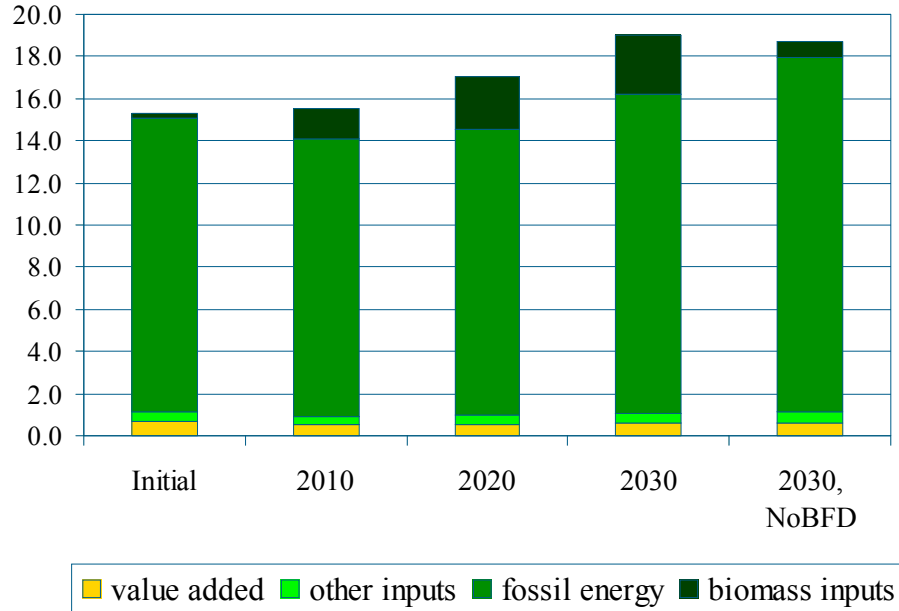
Figure 9b: Share of employment in biomass production, in %



The development of the cost structure of the Dutch petrol industry under the NatLowTech scenario is presented in Figure 10. This figure describes total production of the Dutch petrol industries, i.e. production for domestic use and for exportation. Please note that the blending shares are assumed for the entire EU and that exported petrol also meets the blending requirements.

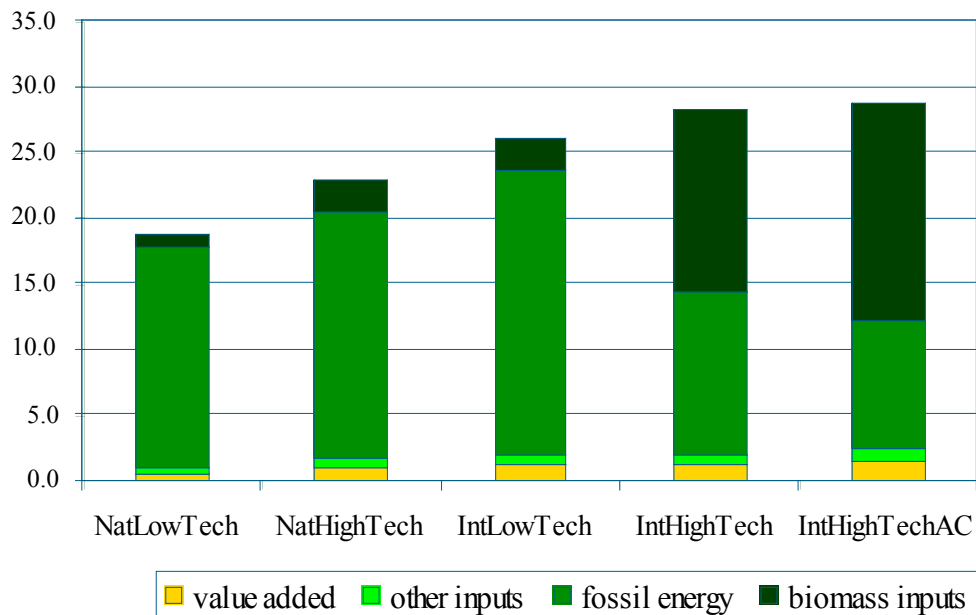
While biomass use is relatively low in the initial situation the relative importance grows until 2030. Even without enforced biomass use the utilisation of biomass increases due to the change in relative prices between biomass and fossil inputs. The question, if petrol is mainly based on fossil energy inputs (as modelled in NoBFD scenarios) or produced with higher biomass shares, this has only limited impact on the total added-value generated in the petrol sector, (compare the last two columns in Figure 10).

Figure 10: Cost structure in petrol sector, in bln €, the Netherlands under NatLowTech scenario



With relatively low blending shares under the NatLowTech scenario the share of biomass use significantly increases in different scenarios and under the IntHighTech (IntHighTechAC) scenario, 60% (75%) of transportation fuel is based on biomass inputs, see Figure 11. Please note that the shares presented in Figures 10 and 11 refer to the value share of the respective inputs and not to the volume share.

Figure 11: Cost structure in petrol sector under different scenarios, in 2030 in bln €, the Netherlands



The Dutch petrol industry is highly integrated into the single European market and a large share of crude oil, which is imported, then processed in the Netherlands, before being exported to other EU Member States. The following two graphs illustrate the trade structure of the Dutch petrol sector under the NatLowTech scenario.

Figure 12a: Trade in crude oil and petrol, in mill. €, the Netherlands (NatLowTech scenario)

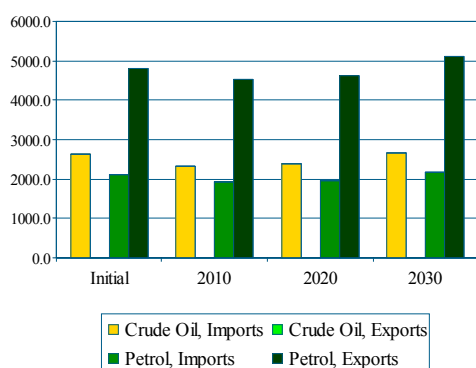


Figure 12b: Production and exports in petrol, in mill. €, the Netherlands (NatLowTech scenario)

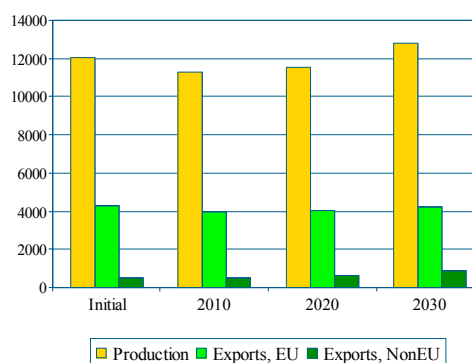
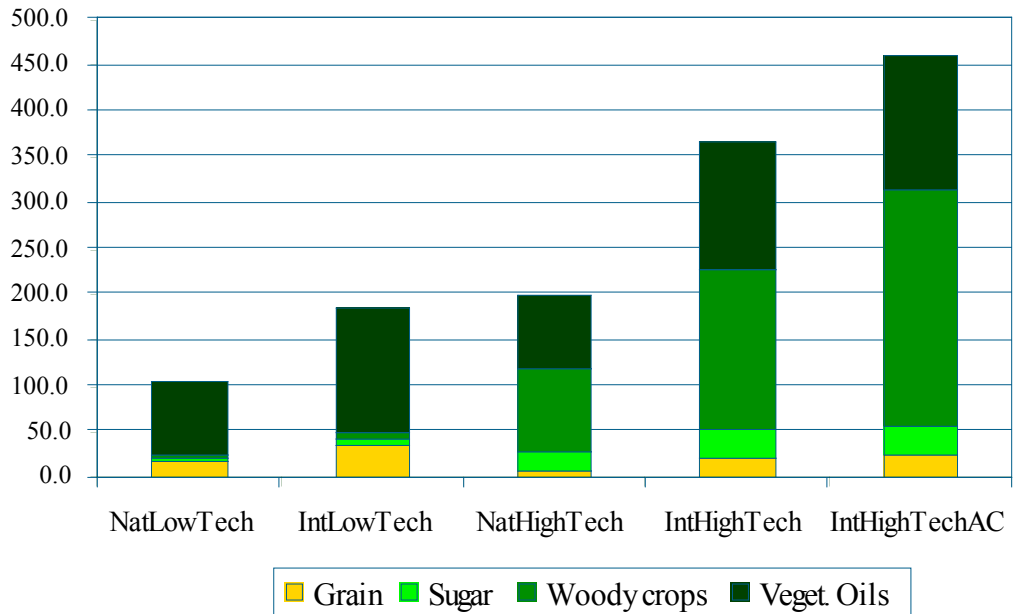


Figure 12a shows the large trade surplus in Dutch petrol trade. Around 50% of total Dutch petrol production is exported after processing, see Figure 12b. Figure 12a also shows that imports and exports of oil and petroleum products increase at almost the same magnitude. Therefore the strong increase in the Dutch trade deficit, as described above, is not related to the petrol sector.

Figure 13 illustrates the composition of biomass inputs in the Dutch petrol sector in terms of energy value of the various inputs. These numbers show how the estimated amount of biomass inputs from the bottom-up process are integrated into the macro-economic model. The total amount of biofuel crops is determined by two factors: a) the autonomous trend towards a bio-based economy and b) by an enforced biomass use due to blending targets of biomass use. The first effect is induced by the change in the relative prices between biomass and fossil energy.¹² As outlined already in the report concerning the bottom-up approach, the composition is changing. Under the LowTech scenarios 1st-generation biomass crops (domestic and imported) dominate the use of biomass crops, while under the HighTech Scenarios the share of 2nd-generation biomass (woody-crops) becomes more important. These numbers are also reflected by the outcome of the macro-economic model; see first two columns in Figure 13a. Figures 13b and 13c show the composition of biomass inputs in the electricity and the fine chemical sectors, respectively.

12 The average change in relative prices between (aggregated) biomass and fossil energy under the NoBFD scenarios is around -30% under the NatLowTech scenario.

Figure 13a: Composition of biomass inputs in petrol sector, in 2030 in PJ, Netherlands



It should be noted that – as already explained above – ethanol is not modelled as an individual product in the current version of LEITAP. Therefore, the increased use of sugar under the both HighTech scenario may be interpreted as a proxy for the increase in ethanol production based on 1st-generation crops. Comparing the outcome of the macro-economic model with the estimate of the bottom-up approach one could expect a larger share of 2nd-generation biomass, especially for the HighTech scenario. Under the IntHighTech scenario oil-seeds still contribute a significant amount to total biomass use in the petrol industry.

Figure 13b: Composition of biomass inputs in electricity, in 2030 in PJ, the Netherlands

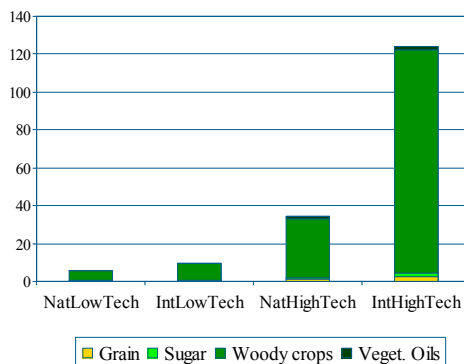
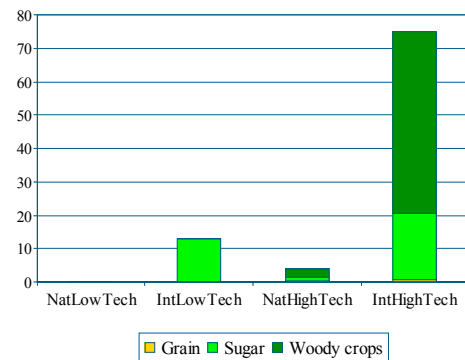


Figure 13c: Composition of biomass inputs in fine chemicals, in 2030 in PJ, the Netherlands



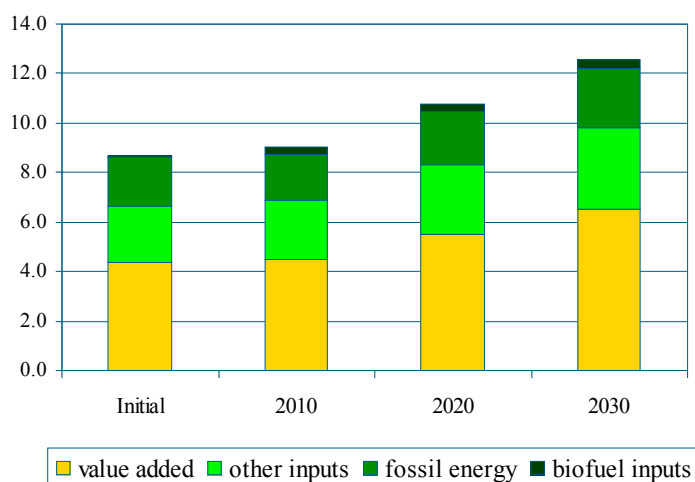
This outcome is explained by the underlying technology assumption of the LEITAP model. Due to the fact that technology changes follow a path of substituting an existing technology (based on 1st-generation biomass) with a new and modern one (based on 2nd-generation biomass) the model seems to react a bit ‘sticky’. Thus, LEITAP does not allow for drastic changes in the composition of the feedstock in the

biomass sector.¹³ Thus, even in the IntHighTech scenario, 1st-generation biomass crops, such as oil-seeds, continue to contribute to biofuel production at a significant level. Based on the economic model applied for this study, the achieved results indicate that an economy fully based on 2nd-generation biomass inputs would require a longer timeframe for adjustment.

Due to the remaining use of 1st-generation biomass crops even under the HighTech scenario some subsidies are still necessary to meet the blending target. The 'persistent' contribution of 1st-generation biomass also has consequences for the calculation of social costs of an enforced utilisation of biomass crops in the bio-based industries, see Table 1. The compositions of biomass use in the two other bio-based industries – electricity and fine chemicals – are more biased towards a single input (woody crops) in electricity, and a mix of sugar and woody crops in fine chemical industries.

Similar to the development of biomass use in the petrol sector (Figure 10), the electricity sector uses only a small amount of biomass inputs under the NatLowTech scenario, see Figure 14. In 2030 it is assumed that 5.7% of total energy inputs in the Dutch electricity production are based on biomass inputs. It should also be mentioned that the composition of the electricity sector differs significantly from the petrol sector. In the electricity sector value added represents the largest cost shares, with more than 50% in total costs, which also contributes to the large share of electricity in the aggregated bio-based sectors.

Figure 14: Cost structure in electricity sector, in bln €, the Netherlands under NatLowTech scenario



For the other three scenarios, biomass inputs will not dominate the demand of

13 Other modelling approaches such as a linear-programming model would allow for these immediate shifts in the mix of 1st- and 2nd-generation biomass. However, these modelling approaches neglect other important features such as the endogenous development of relative prices between different inputs.

energy-related inputs in the electricity sector, see Figure 15. Under the IntHighTech scenario, biomass inputs are assumed to contribute by almost 1/3 to total energy-related input demand.

Figure 15: Cost structure in electricity sector under different scenarios, in 2030 in bln €, the Netherlands

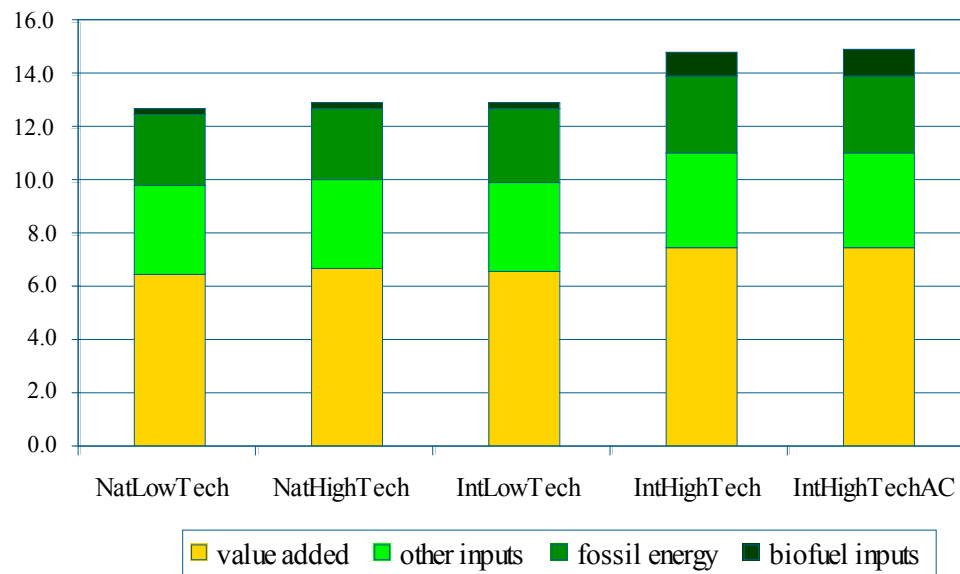


Table 1 presents the burden to taxpayers of an enforced use of biomass in the Dutch petrol industry. With around 14 billion litres, the amount of total petrol consumed is very similar between the different scenarios and the differences are due to different petrol prices. However, with different blending rates the amount of biofuels (including the naphtha substitution) produced in 2030 varies from 1.4 billion in the NatLowTech to 8.6 billion litres in the IntHighTech scenario, and 10.6 billion litres under the additional IntHighTechAC scenario.

Table 1: Tax burden of using biomass inputs for liquid petrol production, 2030 in the Netherlands

	NatLowTech	IntLowTech	NatHighTech	IntHighTech	IntHighTechAC
Fuel consumption (mill. litres)	14218	14035	14364	14286	14160
Substitution share in %	10	20	20	60	75
Amount of biofuel (mill. litres)	1422	2807	2873	8572	10620
Subsidies, million €	578	347	828	293	421
€/litre of biofuel	0.407	0.124	0.288	0.034	0.040

With these different volumes of biofuels produced, the absolute spending in subsidies is also very different and depends on the assumed technology. The highest spending on subsidies to compensate petrol producers for the (otherwise) unprofitable product is projected for the NatHighTech scenario where annual taxpayers' burden of biomass use in the petrol industry is more than 800 million €. To compare the costs across different scenarios we calculate the required subsidies

of producing 1 litre of biofuel. The results show a strong decline in subsidies per litre of biofuel in moving from LowTech to HighTech scenarios and in moving from national to international scenarios. As discussed already for Figure 13, under the IntHighTech scenario, subsidies of 0.034 €/litre of biofuel are still required due to the (remaining but declining) use of 1st-generation biomass crops. Similar results are achieved for the IntHighTechAC scenario, where blending rates are at the 75% level. Here the required subsidy per litre of biofuel is 0.04 €/litre, which is higher compared to the IntHighTech scenario. The questions (whether 2nd-generation biomass crops still needs subsidies to be profitable compared to fossil energy) strongly depends on the technology and the prices for fossil energy. Under the very optimistic assumptions of the IntHighTech scenario the scenario results indicate that 2nd-generation biomass becomes competitive at a price level of 75 US\$/bbl (in 2006 US\$).

Results of the Sensitivity Analysis

Because the market for bioenergy and bio-based materials is surrounded by uncertainties, the sensitivity analysis shows the impact of the most crucial assumption for this study: the development of the world market price of fossil energy. Two additional scenarios have been calculated with regard to the development of world fossil energy prices. Under the scenario IntHighTechHigh, the increase in fossil energy prices is 50% (which is 112 USD/bbl, in 2006 USD) higher than in the reference IntHighTech scenario. Under the scenario IntHighTechLow, fossil energy prices are assumed to be 25% lower compared to the IntHighTech scenario, which is 56 USD/bbl, in 2006 USD. To identify the impact of different developments of fossil energy prices in the IntHighTech scenario all other assumptions, including the blending rates of biomass utilisation in the bio-based sectors, are kept unchanged in the two sensitivity scenarios.¹⁴ The following graphs only show those results that indicate a significant difference in the results of the two sensitivity scenarios compared with the IntHighTech scenario.

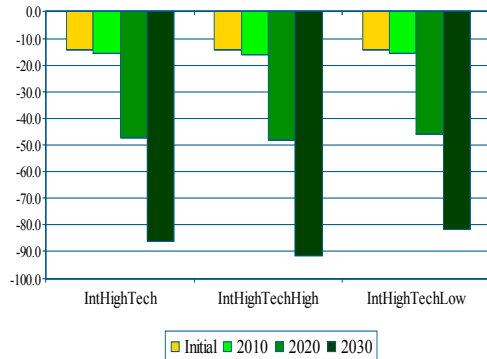
Under higher fossil energy prices the Dutch trade balance will further deteriorate due to higher expenses for energy import, while lower energy prices will lower the Dutch trade deficit, see Figures 16a and 16b.

Figure 16a: Sensitivity scenarios: Balance in total trade,

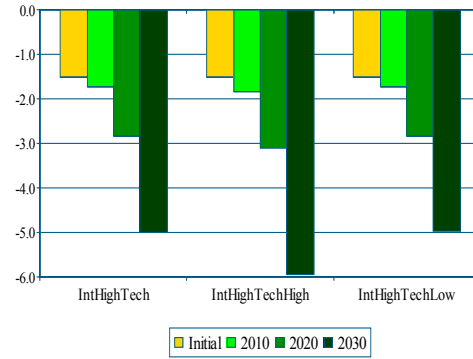
Figure 16b: Sensitivity scenarios: Balance in

14 It should be mentioned that, due to limited amount of time and space, the sensitivity scenarios have been calculated only for the IntHighTech scenario and not for all other three main scenarios presented in the previous chapter.

in bln €, the Netherlands



biomass crop trade, in bln €, the Netherlands

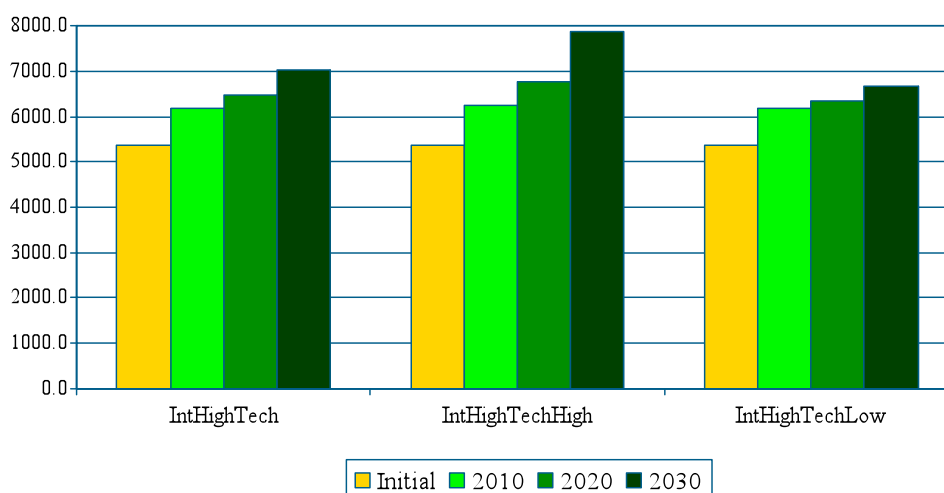


Under the IntHighTechLow sensitivity scenario the Dutch balance in trade with biomass crops change only little relative to the IntHighTech scenario, see Figure 16b. However, with higher fossil oil prices, more biomass crops will be used compared to the IntHighTech scenario, i.e. with higher fossil energy prices biomass use becomes more profitable. This result indicates that with lower fossil energy prices, the blending shares applied in the scenarios remain 'binding' constraints. The lower profitability of biomass crops – due to lower fossil energy prices – will lead to higher subsidies on biomass inputs, even under the IntHighTech scenario, see below.

Due to the limited availability of agricultural land, Dutch agriculture does not benefit from this increase in biomass demand in the bio-based sectors. The additional demand is almost entirely covered by an increase in biomass imports, with South America as the most important origin for imports.

The increase in demand of biomass crops in the bio-based sectors positively affects income generated in those sectors, see Figure 17. Under the IntHighTechHigh scenario, total income in the bio-based industries is around 800 million € higher compared to the IntHighTech scenario. Lower energy prices lowers total income in the bio-based sector, which is due to changes in the relative factor prices.

Figure 17: Sensitivity scenarios: Income in bio-based industries, in mln € the Netherlands



With a higher demand for biomass inputs in the bio-based industries the composition of biomass remains unchanged. However, the level of fossil energy prices determines the competitiveness of biomass inputs relative to fossil inputs in the bio-based sectors. The lower the fossil prices the more 'costly' is the use of biomass inputs. Without blending shares which are set as minimum blending requirements for the bio-based sectors, less biomass would be used, i.e. additional subsidies are required to maintain the blending shares at their minimum level. Higher fossil energy prices increase the relative competitiveness of biomass inputs. The sensitivity analysis shows that under the IntHighTech scenario with high fossil energy prices the required subsidies become very low, see Table 2.

Table 2: Sensitivity analysis: Tax burden of using biomass inputs for liquid petrol production, 2030 in the Netherlands

	IntHighTech	IntHighTechHigh	IntHighTechLow
Fuel consumption (mill. litres)	14286	13286	14786
Substitution share in %	60	62	60
Amount of biofuel (mill. litres)	8572	8237	8872
Subsidies, million €	293	121	521
€/litre of biofuel	0.034	0.015	0.059

The sensitivity analyses shows that the qualitative results are not fundamentally different, but the extent of the effects can change substantially. The sensitivity analysis shows that, despite the ambitious biomass blending targets in the IntHighTech scenario, at crude oil prices of 112 USD/bbl, biomass becomes competitive and increases the demand for bioenergy crops. The results, i.e. bio-based production, however are still in line with the baseline situation. The required subsidies for bio-based substitution of fossil energy carriers is sensitive to fossil energy prices as displayed in Table 2.

SUMMARY

The macro-economic analyses results cover impacts of the different bio-based scenarios on the Dutch trade balance, GDP, sectoral effects (in particular agriculture, energy and chemical), employment, all compared to the baseline development where only a low share of biomass use (mainly for energy) is included. To summarise the results of the quantitative analysis the following conclusions can be drawn:

- All bio-based scenarios have a positive effect on the trade balance of the Netherlands. In 2030 the net (positive) impact compared to the baseline developments simulated by LEITAP are about 2000 (LowTech scenario) to 4000 (HighTech scenario) million € per year.
- Imports of biomass (and biofuels, especially ethanol; depending on the scenario) are substantial, varying between over 2600 million € (NatLowTech) up to 7400 (IntHighTechAC) million € annually. South America, in particular, is a likely major supplier.
- The production of biomass used in the Dutch bio-based economy varies in value between some 180 Million € (IntLowTech) and almost 720 million € (IntHighTechAC). This is substantial, but also reflects the relatively modest role of national biomass resource production compared to imports.
- In terms of employment generated, the share of employers working in the bio-based ‘part’ of the bio-based sectors (fuel, electricity and fine chemicals), the total employment in these three sectors remains relatively stable over the projected period, but the increasing share in employment in the ‘bio-based part’ indicates a growing importance of the bio-based economy for those sectors. The results show that, with a shift towards a bio-based economy, agricultural employment will continue to decline. However, a growing demand for biomass will slightly dampen this structural change in agriculture.
- The macro-economic modelling results confirm the large shares of 1st-generation biofuels for the LowTech scenarios as defined by the bottom-up approach. The use of lignocellulosic biomass (both for fuels and for biomaterials) covers over half the total demand for the HighTech scenarios in 2030.
 - This result, different from the bottom-up scenarios, where this share is even higher, is explained by the incorporation of continuous functions in the modelling framework that basically take into account the lifetime of investments and reasonable rates of change in production capacity over time.
 - With the base scenario assumptions, the share of lignocellulosic-based biomass applications will increase further after 2030 and overall costs will go down. Furthermore, this share is sensitive to the rate of technological progress (learning) of new technologies. A more conservative progress would lead to lower shares and vice versa.
- Required support levels to ensure the realisation of the projected shares of biofuel shares in the different scenario’s differ strongly between the scenarios (the following data all relate to a reference oil price of 75 US\$/bbl (in 2006 US\$):
 - The NatLowTech scenario requires (for a modest share of 10%) a subsidy of about half a billion per year (and around 0.40 €/litre of biofuel).

- For IntLowTech this is reduced to 350 million € annually and 0.12 €/litre of biofuel for a 20% share (especially due to lower costs of imports such as ethanol). Costs increase again for the NatHighTech scenario (due to higher feedstock costs).
- IntHighTech achieves the 60% share of biofuels in 2030 with some 300 million € per year subsidies (and a low 0.034 €/litre biofuel subsidy). This subsidy is only required for the 1st-generation biofuel part and, to some extent, for 2nd-generation biodiesel; in this scenario competitive production costs are achieved for 2nd-generation ethanol production, given the technology assumptions and base oil price of 75U\$/bbl.
- In addition to the IntHighTech scenario, the IntHighTechAC scenario also includes bio-based production of natural gas and petroleum products and in both the specialty and bulk chemical industries. Under the (extreme) high blending shares assumed under IntHighTechAC imports of biomass are projected to increase to more than 5 billion €, with most of these imports coming from South American countries. Additional income and employment under the IntHighTechAC scenario are mainly created in the petrol sector; while around ¼ is generated in the electricity and chemical sectors.
- These results are highly sensitive to the oil price; with lower oil prices, required support increases and vice versa. In addition, the scenarios assume a fixed (and high) diesel demand in the transport sector. If this could be replaced by 2nd-generation bioethanol or cheaper synfuels than Fischer-Tropsch diesel (such as methanol or DME), costs would go down and be competitive at the 75 U\$/barrel reference oil price. However, this also implies more adjustment investments in the transport sector (e.g. engine adjustments, fuel distribution).
- Shares of additional income across the bio-based industries in 2030 for the IntHighTech Scenario) due to biomass expansion amount to 19% for electricity production using biomass, 78.5% for production of biofuels and 2.5% due to the production of the assumed biomass-derived chemicals.

REFERENCES

Birur, D.K., Hertel, T.W. and Tyner, W.E. (2007), *The Biofuel Boom: Implications for World Food Markets*. Paper presented at the Food Economy Conference, The Hague, Netherlands.

Burniaux, J.-M. and T.P. Truong (2002), *GTAP-E: An Energy-Environmental Version of the GTAP Model*. GTAP Technical Paper, No. 16. Revised Version.

CPB (2003), *Four Futures of Europe*, Netherlands Bureau for Economic Policy Analysis, the Hague, the Netherlands. See: <http://www.cpb.nl>

F.O. Licht (2007), *Licht Interactive Data*.

Huang, H., F. van Tongeren, F. Dewbre and H. van Meijl (2004), *A New Representation of Agricultural Production Technology in GTAP*. Paper presented at the Seventh Annual Conference on Global Economic Analysis, June, Washington, USA.

IEA – International Energy Agency (2008), *IEA Bioenergy Task 39 'Commercializing 1st and 2nd Generation Liquid Biofuels from Biomass'*. Various reports. (<http://www.task39.org/>)

Kopetz, H., J.M. Jossart, H. Ragossnig, Ch. Metschina, (2007), *European Biomass Statistics 2007*. A statistical report on the contribution of biomass to the energy system in the EU 27. European Biomass Association (AEBIOM), Brussels

Meijl, H. van, T. van Rheenen, A. Tabeau and B. Eickhout (2005), *The impact of different policy environments on land use in Europe, Agriculture, Ecosystems and Environment*, 114-1: 21-38.

Wageningen UR and Netherlands Environmental Assessment Agency (2007), *Eururalis 2.0*. A scenario study on Europe's rural Areas to support policy discussion.

Wielen, L. A. M. v. d., P. M. M. Nossin, et al. (2006). *Potential of Coproduction of Energy, Fuel and Chemicals from Biobased Renewable Resources*. Transition Path:3 Co-production of Energy, Fuels and Chemicals. Delft, Delft University of technology.

ANNEX

Table A1. Regional aggregation

Regions	Original GTAP v 6 regions
belu	Belgium; Luxembourg
dnk	Denmark
deu	Germany
grc	Greece
esp	Spain
fra	France
irl	Ireland
ita	Italy
nld	Netherlands
aut	Austria
prt	Portugal
fin	Finland
swe	Sweden
gbr	United Kingdom
euba	Estonia; Latvia; Lithuania
euis	Cyprus; Malta
cze	Czech Republic
hun	Hungary
pol	Poland
svn	Slovenia
svk	Slovakia
apeu	Bulgaria; Romania
reur	Switzerland; Rest of EFTA; Rest of Europe; Albania; Croatia
fsu	Russian Federation; Rest of Former Soviet Union
tur	Turkey
meast	Rest of Middle East
nafta	United States, Canada, Mexico
ram	Rest of North America; Colombia; Peru; Venezuela; Rest of Andean Pact; Argentina; Chile; Uruguay; Rest of South America; Central America; Rest of FTAA; Rest of the Caribbean
bra	Brazil
oce	Australia; New Zealand; Rest of Oceania
jp_ko	Japan; Korea
chi	China; Hong Kong; Taiwan; Rest of East Asia
ras	Indonesia; Malaysia; Philippines; Singapore; Thailand; Vietnam; Rest of Southeast Asia; Bangladesh; India; Sri Lanka; Rest of South Asia; Canada
naf	Morocco; Rest of North Africa
ssaf	Botswana; Rest of South African CU; Malawi; Mozambique; Tanzania; Zambia; Zimbabwe; Rest of SADC; Madagascar; Uganda; Rest of Sub-Saharan Africa
saf	South Africa

Table A2: Sector aggregation

Sectors in GTAP	Original GTAP v 6 sectors
pdr	Paddy and processed rice
wht	Wheat
grain	Cereal grains nec
oils	Oil seeds
sug	Sugar cane, sugar beet
hort	Vegetables, fruit, nuts
wdcrp	Woody crops (split out of 'other crops')
crops	Plant-based fibres; Crops nec.
cattle	Cattle, sheep, goats, horses; Wool, silk-worm cocoons; Meat: cattle, sheep, goats, horse
oap	Animal products nec; Meat products nec.
milk	Raw milk
dairy	Dairy products
sugar	Sugar
vol	Vegetable oils and fats
ofd	Food products nec.
agro	Fishing; Beverages and tobacco products
frs	Forestry
c_oil	Oil
petro	Petroleum, coal products
gas	Gas; Gas manufacture, distribution
coa	Coal
ely	Electricity
fchem	Fine chemicals (split out of 'chemicals, plastic and rubber')
bchem	Bulk chemicals (rest of 'chemicals, plastic and rubber')
ind	Minerals nec; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Mineral products nec; Ferrous metals; Metals nec; Metal products; Motor vehicles and parts; Transport equipment nec; Electronic equipment; Machinery and equipment nec; Manufactures nec.
ser	Water; Construction; Trade; Transport nec; Sea transport; Air transport; Communication; Financial services nec; Insurance; Business services nec; Recreation and other services; Public administration, defence, health and education; Dwellings

ANNEX I: MODEL DESCRIPTION: LEITAP – GLOBAL ECONOMY-WIDE PROJECTIONS

The analysis is carried out using an adapted version of the general equilibrium model of the Global Trade Analysis Project [GTAP, Hertel, 1997]. The first part of this section provides a brief overview of the standard GTAP model and the second part focuses on extensions. The standard model was improved with a new land allocation method that takes into account the degree of substitutability between different types of land-use. A new land supply curve allowing for conversion and abandonment of land is described in following section. The linkage of the adapted economic model to the IMAGE framework in order to model yields and feed efficiency rates is also described. Additionally, we used information from the OECD's Policy Evaluation Model (PEM) to improve the production structure and introduced an endogenous quota mechanism. This chapter finishes with a description of the projection methodology and a discussion of the database and the regional as well as sectoral aggregation of the model for this study.

Global Trade Analyses Project: the standard model

GTAP was initiated with the aim of supporting high-level quantitative analysis of international trade, resource and environmental issues in an economy-wide context. The GTAP project is supported by the leading international agencies (e.g. WTO, World Bank, OECD, and UNCTAD) in trade and development policy, as well as a number of national agencies with active research programmes on these issues. The GTAP project develops and maintains a database, a multi-region multi-sector general equilibrium model. It also provides training courses and organises an annual conference on global economic analysis. This project has grown rapidly since its inception in 1993. There is no doubt that the GTAP database and its associated modelling efforts represent a major achievement for advancing quantitative analysis of international trade, resource and environmental issues. The success of this approach is reflected in a high degree of academic recognition as well as the increasing usage for policy analysis by international and national agencies.

Standard model characteristics

There are basically two strands of quantitative modelling in policy analysis. One approach is to build issue-specific models, depending on the question at hand. These models will usually be capable of capturing many relevant aspects of one specific policy question, but are of less use in a different policy context. The other approach sets out to construct more general and flexible models, which do not necessarily attempt to capture all details but are flexible enough to allow elaborations in face of specific policy questions. The Global Trade Analysis Project (GTAP) provides such a modelling framework.

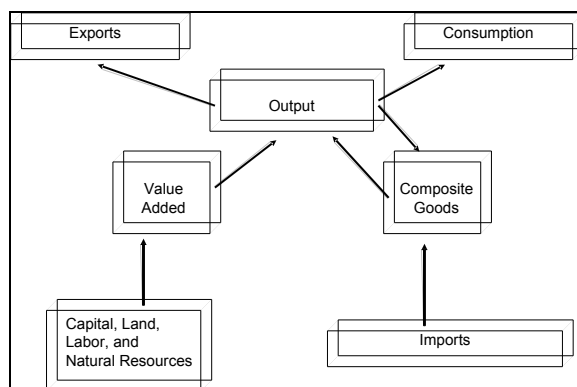
The standard GTAP model¹⁵ is a comparative static multi-regional general equilibrium model. In its standard version constant returns to scale and perfect competition are assumed in all markets for outputs and inputs. A detailed discussion of the basic algebraic model structure of the GTAP model can be found in Hertel [1997]¹⁶. In the GTAP model each country or region is depicted within the same structural model.

The general conceptual structure of a regional economy in the model is represented in Figure I.1. Within each region, companies produce output, employing land, labour, capital, and natural resources, and combine these with intermediate inputs. This output is purchased by consumers, governments, the investment sector, and by other companies. This output can also be sold for export. Land is only employed in the agricultural sector, while capital and labour (both skilled and unskilled) are mobile between all production sectors.

The model is characterised by an input-output structure (based on regional and national input-output tables) that explicitly links industries in a value-added chain from primary goods, through continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption. Inter-sectoral linkages are direct, such as the input of steel in the production of transport equipment, and indirect, via intermediate use in other sectors. The model captures these linkages by modelling the companies' use of factors and intermediate inputs. The most important aspects of the model can be summarised as follows:

- (i) it covers all world trade and production;
- (ii) it includes intermediate linkages between sectors.

Figure I.1: The flow of production



15 We deliberately refer to the 'standard GTAP model' as the model version that is supported by the GTAP consortium. GTAP users have developed numerous variations on the standard model. In this study we also make some modifications to the standard model. These are discussed more extensively in subsequent chapters.

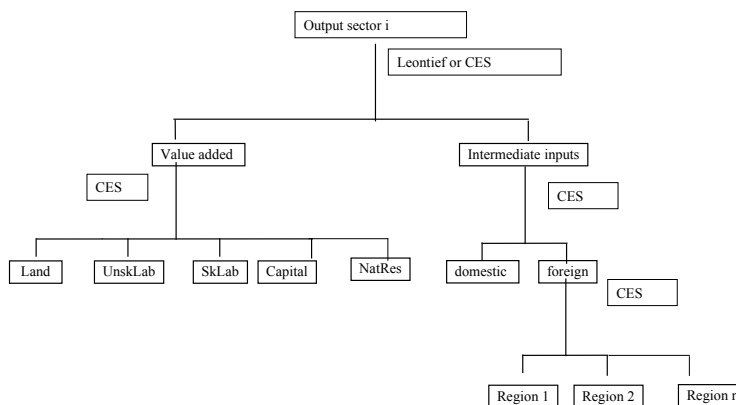
16 Or on the internet <http://www.agecon.purdue.edu/gtap/model/chap2.pdf>

The consumer side is represented by the regional household to which the income of factors, tariff revenues and taxes are assigned. The regional household allocates its income to three expenditure categories: private household expenditures, government expenditures and savings. For the consumption of the private household, the non-homothetic Constant Difference of Elasticities (CDE) function is applied.

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 to produce a single sectoral output. In the case of crop production, farmers also make decisions on land allocation. Intermediate inputs are produced domestically or imported, while primary factors cannot move across countries. Markets are typically assumed to be competitive. When making production decision, farmers and companies treat prices for output and input as given. The primary production factors land and capital are fully employed within each economy, and hence returns to land and capital are endogenously determined at the equilibrium, i.e. the aggregate supply of each factor equals its demand.

The production structure is depicted with a production tree with four nests (Figure I.2). The Leontief and the Constant Elasticity of Substitution (CES) functional forms are used to model the substitution relations between the inputs of the production process. In the output nest, the mix of factors and intermediate inputs are assembled together, forming the sectoral output. The functional form can be Leontief (fixed proportions) or CES. The substitution relations within the value added nest are depicted by the CES function. While labour and capital are considered mobile across sectors the Constant Elasticity of Transformation (CET) function is used to represent the sluggish adjustment of the factor land; i.e. land can only imperfectly move between alternative crop uses. The CES function is applied in the composite intermediate nest depicting the substitution between domestic and imported products. The last nest illustrates the relation between imports of the same item from different regions. The Armington approach treats products from different regions as imperfect substitutes.

Figure I.2: Production tree



Source: Hertel (1997)

Prices of goods and factors adjust until all markets are simultaneously in (general) equilibrium. This means that we aim for equilibria in which all markets are 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, though this does not preclude changes in gross capital flows. To summarise, factor markets are competitive, and labour and capital are mobile between sectors, but not between regions.

The GTAP model includes two global institutions. All transport between regions is carried out by the international transport sector. The trading costs reflect the transaction costs involved in international trade, as well as the physical activity of transportation itself. In using transport inputs from all regions, the international transport sector minimises its costs under the Cobb-Douglas technology. The second global institution is the global bank, which takes the savings from all regions and purchases investment goods in all regions depending on the expected rates of return. The global bank guarantees that global savings are equal to global investments. With the standard closure, the model determines the trade balance in each region endogenously, and hence foreign capital inflows may supplement domestic savings. The model does not have an exchange rate variable. However, by choosing as a numeraire an index of global factor prices, each region's change of factor prices relative to the numeraire directly reflects a change in the purchasing power of the region's factor incomes on the world market. This can be directly interpreted as a change in the real exchange rate.

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

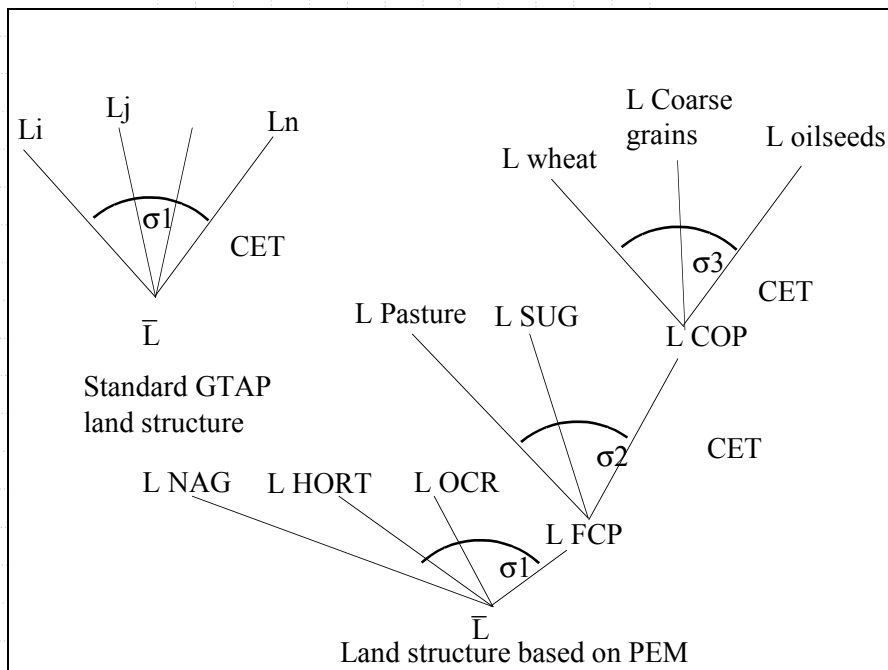
The GTAP model is implemented in GEMPACK – a software package designed for solving large applied general equilibrium models. A description of Gempack can be found in Harrison and Pearson [2002]¹⁷.

Various GTAP users have developed adaptations of the standard model. Such elaborations include increasing returns to scale and imperfect competition, dynamic equilibrium formulations and incorporation of non-continuous policy instruments such as the tariff rate quota that resulted from GATT Uruguay round, or production quota as applied in the European milk and sugar sectors. For a model version that uses both increasing returns and production quota, see Francois et al. [2002] and Francois et al. [2003].

Extensions to the standard GTAP model

For the purpose of this study, we have applied a special purpose version of the GTAP database and model, designed to make it more appropriate for the analyses of the agricultural sector. We use information from the OECD's Policy Evaluation Model (PEM) to improve the production structure.

Figure I.3: Land allocation 'tree'



Land allocation under the heterogeneity of land assumption:

The base version of GTAP represents land allocation in a CET structure (see left part of Figure I.3). It is assumed that the various types of land-use are imperfectly substitutable, but the substitutability is equal among all land-use types. We extended the land-use allocation structure by taking into account that the degree of substitutability of types of land differs between types [Huang et al., 2004]. We use the OECD's Policy Evaluation Model [OECD, 2003] structure, as it has more detail. 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, oil-seeds, sugar cane/beet and other agricultural uses). The lower nest assumes a constant elasticity of transformation between 'vegetable 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)¹⁸. The transformation is governed by the elasticity of transformation σ_1 . The FCP group is itself a CET aggregate of Cattle and Raw Milk (both Pasture), 'Sugarcane and Beet' (SUG), and the group of 'Cereal, Oil-seed and Protein crops' (COP). Here the elasticity of transformation is σ_2 . Finally, the transformation of land within the upper nest, the COP-group, is modelled with an elasticity σ_3 .

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 $\sigma_3 > \sigma_2 > \sigma_1$. 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 e.g. vegetables. The values of the elasticities are taken from PEM (OECD, 2003).

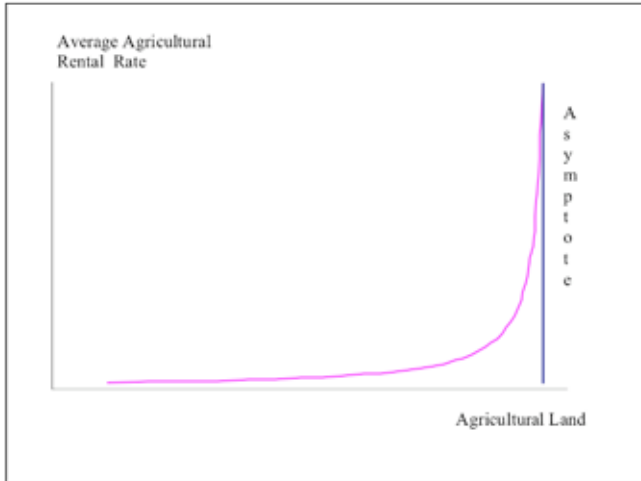
Variability of total area

In the standard GTAP model, the total land supply is exogenous. In this 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 rental rate [Meijl et al., 2006]. Land supply to agriculture as a whole can be adjusted as a result of idling of agricultural land, conversion of non-agricultural land to agriculture, conversion of agricultural land to urban use and agricultural land abandonment.

The general idea is that when there is enough agricultural land available, increases in demand for agricultural purposes will lead to land conversion to agricultural land and a modest increase in rental rates (see left part of Figure I.4). However, if almost all agricultural land is in use, then increases in demand will lead to increases in rental rates (land becomes scarce, see right part of Figure I.4). When land conversion and abandonment possibilities are low, the elasticity of land supply in respect to land rental rates are low and land supply curve is steep.

18 The non-agricultural commodities do not use land in the current GTAP model version. However, since land allocation in GTAP is defined over all commodities we add the non-agricultural land to the land allocation tree.

Figure I.4: Land supply curve: land conversion and abandonment.



We have assumed the following land supply function:

$$\text{Land supply} = a - b/\text{real land price} \quad (1)$$

where: a (>) is an asymptote, b is a positive parameter and the land supply elasticity E in respect of the land price is equal to

$$E = b/(a \cdot \text{real land price} - b) \quad (2)$$

We have calibrated the parameters a and b of the land supply function in such a way that it reproduces the GTAP land data for 2001. We have assumed the available agricultural land expressed by asymptote a is a sum of the agricultural land used currently in the production process and abandoned agricultural land. We have used the agricultural land changes per region for 2030 predicted by FAO as indicators of agricultural land availability. In general, we have assumed that higher predicted increase of the agricultural land means higher availability of abandoned agricultural land in the region. If the decrease of the agricultural land was predicted, we have assumed the scarcity of the agricultural land. Based on these considerations, we set the asymptote a .

Having asymptote a , we have used GTAP land-use data for 2001 as the land supply and observation for 2001 the initial GTAP real land prices equal to one to calculate the parameter b of the land supply function from the formula:

$$b = a - \text{Land supply} \quad (3)$$

and the land supply elasticity E in respect of the land price from formula (2).

Yield and feed conversion: linkage with IMAGE

Yields are only dealt with implicitly and the feed livestock linkage in the GTAP is calculated using input-output coefficients. To improve the treatment of these issues the adjusted GTAP model was linked with the IMAGE model [Alcamo et al., 1998; IMAGE Team, 2001]. The objective of IMAGE 2.2 is to explore the long-term dynamics of global environmental change. Ecosystem, crop and land-use models are used to compute land-use on the basis of regional production of food, animal products and timber, and local climatic and terrain properties. The production of food and animal products come from the adjusted GTAP model. The coinciding land-use change and greenhouse gas emissions are determined. The atmospheric and ocean models calculate changes in atmospheric composition by employing the emissions and by taking oceanic CO₂ uptake and atmospheric chemistry into consideration. Subsequently, changes in climatic properties are computed by resolving oceanic heat transport and the changes in radiative forcing by greenhouse gases and aerosols. The impact models involve specific models for sea-level rise and land degradation risk and make use of specific features of the ecosystem and crop models to depict impacts on vegetation and crop growth [Leemans and Eickhout, 2004]. Since the IMAGE model performs its calculations on a grid scale (of 0.5 by 0.5 degrees) the heterogeneity of the land is taken into consideration [Leemans et al., 2002].

Yields

In the adjusted GTAP model, yield is only dependent on a trend factor and on prices. The production structure used in this model implies that there are substitution possibilities among factors. If land gets more expensive, the producer uses less land and more other production factors such as capital. The impact 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 (the 'management factor' component).

First, the exogenous trend of the yield is taken from the FAO study 'Agriculture towards 2030' [FAO, 2003], in which the authors combined macro-economic prospects 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 this data is used as exogenous input for a first model run with the adjusted GTAP model. However, many studies indicated that this change in productivity would be enhanced or reduced by other external factors, of which climate change is mentioned most often [Rosenzweig *et al.*, 1995; Parry *et al.*, 2004; Fischer, 1996]. These studies indicated that increasing adverse global impacts because of climate change would be encountered with temperature increases above 3-4 °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 homogeneously distributed over each region.

In our approach, the exogenous part of the yield is updated in an iterative process with the IMAGE model. The output of GTAP used for the IMAGE iteration 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 on 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. Crop productivity is also affected by climate change. 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 additional changes in yields, which are given back to GTAP. A general feature is that yields decline if large land expansions occur since marginal lands are taken into production.

Segmentation of factor markets and endogenous production quota

If labour resources were perfectly mobile across domestic sectors, we would observe equalised 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, 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 [2001].

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 the 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 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 \bar{q} and output q , then the complementary problem can be written as:

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

and

$$\text{either } t > 0 \text{ and } r = 0 \\ \text{or } t = 0 \text{ and } r \geq 0$$

the quota is binding
the quota is not binding.

Projection methodology

The four analysed scenarios do not differ by macro-economic assumptions regarding the GDP, population and employment growth and productivity development in agricultural sector. Both approaches, the macro-economic and the bottom-up approach, are built on the same assumptions concerning these key economic parameters.

The economic consequences for the agricultural system, on the basis of the scenario assumptions outlined in the section above are calculated by GTAP. The output of GTAP is, among others, sectoral production growth rates, land-use and a management factor describing the degree of land intensification.

While key economic parameters are kept constant between the four scenarios, technologies differ, e.g. the substitutability between different energy inputs and the substitutability between inputs from different origin. Different values for these parameters reflect the differences in technologies outlined in Part I of the report.

REFERENCES FOR MODEL DOCUMENTATION

- Alcamo, J., Leemans, R., Kreileman, E. (1998), *Global Change Scenarios of the 21st Century. Results from the IMAGE 2.1 Model*. Elsevier, London.
- de Janvry, A. (1991), *The Agrarian Question and Reformism in Latin America*. Baltimore: Johns Hopkins University Press.
- Eickhout, B., van Meijl, H., Tabeau, A. and H. van Zeijts (2004), *Between Liberalization and Protection: Four Long-term Scenarios for Trade, Poverty and the Environment*, Presented at the Seventh Annual Conference on Global Economic Analysis, June, Washington, USA.
- Fischer, G., K. Frohberg, M.L. Parry, and C. Rosenzweig (1996), *The potential effects of climate change on world food production and security*. In: *Global Climate Change and Agricultural Production* [Bazzaz, F. and W. Sombroek (eds.)]. John Wiley and Sons, Chichester, United Kingdom, 345 pp.
- Food and Agriculture Organisation FAO (2003), *Agriculture towards 2030*. Rome.
- Francois, J., van Meijl, H. and van Tongeren, F. (2002), *Economic benefits of the Doha round for The Netherlands (also world and EU level)*, Agricultural Economics Research Institute, Report 6.03.02.
- Francois, J., van Meijl, H. and van Tongeren, F. (2003), 'Trade Liberalization and Developing Countries Under the Doha Round'. CEPR Discussion Paper no. 4032. London, Centre for Economic Policy Research. <http://www.cepr.org/pubs/dps/DP4032.asp>.
- Harrison, J. and Pearson, K. (2002), *Getting started with GEMPACK: Hands-on Examples*. Monash University.
- Hertel, T and Keening, R. (2003), "Assessing the Impact of WTO Reforms on World Agricultural Markets: A New Approach".
- Hertel, T.W., 1997. *Global Trade Analysis: Modelling and Applications*. In: Cambridge University Press, Cambridge.
- Hertel, T.W., Anderson, K., Francois, J.F., Hoekman, B. and Martin, W. (1999), *Agriculture and non-agricultural liberalization in the millennium round*, Paper prepared for the World Bank's integrated program of research and capacity building to enhance participation of developing countries in the WTO 2000 Negotiations, Presented at the Conference on Agriculture and the New Trade Agenda in the WTO 2000 Negotiations, Geneva, 1–2 October.

Huang, H., van Tongeren, F., Dewbre, J. and van Meijl, H. (2004), A New Representation of Agricultural Production Technology in GTAP, Paper presented at the Seventh Annual Conference on Global Economic Analysis, June, Washington, USA.

IMAGE-team (2001), The IMAGE 2.2 implementation of the SRES scenarios. A comprehensive analysis of emissions, climate change and impacts in the 21st century. RIVM CD-ROM publication 481508018, National Institute for Public Health and the Environment, Bilthoven, The Netherlands.

Leemans R, Eickhout B, Strengers B, Bouwman L, Schaeffer M (2002), The consequences of uncertainties in land use, climate and vegetation responses on the terrestrial carbon Science in China (Series C) Vol. (45), pp. 126-141

Leemans, R., Eickhout, B. (2004), Another reason for concern: regional and global impacts on ecosystems for different levels of climate change. Global Environmental Change Part A 14, 219-228.

Meijl, H. van, T. van Rheenen, A. Tabeau and B. Eickhout (2006), The impact of different policy environments on land use in Europe, Agriculture, Ecosystems and Environment, Vol. 114, pp. 21-38.

Netherlands Bureau for Economic Policy Analysis CPB, (2003), Sectoral TFP Developments in the OECD. CPB Memorandum No. 58. To be outlined

OECD (2001), Market Effect of Crop Support Measures. Paris.

OECD (2003), OECD Agricultural Outlook 2003 – 2008. Paris.

OECD, 2003, Agricultural Policies in OECD Countries 2000. Monitoring and Evaluation. Organization for Economic Co-operation and Development, Paris.

Parry, M.L., Rosenzweig, C., Iglesias, A., Livermore, M., Fischer, G. (2004), Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Global Environmental Change 14, 53-67.

Rosenzweig, C., M.L. Parry, and G. Fischer (1995), World food supply. In: As Climate Changes: International Impacts and Implications [Strzepek, K.M. and J.B. Smith (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 27-56.