Influence of the biobased economy on agricultural markets

Preparation of a modelling approach

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This report is the conclusion of research undertaken to better understand the impact of the developing biobased economy on agricultural land markets. This has involved understanding the true dimension of the biobased economy, namely the large range of products for which a biobased component exists or could exist, and in this regard the likely evolution in the substitution of elements produced from fossil oil. This research is also a first step to determine whether the overall result of the development of the biobased economy will be positive, negative or neutral for the Dutch economy as a whole.

Dit rapport vormt de conclusie van een onderzoek dat is uitgevoerd om meer inzicht te krijgen in de bio-economie die zich aan het ontwikkelen is op de markten voor landbouwgrond. Het ging onder andere om inzicht in de ware omvang van de bio-economie, dat wil zeggen: het grote aanbod aan producten die gedeeltelijk uit biomassa bestaan of kunnen bestaan, en in dat verband de te verwachten ontwikkeling dat elementen die uit fossiele oliën zijn geproduceerd, worden vervangen. Dit onderzoek is bovendien een eerste stap om te bepalen of het resultaat van de ontwikkeling van een bio-economie over het geheel genomen positief, negatief of neutraal zal zijn voor de totale Nederlandse economie.

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Preface

Since 2007 the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) has been financing work by Wageningen University & Research centre (LEI and Food & Biobased Research) to better understand the impact of the developing biobased economy on agricultural land markets. This has involved understanding the true dimension of the biobased economy, namely the large range of products for which a biobased component exists or could exist, and in this regard the likely evolution in the substitution of biobased material for elements produced from fossil oil. The research has required innovative use of the EU ProdCom statistics in the first stage, and then the testing of certain hypotheses using a custom-tailored input-output table, a partial equilibrium model (AGMEMOD), an adaptation of the proprietary LEITAP general equilibrium model and, in 2009, a specific application of a newly constructed national general equilibrium model for the Netherlands: ORANGE.

We are grateful for the continuing support of LNV, and we would like to specifically recognise the contribution of the steering committee within the Ministry for the final stage of the research that is the subject of this report. The LNV Supervisor for this project has been Dr. Roeland A. Bosch. The other members of LNV following this project have been Drs. Roel P.J. Bol, Drs. Alison J. Middleton and Drs. Irene M. Mouthaan.

Prof. Dr R.B.M. Huirne
Managing Director LEI

Summary

The development of a national CGE model (specifically for the Netherlands), equipped with some biobased economy interactions, has been an important aim of this study. Using expert knowledge, it has been possible to integrate technical biobased data into the original economy-based database of the model. The model was applied to the effects of substitution of biobased polylactic acid (PLA) as an intermediary product within the plastics industry, in place of oil-based substances. The effects on the national economy, and agricultural commodity prices and on land markets were observed.

The results demonstrate, firstly, that it is possible to combine information on technical biobased production processes (in chemical terms) with economic based production processes of sectors (in euros). Secondly, the testing of the CGE model specifically adapted for handling the biobased economy shows that it is possible to provide outcomes with regard to precise issues; the particular experiment chosen was the substitution of biobased PLA in the place of an oil-based substance.

In terms of the underlying theme of this research - the influence of the biobased economy on agricultural markets - it is certain that the biobased economy will create a new demand for agricultural commodities for the production of goods that are now using primary or intermediary materials coming from the oil-based economy. This shift between two economic systems will:
(a) create greater demand for agricultural output and, as a consequence;
(b) require more land for the agricultural sector.

Some of the satisfaction of this new demand will be sourced domestically (within a nation state), but the amount of land required will be far beyond the capacity of a densely populated country such as the Netherlands to provide. This will have the outcome of increasing crop and land prices domestically, reducing the export of some crops, and increasing imports for the balance of the agriculturally produced commodities required. It is not possible, within the scope of this research project, to determine whether the overall result will be positive, negative or neutral for the Dutch economy as a whole. But certainly the agricultural sector will benefit, on the one hand, from the increased commodity prices; but it may also suffer, on the other hand, from the increased rental value of land and the increased cost of living generated by higher agricultural prices. The overall cost of living - for farming and non-farming households alike - will be

determined by the extent of a decrease in costs that biobased production may bring about in general.

It is recommended that the integration of technical biobased data into the national CGE ('ORANGE') that has been developed should be continued, perhaps as part of the KennisBasis programme. To do so requires a substantive research effort (building a new type of knowledge, which is still in its early stage of development). It is also recommended to check or validate the model's performance by carrying out additional experiments. A timely example would be to test the impact of the 10% blending rate for transportation fuel, as is mandated by the EU Renewable Energy Directive for 2020.

Samenvatting

Deze studie had als doel om een algemeen evenwichtsmodel voor Nederland te ontwikkelen met daarin een aantal 'biobased economy'-relaties tussen agrarische en niet-agrarische sectoren. Zulke relaties zitten momenteel niet in de originele database (die is uitgedrukt in financiële termen) van het model, omdat de CBS-statistieken deze simpelweg nog niet duidelijk waarnemen. Dit probleem is ondervangen door technische informatie over biobased productieprocessen van de industrie te vertalen naar kosten- en opbrengstenstructuren en te integreren met de originele database. Het model onderzoekt vervolgens de gevolgen voor de substitutie tussen fossiele en biobased PLA (polymelkzuren) inputs door de chemische industrie als het gebruik van PLA input wordt gesubsidieerd. Het model, ORANGE genaamd, geeft effecten voor de macro-economie, de prijzen van landbouwproducten en de agrarische grondmarkt op in Nederland.

Op basis van expertkennis is het mogelijk om technische informatie over biobased productieprocessen (in chemische termen) op een zinvolle manier te combineren met informatie over economische productieprocessen (in euro's). Een tweede conclusie is dat het ontwikkelde algemene evenwichtsmodel bruikbaar is voor analyses over biobased economy-onderwerpen. Het experiment in deze studie geeft een indicatief voorbeeld daarvan door de relatie tussen het gebruik van fossiele en PLA gerelateerde input door de plastic industrie te bekijken.

Dit onderzoeksthema - de invloed van de biobased economy op landbouwmarkten - roept mogelijke nieuwe vragen op over het gebruik van biobased en niet-biobased grondstoffen. Zulke verschuivingen in het productieproces van de industrie kunnen leiden tot extra vraag naar landbouwproducten en extra beslag op landbouwgrond die door de binnenlandse markt worden gevoed. Bij een te hoge additionele vraag kan de beschikbare landbouwgrond in het dichtbevolkte Nederland echter een beperkende factor worden en zullen extra importen nodig zijn. Dit keuzevraagstuk zou tevens tot hogere prijzen voor landbouwproducten en landbouwgrond in Nederland kunnen leiden. Binnen dit project is overigens niet onderzocht of het experiment een positief, negatief of neutraal effect heeft op de Nederlandse economie als geheel. Enerzijds zal de agrarische sector kunnen profiteren van de hogere grondstoffenprijzen, maar anderzijds krijgt ze te maken met hogere koste voor pacht en voor levensonderhoud (dit laatste geldt voor zowel agrarische als niet agrarische huishoudens). De totale uitgaven aan levensonderhoud worden overigens ook beïnvloed door mogelijke lagere kosten die met de 'biobased economy' industriële productie samenhangen.

Het verdient aanbeveling om de ervaringen met het opnemen van technische biobased productieprocessen in de economische database van ORANGE verder uit te bouwen, bijvoorbeeld als onderdeel van het Kennisbasisprogramma. Omdat het om een nieuw kennistype gaat, waarvan de ontwikkeling zich nog in een beginstadium bevindt, zal een substantiële onderzoeksinspanning nodig zijn. Het verdient aanbeveling om met het CBS te overleggen bij het verzamelen van dit nieuwe datatype over het gebruik van 'biobased economy' input door de industrie. Verder is het zinvol om de uitkomsten van het model verder te valideren door het uitvoeren van extra simulaties. Zo kan het macro-economische effect worden nagegaan van een 10% menging van 'biofuels' bij transportbrandstoffen in 2020, zoals vermeld in de EU-richtlijn voor Duurzame Energie.

1 History of the biobased economy project

1.1 Introduction to the study conducted in 2009

This report is the conclusion of research undertaken to understand the impact of the developing biobased economy on agricultural land markets, which has turned out to be a first phase rather than a final outcome of this research objective. The resolution of this objective has required, as it was discovered during the course of the research, the preparation of a modelling approach, in order to take account of the interrelations within the sectors of the economy that biobased production has an influence upon, and which will ultimately determine the impact on agricultural markets. The first step in the research programme (in 2007) involved understanding the true dimension of the biobased economy, namely the large range of products for which a biobased component exists or could exist, and in this regard the likely evolution in the substitution of elements produced from fossil oil.

It was then found that the complexity of the substitution process, and its multiple economic implications, could only be addressed by the preparation of a modelling approach. On the basis of an innovative use of the EU ProdCom statistics in the first stage, there has been the testing of certain hypotheses about the sectoral linkages of the biobased economy; this was done using a custom-tailored input-output table, a partial equilibrium model (AGMEMOD), and an adaptation of the proprietary LEITAP general equilibrium model. This series of modelling exercises has ultimately lead, in 2009, to a specific application of a newly constructed national general equilibrium model for the Netherlands (ORANGE) to the research objective. The outcome demonstrates that this is the right approach, and now future advancement on the research objective will require collecting further data related to the intermediate and final products within the sectors involved, and then an analysis through the modelling approach which has been developed.

From the outcomes so far, it has not been possible, within the scope of this research project, to determine whether the overall result of the development of the biobased economy will be positive, negative or neutral for the Dutch economy as a whole. But certainly the agricultural sector will benefit, on the one hand, from the increased commodity prices; but it may also suffer, on the other hand, from the increased rental value of land and the increased cost of living generated by higher agricultural prices. The overall cost of living - for farming and non-farming households alike - will be determined by the extent of a decrease in costs that biobased production may bring about in general. The current state of the research work undertaken has prepared a modelling approach that can be confidently developed to give far greater insight to the theme under investigation.

As is presented in the following section, this investigation into the impact of the biobased economy on the agricultural markets in the Netherlands has been running for three years. The research undertaken in 2009 completes the 'architecture' of the capacity to investigate the impact of the biobased economy by the development of a computable general equilibrium model (CGE) at the national level (ORANGE), with some biobased interactions between sectors already integrated within it.

The results in 2009 demonstrate, firstly, that it is possible to combine information on technical biobased production processes (in chemical terms) with economic based production processes of sectors (in euros). Secondly, the testing of this CGE model specifically adapted for handling the biobased economy shows that it is possible to provide outcomes with regard to precise issues; the particular experiment chosen was the substitution of biobased PLA for an oil-based substance.

1.2 Studies conducted in 2007 and 2008

Since 2007 a study has been underway to examine how the use of biobased materials would influence the agricultural situation in the Netherlands, in terms of the relative prices for agricultural commodities, the influence of prices on shares of domestic commodity production as compared to imports, and the incidence of changes in commodity production on agricultural land values. This is a complex set of issues to resolve, and the investigation had first to work out the basic assumptions about the potential demand for biobased materials. Hereupon, the investigation as how to model the three related issues became the objective for 2008, taking regard of the evolution of Dutch agri-complex and farm structures under the influence of the biobased economy (biofuels and other products).

Several modelling approaches were used and/or analysed in the 2008 project to represent the macro-economy interactions among sectors and, hence, the potential analysis of impacts of alternative policies. The procedures involved are broadly categorised into fixed-price (input-output) impact analysis and the endogenous price, quantity and income computable general equilibrium (CGE) methods.

Input-output analysis
Input-output analysis, attributed to Leontief, has been used for assessing the impact of a change in the demand conditions for a given sector of the economy. Input-output analysis hinges on the crucial assumption that sectoral production is completely demand-driven, implying that there is always excess capacity in all sectors that is capable of meeting increased demand with no price increase. Because this assumption is likely to be unrealistic, input-output models are more useful as guidelines to potential induced linkage effects and as indicators of likely bottlenecks that may occur in a growing economy, than as predictive models. Furthermore, input-output models assume a constant returns to scale production function with no substitution among the different inputs. Prices are also assumed constant, which is not a major problem as substitution among factors is expected to be induced only by nonexistent relative price movements. Extension of the input-output model to a social accounting matrix (SAM) framework is performed by partitioning the accounts into endogenous and exogenous accounts and assuming that the column coefficients of the exogenous accounts are all constant. Endogenous accounts are those for which changes in the level of expenditure directly follow any change in income, while exogenous accounts are those for which we assume that the expenditures are set independently of income. In determining exogenous accounts, it is common practice to pick one or more among the government, capital, and the rest of the world accounts based on macroeconomic theory and the objectives of the study. The SAM is explained in more detail below, followed by the computable general equilibrium model (CGE) that is the next step in market analysis after the SAM, wherein the full interplay of relative prices and consequent substitution effects is generated.

SAM (Social Accounting Matrix)
The SAM is a square matrix representing a series of accounts which describe flows between agents of commodity and factor markets and institutions. It is a double-entry book-keeping system capable of tracing monetary flows through debits and credits and constructed in such a way that expenditures (columns) and receipts (rows) balance.

Like input-output accounts, social accounting matrices provide a comprehensive accounting structure of market-based productive activities and utilise similar double-counting book-keeping entries. Unlike input-output, however, social accounts focus on the household as the relevant unit of analysis and provide a comprehensive, and additional, set of accounts that track how household income is generated and distributed. Where input-output tables are focused on industries and their respective relationships with regional output, SAMs extend this into a more complete range of market mechanisms associated with generating household income.

From an input-output perspective, the rows and columns that correspond to industry and commodity are the focus. Whereas input-output is limited to this industrial perspective, social accounting matrices extend the dataset to more fully capture income distribution resulting from returns to primary factors of production (land, labour, and capital). In this way, the circular flow of goods and services to households from firms, and the corresponding factor market flows to firms from households, are captured.

CGE (Computable General Equilibrium)

The CGE framework encompasses both the input-output and SAM frameworks by making demand and supply of commodities and factors dependent on prices. A CGE model simulates the working of a market economy in which prices and quantities adjust to clear all markets. The general equilibrium model is a framework for analysing linkages between markets, and thus interactions between industries, factor resources and institutions. Inter-industry linkages are best captured in a general equilibrium framework. In the past, implementation of general equilibrium analysis was constrained by inadequate data and computational resources. Currently, however, the existence of large-capacity computer technology has made possible applications of such models to actual market situations.

Unlike input-output and SAM models, which are based on Leontief technology, neoclassical theory guides specification of production in regional CGE models. In consequence, the CGE model does not represent factor demands as linear functions of output. Instead, factor demands depend on both output and relative prices. The only exception, however, is in relation to treatment of those goods and services that are used as intermediate inputs. The Leontief input-output production function is used to represent production of regional output with fixed proportions of composite primary factors and composite intermediate inputs.

The composite primary factors generally enter the production process in a manner allowing factor substitution. Thus, production is best described as a multi-level or nested production process. All factors in a constant elasticity of substitution (CES) function have the same elasticity of substitution between any pair of factors. To allow for differing elasticities between sets of factors, multi-level or 'nested' production function forms are used in CGE, with each level containing a different set of factors and their own corresponding elasticities of substitution. That is, the use of a multi-level structure allows for use of both fixed-coefficients and price responsiveness in the CES form.

1.3 Recommendation from 2008

The knowledge gained in 2008 had been only partial with regard to what was originally planned:
(a) the analytical framework had to be improved;
(b) the full potential impact of biobased products on Dutch agricultural production - including upon commodity shares, commodity prices and land values - depends on a general equilibrium model that remained to be developed;
(c) the relative influence of biofuels and other biobased products on the Dutch agri-complex and farm structures had to be worked out, which is an additional reason to develop a custom-designed general equilibrium model as a basis for continuing this research agenda.

The outcome of the research engaged in 2008 was to understand how to organise the modelling capacity to reply to the objective for this research project. Two first analyses were made with LEI's agricultural input-output and the LEITAP CGE model. This required securing sufficient data from several sources, using publically available information as well as the results of specific industrial sector research.

Generally speaking, the sector detail in LEI's agricultural input-output model is more disaggregated than in the LEITAP CGE model. This would make the input-output approach better applicable for analysing biobased economy effects of agricultural and chemical industries. On the other hand, through its assumption on constant prices and fixed input-output relations, the input-output model is not really suitable to conduct long-term analyses to which biobased studies belong. However, because LEITAP takes care of price and quantity adjustments, it could be used for conducting long-term biobased studies. Thus, both approaches have their pros and contras. From that point of view, an outcome of the 2008 study was to combine the advantages of both approaches into one modelling system.

That outcome led to the recommendation to establish a national CGE for the Netherlands designed to take into account biobased materials and a complete understanding of the relationship between production factors - notably with regard to land values. Such a model should be helpful to answer questions such as: 'Will Dutch producers be likely to source locally or through imports?', and 'What additional consequences would this have on the evolution of agricultural markets within the Netherlands?'.

The development and implementation of this more custom designed general equilibrium model for the Netherlands has been the outcome for 2009. The test case has been this application to the biobased economy: the effect of the biobased production of polylactide (PLA) in the Netherlands.

2 ORANGE: Dutch CGE model

2.1 Introduction

The purpose of this chapter is to give an overview of the aim, theory, scope and layout of the computable general equilibrium model of the Netherlands, named ORANGE, which has been under development since early 2009. One of the reason to undertake the establishment of this CGE model is to analyse the influence of the biobased economy on the Dutch agricultural complex as mentioned in the previous chapter.

ORANGE belongs to the class of dynamic general equilibrium models and thus describes a market equilibrium for a broad number of sectors. This means that there is a feedback between, for example, the agricultural industry and the rest of the economy. Dynamic equilibrium models assume that sectoral production and consumption adjust to policy and market changes until new equilibriums are found for a longer-term projection period. Comparing this new equilibrium with the initial situation shows the medium term policy and market effects.

Section 2.2 provides the objectives of ORANGE, while the focus of Section 2.3 is on potential linkages of this model to other LEI models. Section 2.4 gives a general description of the model, including an overview of its sector coverage.

2.2 Objectives

The focus of ORANGE is on interactions between agro-food and non-agro-food sectors through relations across production, consumption, investments, trade and factor markets. ORANGE is aimed to concentrate on the effects of policy and market changes on the performances of single sectors and the macro-economy as a whole.

ORANGE has the following objectives regarding the *database* and *software structures*:

- the CGE must be developed according to LEI quality standards;
- the database is presented by the disaggregated IO tables (basic prices and producer prices), constructed yearly by LEI. At the same time, this IO table

must be extended into a SAM format by implementing household, government and rest of world information;

- it must fit in LEI's model funnel in the sense that the CGE model can communicate with other models such as DRAM and LEITAP;
- the programming language for reasons of model and knowledge sharing must be the GAMS process manager linked to GEMPACK modelling program.

ORANGE has the following objectives regarding *the modelling structure*:

- to assess the implications of changing policy and market conditions for the Dutch agro-food industry;
- to carry out policy relevant scenarios reflecting the impacts of changing policy or technological conditions on potential biobased industries such as the chemical sector;
- to assess forecasts based on underlying quantitative and qualitative assumptions on macroeconomic and other variables reported from other institutes (e.g. the central bank) and technological shifters;
- to estimate the economic effects of measures to reduce greenhouse gas emissions.

ORANGE must generate the following *model outputs*:

- a CGE model for the Netherlands, that is suitable for longer term simulations;
- an actual database, in which the agricultural and food processing sectors are sufficiently disaggregated (on input and output side) in order to conduct agricultural, environmental (including biobased economy types), tax and trade policy analyses;
- an actual database, in which e.g. the chemical sectors can be sufficiently disaggregated (on input and output side) in order to conduct biobased economy type of analyses;
- an actual database, which contains detailed figures on basic prices, commodity taxes, commodity margins for the distinguished industries;
- a balanced SAM;
- a set of actual elasticities that captures behavioural responses, i.e., elasticities that measure how easily inputs to production may be substituted for one another or expenditure elasticities that show how household demands respond to income changes;

- a researcher friendly programming tool, which fits within LEI's strategy of software and modelling use.

2.3 LEI model funnel

Most models of LEI's funnel are partial equilibrium models, with focus on the agricultural sector at various geographic levels:
- Global level: LEITAP, IMAGE (sector level);
- EU and national level: AGMEMOD, HORTUS (commodity level);
- EU regional level: CAPRI (commodity level), FIONA (farm level);
- Dutch regional level: DRAM (farm type level), standard input-output model (sector level), ORANGE (sector level).

The global economy-wide dimension in LEI's model funnel is covered by the economic LEITAP model (LEI version of GTAP) and the biophysical IMAGE model. Also, the standard input-output modelling tool is used to examine economy-wide effects for the Netherlands as a whole or for Dutch regions. An important advantage of using the standard input-output model above the more advanced LEITAP model is that the input-output model has been updated annually since 1990, so that a rich source of input-output tables are available. This is less the case for LEITAP, which has the disadvantage that the underlying database is only periodically updated - it is a very time consuming process as it is part of the entire GTAP database update - and that the database is more aggregated in respect with the agro-food industry or other industries.

The agro-food sector consists of heterogeneous sectors, which all have specific input and output structures. For example, livestock farming significantly depends on inputs from the feed industry, while greenhouse farming is relatively strong related to energy inputs. On the output side, products from livestock farming need to be processed into products like meat, milk, cream, bread, et cetera, before they can be sold on the domestic or foreign markets. On contrary, flowers or plants do not need any processing and can immediately be sold on the market. Every year LEI transforms the original CBS input-output table (available in National Accounts), into a deeper multi-input and multi-output structure in respect with the agricultural and food processing industry with the help of additional data sources such as LEI's Farm Accountancy Data Network (NL) monitoring output. Several times a year, LEI applies these disaggregated input-output tables as bases for conducting standard input-output studies.

Mostly, that kind of standard input-output analysis is suitable to quantify the short term effects of agricultural policy or environmental policy (reforms) on the agro-food sector in terms of value added and employment. Herewith, the input-output model is an interesting component of LEI's model funnel.

However, particularly in long-term simulation studies, the limitations of the standard input-output analyses are felt. Standard input-output analysis assumes fixed relations between inputs and outputs and no substitution between inputs due to price changes. These assumptions imply that the production techniques used by industries remain the same in the sense that inputs are used and outputs are generated in the same ratios. In case the time path of a study is not too long (five years or less), the assumption of fixed proportions between inputs and outputs is valid (Midmore, 1991). However, if a longer time path will be studied, then these assumptions are no longer valid and the input-output model can not be considered as a suitable approach to study long-term overall sector scenarios. Such situations prefer the use of a CGE model, which assigns a more important role to price and factor market effects than the standard input-output model. Thus, where the input-output model assumes, for example, that a fixed amount of labour is required to produce a tonne of iron, the CGE model allows wage levels to (negatively) affect labour demands. Similarly, in the CGE model the proportion of inputs varies with the price level of the inputs.

An important reason for initiating the development of ORANGE is to conduct longer term economy-wide effects on the Dutch (regional) level taking care of (factor) price effects, changes in technology and tastes. Concerning the available LEI models, ORANGE could be linked to GTAP or LEITAP so that it can use variable information, which include effects of European or global changes in policy and market conditions. ORANGE is developed according to the principles of LEI's strategy on achieving synergy effects on data use, model implementation and software.

2.4 General description

Theoretical background

This section gives an overview of the current ORANGE version, despite its very short history. The general structure of ORANGE is similar to the Mini-USAGE model, which is a miniature version of the USAGE (U.S. Applied General Equilibrium) model of the United States (Dixon and Rimmer, 2005). On its turn, USAGE is based on the MONASH model of Australia which has been applied widely in forecasting, policy analysis, estimation of technological trends and analysis of historical events. All the theoretical background of MONASH type models such as ORANGE can be found in Dixon and Rimmer (2002).

Sector detail
Within the common theoretical background, the database of the various MONASH type models could change in respect with the sector disaggregated level. As ORANGE is aimed to carry out policy relevant scenarios reflecting the impacts of changing policy or technological conditions on potential biobased industries such as the chemical sector. This means that it needs a database with sufficient disaggregated agricultural, food processing and chemical sectors (on input and output side) in order to conduct agricultural, environmental (including biobased economy types), tax and trade policy analyses. Appendix 1 presents the current sector detail of the Dutch macroeconomy covered by ORANGE.

3 Biomass for the Dutch chemical industry

Based on discussions between LEI and ASFG, both part of Wageningen UR, two biobased economy cases have been proposed for studying by ORANGE. In the first simulation the proportion of inputs from biobased sources (ethanol and biodiesel) in the chemical petrol producing industry has been specified and implemented in ORANGE. In the second simulation the proportion of inputs from biobased sources (polylactide) in the chemical synthetic producing industry has been specified and implemented in ORANGE. Polylactide (PLA) is a biodegradable polyester derived from renewable resources such as corn starch, sugar canes, maize or wheat. Although PLA has been known for more than a century, it has only been of commercial interest in recent years, in light of its biodegradability.

First, these simulations have been selected due to their expected interest and impact on environmental circumstances as well as their competing claims on factor markets. Second, though limited and not really observed, data on ethanol and PLA uses can be derived from a few sources and can be implemented into the ORANGE framework. In addition, both cases seem applicable to the newly developed ORANGE model and hence they are also important for validating the outcomes of this model.

In both cases, the impact of a 50% oil price rise is investigated in respect to the use of (non-)biobased inputs by the chemical industry. The demand for ethanol, biodiesel and polylactide can be met from domestic or imported sources, depending on the availability of land (and land price) in Dutch agriculture. Consequently, these experiments should also give a picture about where the biobased chemical industry buys its inputs.

Finally, it should be noted that 2005 is the base year of the ORANGE model, which means that the collected biobased data must fit into the Dutch macroeconomic situation of that year.

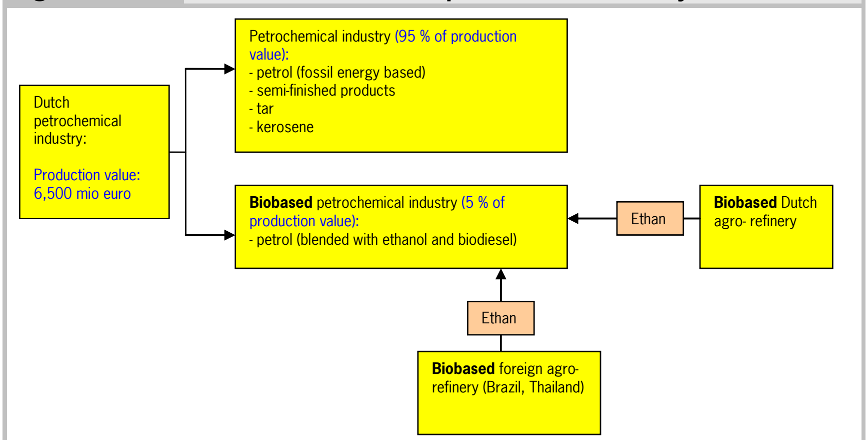
3.1 Proposed Pilot 1: ethanol and biodiesel for petrol

Description of biobased industry structure

The focus of this pilot is on the first generation biofuels, which refer to the fuels that have been derived from sources like starch, sugar, animal fats and vegetable oil. As it is difficult to collect any observed data on the second generation biofuels at this moment (from bio waste like wood), the focus of this pilot is on the first generation biofuels only.

Some of the most popular types of first generation biofuels are ethanol and biodiesel. These fuels can be used for any purposes, but the main use for which they have to be brought is via fuels into the transportation sector. Among other production lines, the production of petrol takes place in the petrochemical industry. Figure 3.1 shows the production structure of the petrochemical industry, which has been disaggregated into two industry types for this study. Both industry types have almost similar input, output and production factor (labour, capital) structures, but they differ regarding the use of fossil energy versus biobased energy inputs. It is assumed here that the fossil based petrochemical industry uses fossil energy inputs, purchased from the petrol and crude oil industries, whereas the biobased petrochemical industry uses ethanol and biodiesel and mixes these with crude oil. This specification allows petrol producers to choose the optimal mix of biobased and non-biobased uses depending on their relative prices of the inputs. Changes in relative prices will change the mix of biobased and non-biobased inputs in the production of a fuel composite for transportation.

Figure 3.1 Production structure of petrochemical industry



The demand for ethanol and biodiesel as inputs into the biobased petrochemical industry can be met from domestic or foreign sources (imports). Currently, the biobased petrochemical industry imports the main part (75%) of ethanol and biodiesels (in fluid version), in particular from Brazil and Germany, respectively. In principle, the biobased petrochemical industry can highly substitute between domestically produced ethanol (from maize, wheat or sugar beets) and imported ethanol (either from sugar cane or from tapioca), depending on the cost price of the primary commodity.

The pattern of factor use of the biobased petrochemical industry follows that of the fossil energy based petrochemical industry, but with ethanol and biodiesel as substitutes for fossil fuels. A priori a shift in the petrochemical industry towards more biobased inputs will increase the demand for ethanol and biodiesel, which in turn will increase the demand for wheat, maize and sugar. As the Netherlands is relatively land scarce, these commodities are likely to be sourced internationally. The overall impact on the balance of trade is unclear a priori as the substituted goods, oil and petrol, are to be mainly sourced from abroad also.

The previous report (Nowicki et al., 2009) envisioned two means by which the transformation to a biomass based chemical industry may take place:

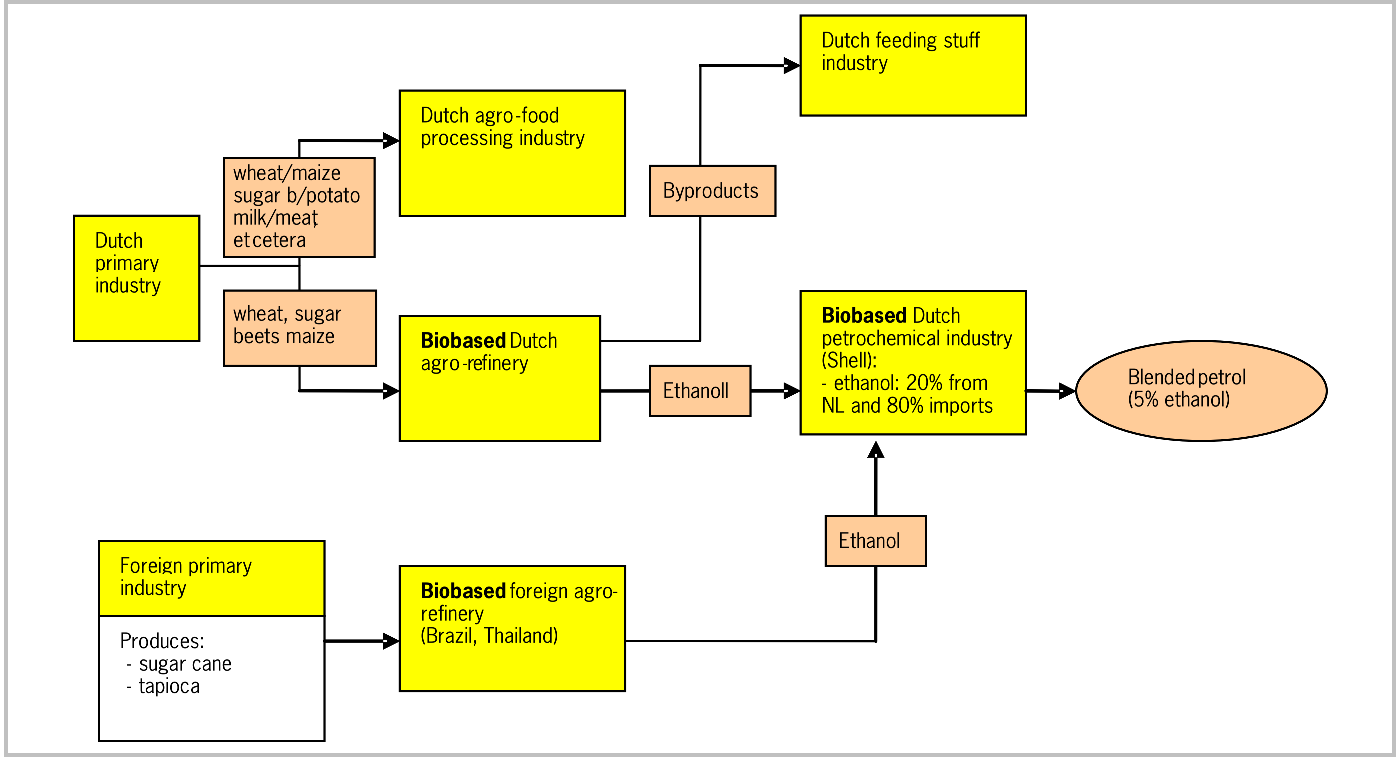
a. Biomass is refined and 'cracked' into the familiar platform chemicals (*i.e.* ethylene, propylene, C4-olefines and BTX) and synthesis gas ('syngas', a mixture of mainly carbon monoxide and hydrogen gas). From these one- to six-carbon building blocks, all other chemicals and materials can be produced. Provided that efficient processes will become available by which oxygen-rich biomass of a varying composition can be transformed into basic hydrocarbon building blocks, the big advantage is that the current petrochemicals infrastructure and processes can be used. The fossil feedstock refining companies of today may then become the biorefineries of tomorrow.
b. A wide range of biobased building blocks, in which as much of the functionality of biomass as possible has been retained, become the raw materials from which all other chemicals and materials are made. Not a few refineries that produce a limited number of platform chemicals will be present, but a large number of (smaller scale) biorefineries that produce a whole array of building blocks.

Due to the current public discussion on the acceptability of using 'food' for 'fuels' and thereby the possible disruption of the global food supply, the petrochemical industry is not willing to produce the ethanol and biodiesel itself. On the other hand, this industry requires the uses of ethanol and biodiesel in order to fulfil the policy target of blending 10% of fossil petrol with ethanol and biodiesel in 2020. For this study, therefore, a *biorefinery* has been introduced in the ORANGE database and has been embedded as an intermediary (product) between agricultural (food) and non-agricultural sectors. The biorefinery buys the wheat, maize and sugarbeets from the primary industry, refines and cracks this biomass into ethanol and biodiesel, and sells these outputs to the biobased petrochemical industry. Figure 3.2 shows that process.

It must be noted that the ethanol and biodiesel production of the biorefinery generates high protein material as by-product (e.g. from corncobs), which are very useful for animal feed. Regarding the cost-benefits of the biorefinery, the selling of the high protein material to the feed industry is an important aspect of its economic viability.

At the moment the costs for producing ethanol are relatively high, with a 60% share allocated to primary commodities. On the other hand, the investment costs to produce ethanol are quite moderate and not that complicated.

Figure 3. 2 **Production process of ethanol from 1st generation crops**



Biobased data features
The Dutch input-output table of 2005, which lies beyond the database of the current ORANGE version, neither captures a biorefinery nor a biobased petrochemical industry in its initial form. The main reason for this absence has to do with the issue that the CBS could simply not observe enough data to specify input and output structures for these industries. For this first biobased experiment, however, the ORANGE database needs information on inter-relations between the agro-food sector and the chemical industry. The attempt to introduce biobased economy relations into the input-output table has been established by the following two ways. First, based on additional CBS sources, the petrochemical industry has been split into four parts:

a. petrochemical - petrol-fossil oil-based (35%);
b. petrochemical - petrol-ethanol based (2.5%);
c. petrochemical - diesel-biodiesel based (2.5%);
d. petrochemical - bitumen, intermediate products, kerosene (60%).

The second way brings together technical data (Food & Biobased Research), economic data (LEI) and expert knowledge about the biobased production process. Based on that information, the cost and return structures of the biorefinery have been estimated and have been implemented in the ORANGE database.
The following assumptions are accounted for:

- 345 litres of ethanol can be produced from 1 tonne of wheat;
- 100 litres of ethanol can be produced from 1 tonne of sugar beets;
- 1,000 litres of biodiesel can be produced from 1 tonne of rapeseed oil;
- ethanol price is set on 0.50 euro per litre (1 euro per tonne);
- biodiesel price is set on 0.50 euro per litre (1 euro per tonne);
- Dutch wheat price is 100 euro per tonne in 2008;
- Dutch rapeseed oil price is set on 220 euro per tonne in 2008;
- Dutch sugar beet price is set on 40 euro per tonne in 2008.

Finally, due to the claims of biobased economy sectors on the domestic land use and knowing that the Netherlands is relatively land scarce, LEI data on agricultural land availability and the agricultural land price have been introduced into the ORANGE system.

Table 3.1 and Table 3.2 summarise the input structures of biorefinery and petrochemical-fossil oil-based and petrochemical-ethanol/biodiesel based industries in the Netherlands as these have been implemented in the ORANGE database. Regarding the use of intermediate inputs from other chemical industry types, the traditional petrochemical industry fully depends on fossil oil-based inputs (columns 2 and 3 in Table 3.2), whereas the biobased petrochemical industry significantly uses biobased inputs (columns 4 to 7 in Table 3.2).

Table 3.1	**Input structure of biorefinery (m euro and %), 2005**	
Input	**Biorefinery**	
	m euro	**%**
Domestic		
- wheat, sugar beets	87	62
- chemical inputs	21	15
- other inputs	2	2
Imports		
- wheat	7	5
- other inputs	1	1
Value added	22	16
Production value	141	100

Table 3.2	**Input structure of petrochemical industry (m euro and %), 2005**					
Input	**Chemical-fossil oil-based**		**Chemical-ethanol based**		**Chemical-biodiesel based**	
	m euro	**%**	**m euro**	**%**	**m euro**	**%**
Domestic						
- wheat, sugar beets	0	0	6	2	0	0
- biorefinery	0	0	48	12	10	2
- chemical inputs-fossil based	637	11	30	8	30	8
- chemical inputs-biomass	1	0	15	4	15	4
- other inputs	1,196	21	88	23	123	32
Imports						
- wheat, sugar beets	0	0	1	0	0	0
- biorefinery	0	0	93	24	92	24
- chemical inputs-fossil based	1,106	19	42	11	42	11
- chemical inputs-biomass	5	0	28	7	28	7
Value added	1,547	27	18	5	30	8
Production value	5,801	100	389	100	389	100

Biobased modelling features

The initial ORANGE database does not account for biobased economy issues, which means that there is no direct relation between agro-food sectors and biobased non-agro-food sectors. However, the implemented production structure of the biorefinery and the biobased petrochemical industry provides the possibility to model this relationship.

The biorefinery uses different crops to produce ethanol and biodiesel. It chooses the optimal intermediate input combination of crops (wheat, other cereals, feed grains and sugar beets) by minimising the total input costs of these crops subject to a constant elasticity of substitution (CES) aggregation function. This function describes the composite crop commodity as an aggregate of different not perfectly substitutable crops. The resulting intermediate demand for the specific crop is growing one to one with the biorefinery output growth and proportionally to the difference between composite crop commodity and specific crop prices changes. The proportionality parameter is equal to the elasticity of substitution and indicates the percentage change increase of the intermediate input of crop *x* in response to a 1% decrease of crop *x* in comparison with the composite crop commodity price.

Biobased inputs of the petrochemical industry have been introduced into the production process through intermediate use, which has required a respecification of the input-output database used in ORANGE (according to the desaggregation of the petrochemical industry as described above).

Finally, transport sectors can use all three petrol products (petrol-fossil oil-based, petrol-ethanol based and petrol-biodiesel based) as intermediate input of their production process. They can choose the optimal combination of these substitutable inputs based on their relative prices. It is modelled similarly to the biorefinery use of crops intermediate input described above.

The substitution elasticities among the different types of petrol and the different crops used by biorefinery are taken from Birur et al. (2007). Based on a historical simulation of the period 2001 to 2006, they obtained elasticity values of 3.0 for the EU.

3.2 Proposed Pilot 2: PLA use in the chemical industry

Synthetic organic materials are nowadays predominantly produced from fossil resources. Biobased raw materials are used to a relatively small extent, while oil products are by far the most important feedstock for chemicals for non-energy purposes.

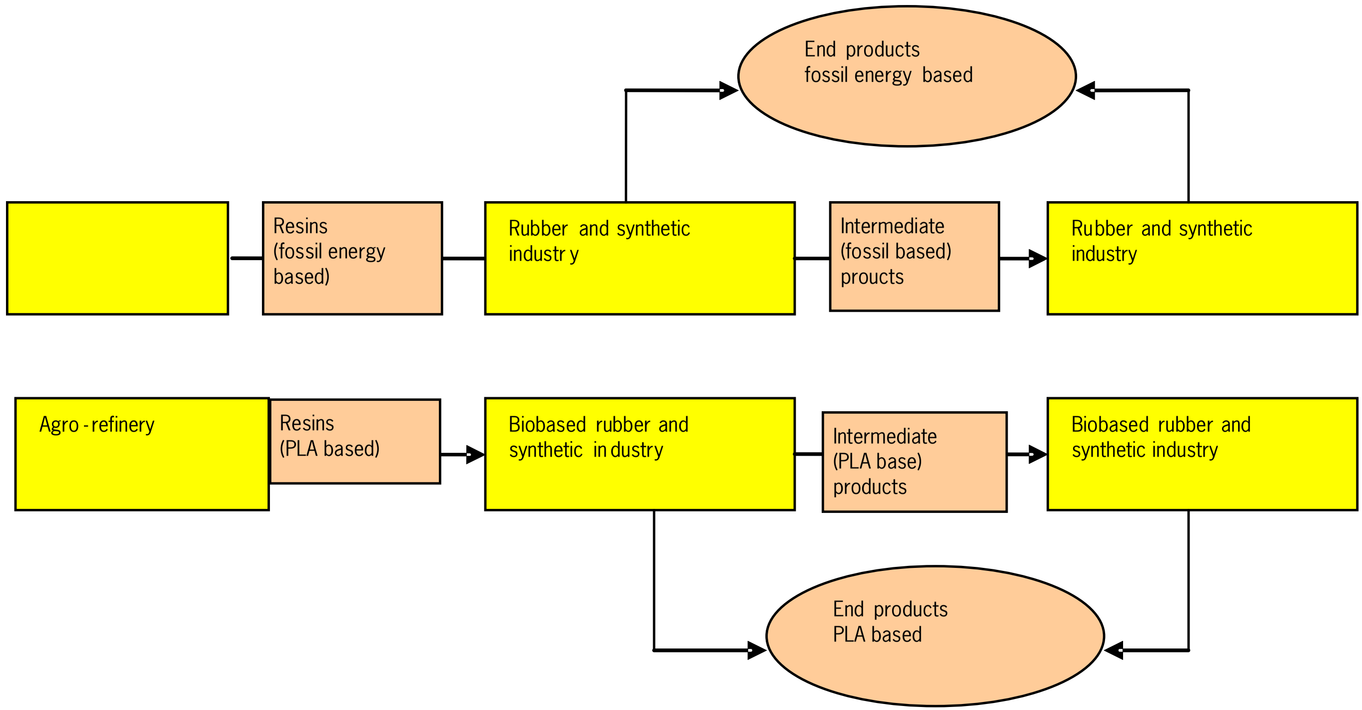
Since 2002, NatureWorks LCC in Blair (Nebraska, USA) has been the biggest producer of PLA in the world with an annual capacity of 140 thousand tonnes. A second group of smaller producers consist of Mitsui Chemicals (Japan), Hisun Biomaterials (China), Galactic (Belgium), Pyramid Bioplastics (Germany) and Purac (Spain, Thailand).

Description of biobased industry structure

An interesting experiment to examine the impact of using biobased materials for agricultural markets seems to be the production of polylactide (PLA) by the synthetic chemical industry. PLA is currently used in a number of biomedical applications and it is also being evaluated as a material for tissue engineering. Because it is biodegradable, it can also be employed in the preparation of bioplastic, useful for producing loose-fill packaging, compost bags, food packaging, and disposable tableware. In the form of fibres and non-woven textiles, PLA also has many potential uses. For example, the Greenery in the Netherlands in principle uses PLA food packaging for all its biological commodities. PLA is a sustainable alternative to petrochemical-derived products, since the lactides from which it is ultimately produced can be derived from the fermentation of agricultural by-products such as corn starch or other carbohydrate-rich substances like maize, sugar or wheat.

PLA is more expensive than many petroleum-derived commodity plastics, but its price has been falling as production increases. On the other hand, the demand for corn is growing, both due to the use of corn for bioethanol and for corn-dependent commodities, including PLA. The demand for PLA by the synthetic chemical industry can be met from domestic or imported sources. The production process of the domestically produced PLA by the biorefinery and their delivery to the biobased synthetic chemical industry is shown in Figure 3.3.

Figure 3.3 **Production process of PLA based commodities**



The biorefinery is producing lactide from dextrose, but this process is still based on a high-quality technology. Hence, large-scale production is a cost-effective manner to produce the lactide, which is in particular an interesting and operational option in some foreign countries. The biorefineries are located in the midst of wide tapioca fields (in Thailand), sugar cane fields (in Brazil) and maize fields (US), which reduces the transportation costs of primary commodities to the refinery. The biobased rubber & synthetics industry then polymerises the lactide into polylactide resin (granules), which are on their turn an efficient manner of transporting the material abroad.

As far as used in the production process, the Dutch synthetic industry mainly imports polylactide resins, in particular from NatureWorks, and then moulds the PLA granules into the desired shape of the product. The use of PLA in products is significantly larger in our neighbouring countries such as Germany, Belgium, United Kingdom and France. However, PLA has started to be produced in the Netherlands on a small scale as well. A synthetic (products) industry (Synbra) has developed sustainable foam to replace polystyrene foam on the basis of PLA, which had been delivered by the sugar industry (CSM).

The PLA based products of the synthetic industry are achieved by combining the primary factors of production and intermediate inputs, where the fossil based intermediate inputs have been substituted by biobased intermediates. The pattern of factor use follows that of the traditional synthetic industry, but without polylactide as a substitute for fossil based inputs. A priori a shift in the synthetic industry towards more biobased inputs will increase the demand for lactose, which in turn will increase the demand for wheat, maize and sugar. As the Netherlands is relatively land scarce, these commodities are likely to be sourced internationally. The overall impact on the balance of trade is unclear a priori as the substituted goods - oil and petrol - are mainly sourced from abroad.

Biobased data features

The Dutch input-output table of 2005, which lies beyond the database of the current ORANGE version, does not capture a biobased synthetic industry in its initial form. Similar as for the absence of the biobased petrochemical industry, this has to do with the issue that the CBS could not observe enough data to specify an input and output structure for this industry. For the second biobased experiment, the ORANGE database also needs information on inter-relations between the agro-food sector and the synthetic chemical industry. The attempt to introduce biobased economy relations into the input-output table has been established by the following two ways. First, based on additional CBS sources, the Rubber and Plastics industry has been split into the Rubber industry (10%) and the Synthetic industry (90%). Next, the Synthetic industry has been split into a PLA based production line (10%, based on own assumption) and a fossil oil-based production line (80%). Actually, the intermediate use structure of the Synthetic-PLA based industry mainly follows that of the Synthetic-fossil based industry, but its fossil oil inputs have been substituted by biobased inputs. On the output side, it is assumed that the end products of both Synthetic industries are highly substitutable and thus show the same output structure.

Secondly, based on knowledge obtained by the first experiment, the interrelation of the synthetic-biobased industry with the biorefinery has been estimated and implemented in the ORANGE database. It is assumed that the synthetic-biobased industry buys 30% of its PLA use from the Dutch biorefinery and that 70% is imported.

Finally, due to the claims of biobased synthetic sector on the domestic land use and knowing that the Netherlands is relatively land scarce, LEI data on agricultural land availability and agricultural land price have been introduced into the ORANGE system.

Table 3.3 summarises the input structures of the synthetic-fossil oil-based and synthetic-PLA based industries in the Netherlands as these have been implemented in the ORANGE database. Regarding the use of intermediate inputs from other chemical industry types, the traditional rubber and synthetic industries fully depend on fossil oil-based inputs (columns 2 to 5 in Table 3.3), whereas the PLA based rubber industry significantly uses biobased inputs (columns 6 and 7 in Table 3.3).

Table 3.3	**Input structure of rubber and plastics industry (m euro and %), 2005**					
Input	**Rubber**		**Synthetic-fossil oil-based**		**Synthetic-PLA based**	
	m euro	**%**	**m euro**	**%**	**m euro**	**%**
Domestic						
- wheat, sugar beets	0	0	0	0	21	3
- biorefinery	0	0	0	0	64	10
- chemical inputs-fossil based	83	13	664	13	2	0
- chemical inputs-biomass	0	0	0	0	29	4
- other inputs	129	20	1,029	20	126	19
Imports						
- wheat, sugar beets	0	0	0	0	7	1
- biorefinery	0	0	0	0	138	21
- chemical inputs-fossil based	173	26	1,384	26	4	1
- chemical inputs-biomass	0	0	0	0	44	7
- other inputs	36	5	286	5	35	5
Value added	234	36	1,875	36	182	28
Production value	654	100	5,238	100	652	100

Biobased modelling features

As already mentioned in respect with the first experiment, the initial ORANGE database did not account for biobased economy issues. Thus, it captured no clear relation between agro-food sectors and the chemical industry. However, the estimated production structures for biorefinery and the synthetic-biobased industry provide the option to describe this relationship. Namely, biobased inputs of the synthetic-biobased industry have been introduced into the production process through intermediate use, which has required a re-specification of the input-output database used in ORANGE.

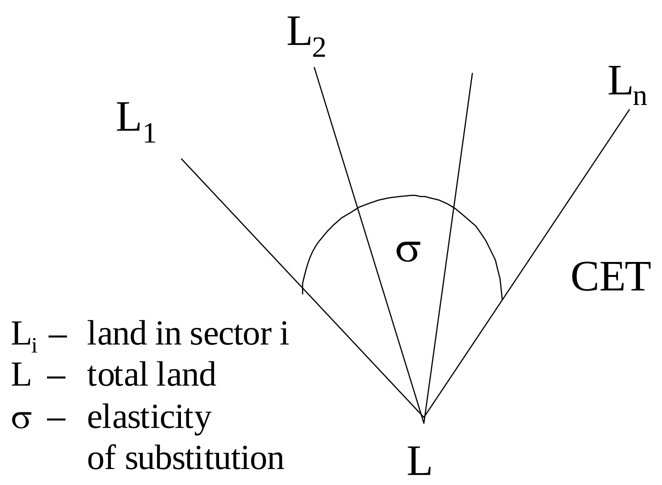
In the production pre-process, all sectors could choose between two synthetic industry products - biobased and fossil based - and use these as intermediate inputs in the production process. This decision process is modelled similarly to the biorefinery decision process concerning the choice of crop intermediate input. The substitution elasticity between biobased and fossil based synthetic commodities is set equal to 3. In the absence of information concerning these elasticity and assumed similarity of these commodities, these elasticities have been set a little bit higher than the elasticity between the different types of petrol.

3.3 Land allocation and land supply in ORANGE

The biorefinery sector uses agricultural commodities as their most important intermediate input. Thus, biorefinery indirectly claims agricultural land, which is however relatively scarce in the Netherlands. Therefore, LEI data on sectoral agricultural land use, the agricultural land price and land rents have been introduced into the ORANGE system. Consequently, the land demand and supply equations have been implemented.

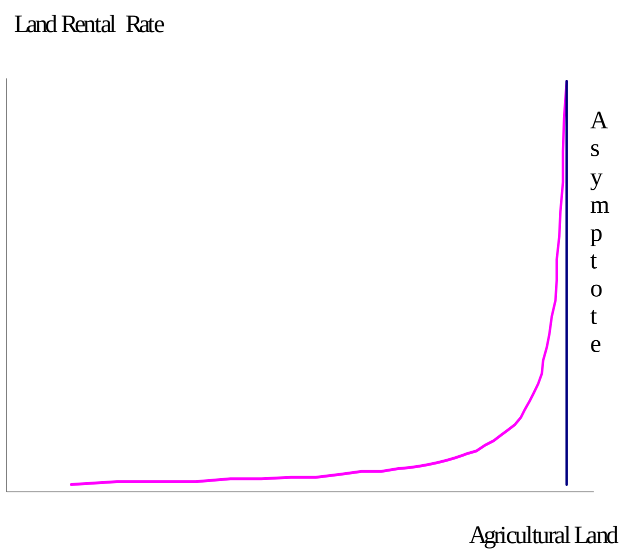
The land allocation per agricultural sector is modelled under the assumption that each sector uses a specific land type and that the various land types are imperfectly substitutable. It means that land is imperfectly mobile across alternative agricultural sectors. This is represented in ORANGE by using a constant elasticity of transformation (CET) structure (Figure 3.4). This application is similar to the land representation used in GTAP (Hertel, 1997). The elasticity of transformation σ is set equal to 1, which is taken from GTAP.

Figure 3.4 Land supply function in ORANGE



The total land supply function (Figure 3.5) is taken from Van Meijl et al. (2006). It depictures a relationship between land supply and the land rental rate. According to Figure 3.5, if the gap between potentially available agricultural land and land used in the agricultural sector is large, the increase in demand for agricultural land will lead to land conversion to agricultural land and a modest increase in rental rates to compensate for the cost to take this land into production. Points situated on the left flat part of the land supply curve in Figure 3.5 depict such a situation. However, when almost all agricultural land is in use, an increase in the demand for agricultural land will mainly lead to high increase of the land rental rates (land becomes scarce). In this case, land conversion is difficult to achieve, and therefore, the elasticity of land supply in respect to land rental rates is low as well. Points situated on the right steep part of the land supply curve in Figure 3.5 describe this situation (Van Meijl et al., 2006). This last situation is relevant for the Netherlands. According, to estimation results of Cixous (2006), the current land supply elasticity in respect of the land price is 0.15.

Figure 3.5 **Land supply curve**



Based on the analysis of the biophysical data in IMAGE and CLUE, it was assumed the Netherlands uses 98% of its agricultural land. Accordingly, the land supply function asymptote was specified.

4 Biobased policy impact on the Dutch economy: simulation experiment with a PLA subsidy

4.1 Introduction

For this report, Proposed Pilot 2 - PLA use in chemical industry - has been chosen to test the ORANGE model. In order create a shock in our model, we introduce a 20% subsidy on the intermediate use of biobased plastics (PlasticBio) through a hypothetical reduction in the sales tax; this makes it theoretically more attractive for all sectors that use this product to choose it over oil-based plastics (PlasticOth). The subsidy is introduced in 2007, and remains through to the end of the trial period, i.e. 2010.

The model used is a recursive dynamic version of the ORANGE model. The model allows industries to substitute between the intermediate use of oil-based and biobased (PLA) plastics (the substitution elasticity is set to 3, so it is relatively easy to substitute). The model run for is 5 years (from 2005-2010).

The a priori expectations were:

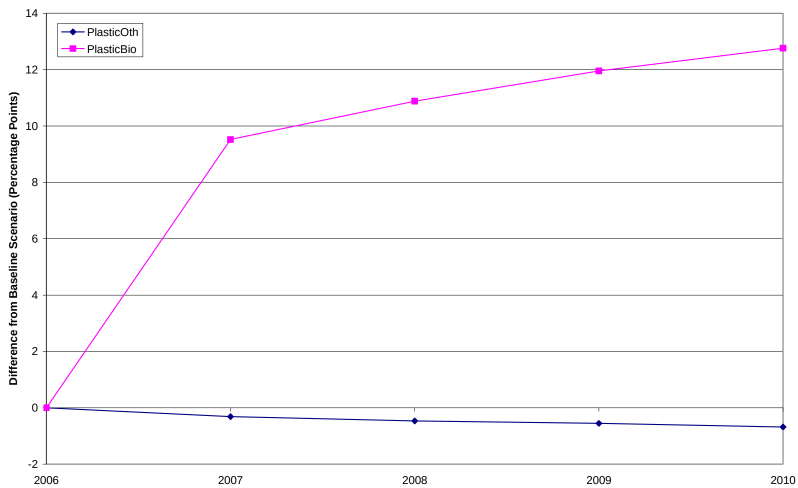
- little effect at the macro level, as biobased plastics is such a small sector. We expect sectoral effects, however, within the sectors that either use PlasticBio or are involved in the process of producing the biobased plastic. Perhaps there may be some losses for the sectors involved in making oil-based plastics;
- an increase in demand for biobased plastics (boost to this sector);
- substitution away from oil-based plastics (reduction in this sector);
- an increase in the demand for the inputs of the biobased plastics sector, including the agricultural products potentially used for these inputs;
- the increase in the demand for agricultural products would include both domestic and imported agricultural commodities, with concomitant increases in the demand for land when domestic crops are involved.

4.2 Macro effects

The macroeconomic impact of a subsidy to PlasticBio is very small. The economy of the Netherlands is projected to be 0.04 percentage points smaller following the introduction of such a subsidy when compared to the Baseline value of the economy. Employment and the capital stock fall slightly in line with the small contraction in the economy by 0.04 and 0.01 percentage points, respectively, but the economy uses slightly more land following the introduction of the subsidy (an increase of 0.03 percentage points).

4.3 Plastic sector effects

Figure 4.1 Impact of subsidy on domestic production of biobased and oil-based plastics



Whereas the effect of the shock is to give a big boost to the domestic production of PlasticBio, there is a corresponding less than proportionate reduction in oil-based plastics, simply because of the different size of this sector (much bigger).

Cost and Demand Structures for the Plastics Sector in 2005

Results depend on the structure of demand for PlasticBio and PlasticOth, i.e. which sectors use it. The sectors that use PlasticBio as intermediate inputs will be boosted because their inputs become relatively cheaper when compared to before the shock.

Table 4.1 shows similar cost structures at an aggregate level for both the PlasticBio and the PlasticOth sectors. The relative size of the two types of industries is different by almost a factor of 10, but it is interesting to note that the share of 'capital' in total costs is twice as great for PlasticBio rather than PlasticOth. On the other hand, this is offset by a substantial difference for 'other costs' that is inversely proportional to the relative size of the industries.

Table 4.1 Cost structures for plastics industries

	PlasticBio	PlasticOth	PlasticBio	PlasticOth
	values (m euro)		share of total costs	
Domestic Intermediates	243	1,693	0.37	0.32
Imported Intermediates	228	1,674	0.35	0.32
Sales tax on intermediates	1	13	0.00	0.00
Margins on intermediates	38	306	0.06	0.06
Labour costs	140	1,119	0.21	0.21
Capital costs	113	450	0.17	0.09
Land costs	0	0	0.00	0.00
Production taxes	0	0	0.00	0.00
Other costs	-111	-16	-0.17	0.00
Total costs of production	652	5,238		

Table 4.2	Top 5 domestic and imported intermediates in the plastics industry				
	PlasticBio			**PlasticOth**	
	value (m euro)	**share of total produc-tion cost**		**value (m euro)**	**share of total produc-tion cost**
Domestic			*Domestic*		
59 AgroRefinery	64.2	0.10	72 OrganicChem	368.8	0.07
83 PlasticBio	20.25	0.03	82 PlasticOth	162	0.03
5 OthArabProd	18	0.03	136 EmployAgency	118.4	0.02
136 EmployAgency	14.8	0.02	100 ElectricProd	111.2	0.02
100 ElectricProd	13.9	0.02	133 LegalAccount	87.2	0.02
Imported			*Imported*		
59 AgroRefinery	138.5	0.21	72 OrganicChem	938.24	0.18
83 PlasticBio	32.29	0.05	82 PlasticOth	258.38	0.05
154 GoodServNES	8.82	0.01	154 GoodServNES	70.57	0.01
5 OthArabProd	5.01	0.01	74 PetroChemOth	67.84	0.01
125 BankService	4.51	0.01	75 PetroChemBen	39.57	0.01

Table 4.2 shows that whilst the total expenditure on imported and domestic intermediates is similar, the detailed intermediate inputs are different. This means that boosting the PlasticBio sector will boost the agro refinery sector (domestic and imports), and the contraction of the PlasticOth sector will reduce the demand for Organic Chemicals from both domestic and imported sources. The link to agriculture comes through the intermediate inputs from the Agro-refinery sector.

Figure 4.2 (next page) shows the impact of subsidy on the production of domestic inputs into biobased plastics production. The subsidy boosts Plastic-Bio both from the demand created by its use as an input into other sectors as well as its use as an input into its own sector (as an intermediary product). The agro-refinery sector receives a boost through the expansion of PlasticBio as it is a main input, as does Other Arable Products. There are only small effects on ElectricProd and EmployAgency sectors, but the demand from PlasticBio is only a small share of the total demand for these sectors.

Figure 4.2 **Change in production of top 5 domestic inputs into biobased plastics production**

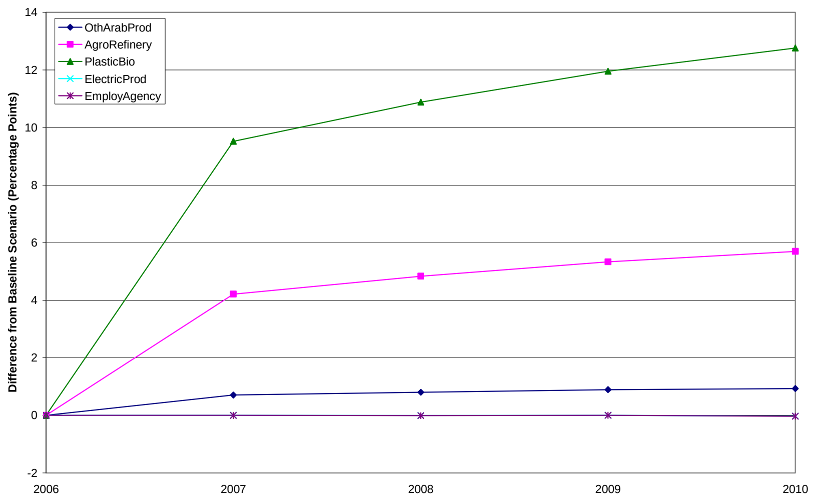
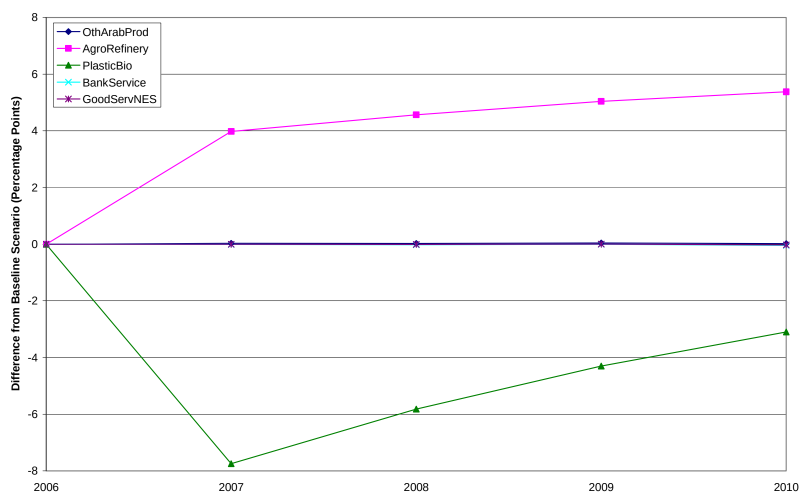
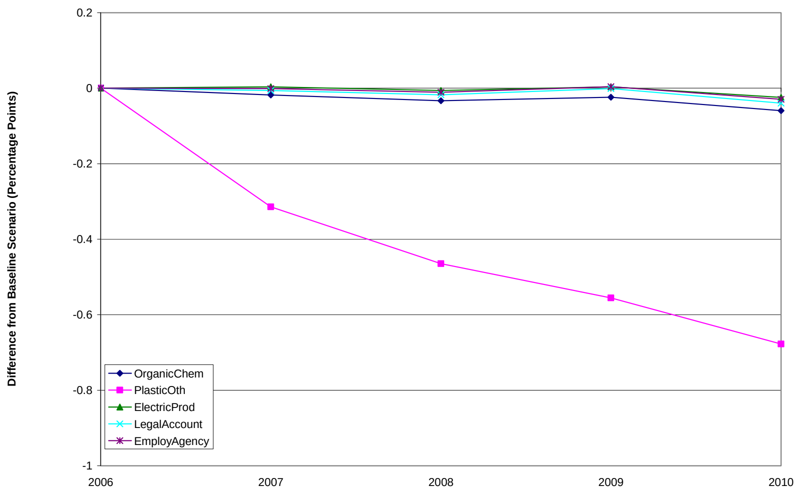


Figure 4.3 **Change in imported quantities of top 5 inputs into biobased plastics production**



There is an increase in agro-refinery imports but lower levels in PlasticBio imports because the domestic source is now cheaper after the subsidy. Over time, however, the higher domestic price of PlasticBio (due to the sectoral expansion of PlasticBio) means that the price advantage of domestic over imported material progressively decreases.

Figure 4.4 **Change in production of top 5 domestic inputs into oil-based plastics production**



Oil-based plastics also uses itself as an input, so in fact the contraction in PlasticOth from the transfer of demand to PlasticBio is compounded by the lower level of intermediate demand by the oil-based plastics sector for its own product. Small reductions are also observed in those sectors that are used as inputs to PlasticOth; many of these are large sectors, so in fact the small subsidy has a relatively large ripple effect.

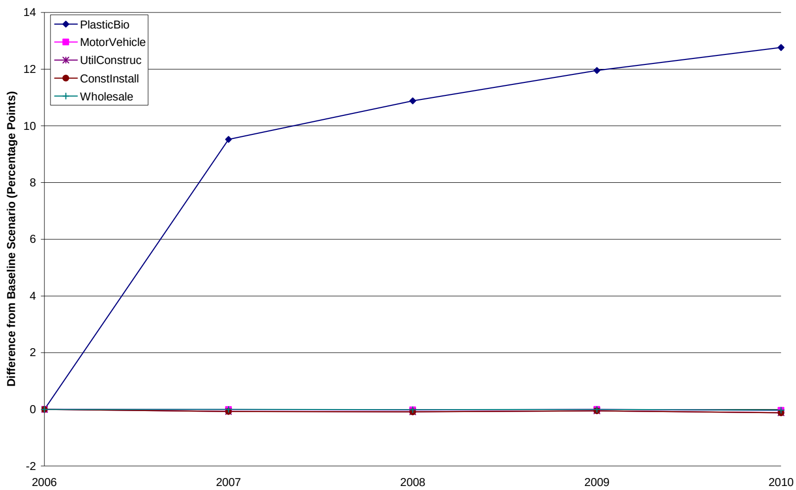
The initial increase in imported oil-based products is followed by lower levels of imports after the introduction of the subsidy. This is because of a shrinkage of the sector because of the reduction in the demand for oil-based inputs.

Figure 4.5	Change in imported quantities of top 5 inputs into oil-based plastics production

Demand side: who uses PlasticBio?

The production of the sectors that demand the largest shares of PlasticBio used as an intermediate product is shown in Figure 4.6. Probably this is linked to the fact that the reduction in the price of PlasticBio through the subsidy causes a substitution effect but not much of an income effect. Although firms switch from PlasticOth to PlasticBio, the overall spending on plastics is not really affected. Therefore these firms do not really get a boost from having cheaper inputs. The positive story is therefore really 'upstream', i.e. the sectors that are used in the production of PlasticBio rather than the sectors that use PlasticBio.

Figure 4.6	Change in production of top intermediate users of PlasticBio



4.4 Impact on agriculture

A boost to the Other Arable Product sector occurs through the increase in intermediate demand from the expanding biobased sector. Other agricultural effects come through the expansion of the Agro-refinery sector; the structure of the Agro-refinery sector is shown below in Table 4.3.

Sugarbeets accounts for over 40% of inputs to the Agro-refinery sector; wheat is the other main agricultural input. We expect the demand for these crops to increase along with the sector Other Arable Products.

We observe higher levels of domestic production of sugarbeets, wheat and other arable products, as well as of oilseeds and other cereals.

Table 4.3	Cost structure for the agro-refinery industry	
	Agro-refinery	
	value (m euro)	share of total production costs
Domestic		
7 Sugarbeets	59.38	0.42
100 ElectricProd	19.60	0.14
1 Wheat	13.79	0.10
2 OthCereals	13.79	0.10
29 ExtrOilGas	1.13	0.01
Other domestic inputs	3.62	0.03
Imported		
1 Wheat	7.06	0.05
51 StarchDo	0.26	0.00
132 ResearDevel	0.07	0.00
125 BankService	0.06	0.00
68 PapBoardProd	0.05	0.00
Other imported inputs	0.41	0.00
Other		
Sales tax on intermediates	-9.45	-0.07
Margins on intermediates	8.39	0.06
Labour costs	8.95	0.06
Capital costs	16.85	0.12
Land costs	0.00	0.00
Production taxes	2.34	0.02
Other costs	-5.00	-0.04
Total costs of production	141.31	

Figure 4.7 **Change in production of selected domestically produced agricultural products**

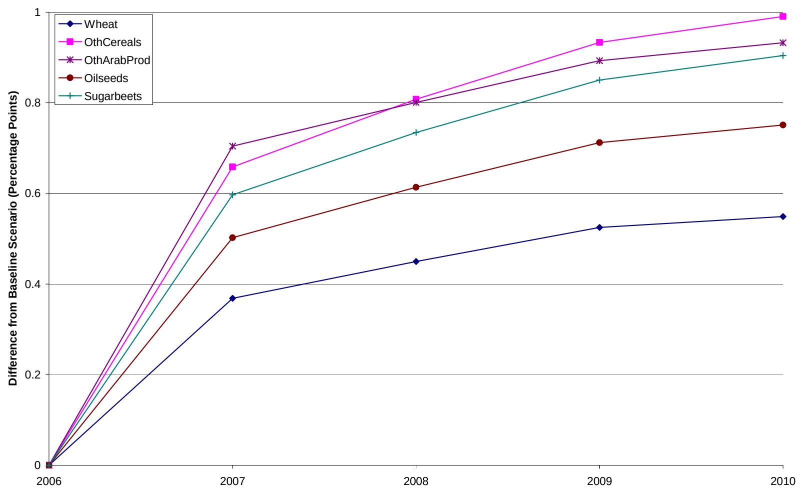
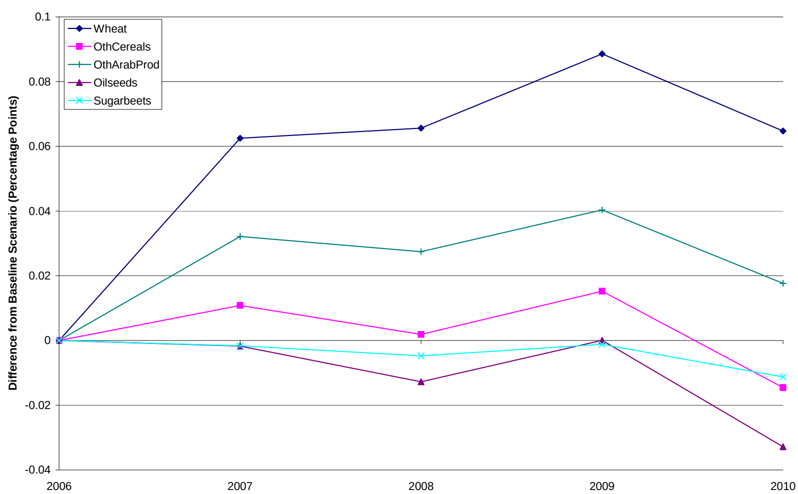


Figure 4.8 **Change in imported quantities of selected agricultural products**



Very small changes (NB: compare Y axes of Figures 4.7 and 4.8) in imported quantities of agricultural products occur: there are more imports of wheat and other arable products to meet the demands of the growing biobased plastics (PlasticBio) sector, as well as more imports of other cereals in a second period (after 2008). There are slightly lower levels of imported sugarbeets and oilseeds from the outset; this is because of growing more oilseeds and sugarbeets domestically (Figure 4.9).

The overall impact on land area is a small increase (0.03 percentage points after 5 years). The different sectoral effects in terms of land use (i.e. by agricultural commodity type) is shown below.

More land is devoted to arable crops and oilseeds. The necessary land is taken from very small land reductions in all other sectors.

Figure 4.9 **Change in land by sector**

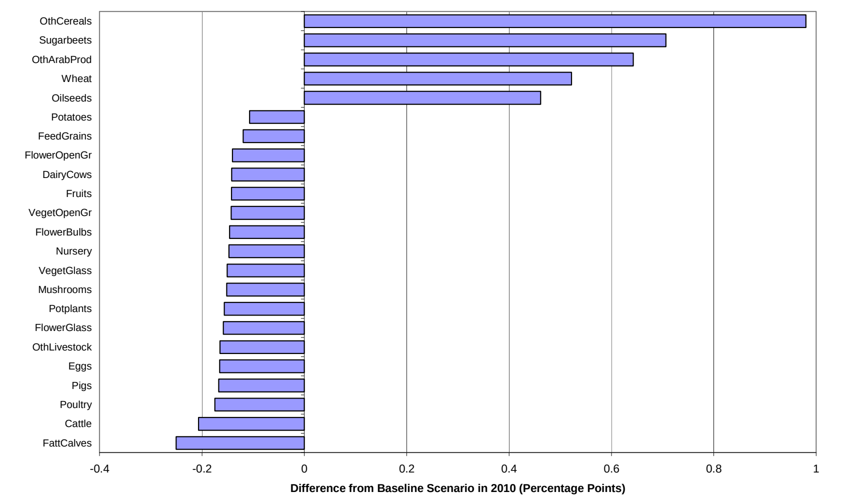
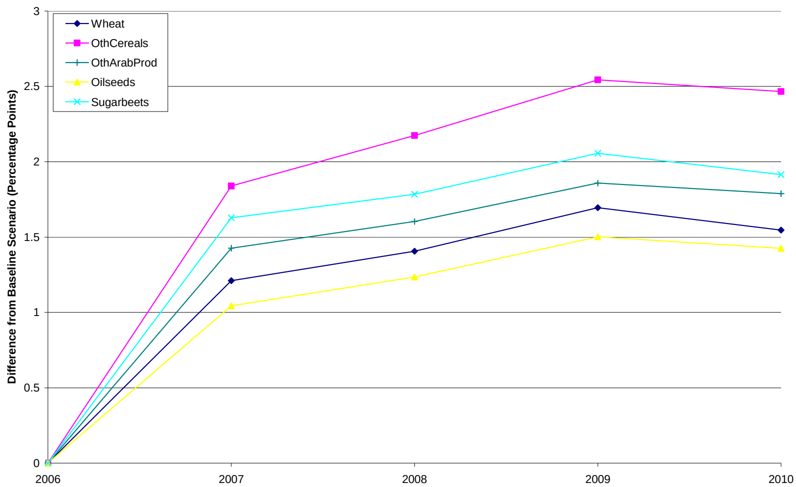


Figure 4.10 **Change in land price by sector**



The price of land in the Netherlands is higher in all sectors following the introduction of a subsidy on biobased plastics. This is due to the increased demand for land for arable crop production. This increase in the price of land reflects the inelastic supply of land in a land-constrained country. The impact of the subsidy on the price of land for crops used for bioplastics is shown above - up to 2.5% higher by 2010. The price of land for other agricultural uses is up to 0.28 percentage points higher by 2010 following the bioplastics subsidy.

5 Conclusions

The development of a national CGE model, equipped with some biobased economy interactions, has been an important aim of this study. An important conclusion is that it is possible to introduce biobased elements in the Dutch CGE model that is being developed at LEI. However, so far we have only accounted for biobased issues in two sectors: the petrochemical and plastic sectors. Using expert knowledge, it has been possible to integrate technical biobased data into the original economy-based database of the model. It should be evident that the CGE database contains more sectors that could be linked to the biobased economy in the future. The same sort of treatment can be made as has been done for ethanol and PLA. *It is therefore recommended* that the integration of technical biobased data be continued as part of the KennisBasis programme, as to do so requires a substantive research effort (building a new type of knowledge, which is still in its early stage of development).

A second conclusion is that the PLA subsidy experiment (Pilot 2) provides reliable results. Therefore it is not only possible to build a model with the right components, but such a model is indeed operational, giving an understanding of the impact of possible biobased substitutions for the existing oil-based parts of the Dutch production system. *It is therefore recommended* to check/validate the model's performance by carrying out additional experiments. A timely example would be the proposed Pilot 1 'ethanol and biodiesel for petrol' case (specifically by testing the impact of the 10% blending rate for transportation fuel that is mandated for 2010). There would undoubtedly be higher impacts on the Dutch economy found than for the PLA case! Moreover, such an additional experiment would be a better test of the newly implemented land supply function in the CGE model developed by LEI. (This function shows the substitution between the availability of land in the Netherlands versus the demand for biofuel crops.)

In terms of the underlying theme of this research - the influence of the biobased economy on agricultural markets - it is certain that the biobased economy will create a new demand for agricultural commodities for the production of goods that are now using primary or intermediary materials coming from the oil-based economy. This shift between two economic systems will:
(a) create greater demand for agricultural output and, as a consequence;
(b) require more land for the agricultural sector.

Some of the satisfaction of this new demand will be sourced domestically (within a nation state), but the amount of land required will be far beyond the capacity of a densely populated country such as the Netherlands to provide. This will have the outcome of increasing crop and land prices domestically, reducing the export of some crops, and increasing imports for the balance of the agriculturally produced commodities required.

It is not possible, within the scope of this research project, to determine whether the overall result will be positive, negative or neutral for the Dutch economy as a whole. But certainly the agricultural sector will benefit, on the one hand, from the increased commodity prices; but it may also suffer, on the other hand, from the increased rental value of land and the increased cost of living generated by higher agricultural prices. The overall cost of living - for farming and non-farming households alike - will be determined by the extent of a decrease in costs that biobased production may bring about in general.

Finally, the future focus will be on the use of second generation biofuel processes by using biomass consisting of the residual non-food parts of current crops, such as stems and leaves that are left behind once the food crop has been extracted. This would generate additional value added per hectare of land: besides the delivery of crops to the food processing industry, the farmer could deliver crop residues to the non-food industry for biomass purposes. This aspect of second generation biofuel processes is not taken into account so far, but is worthwhile to be analysed in the future.

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Appendix 1

Sector detail in ORANGE - including *biobased sectors*

Agricultural industry	**Processing industry**	**Chemical and oil/gas industry**	**Other industry and services**
Wheat	Beef slaughtering	Chemical industry-basis	Textiles
Other cereals	Calf slaughtering	Chemical industry - anorganic products	Confectionery
Potatoes	Pig slaughtering	Petro chemical - other	Leather and footwear
Feed grains	Poultry slaughtering	Petro chemical - Petrol	Timber processing and wood products (not furniture)
Other arable products	Other cattle slaughtering	*Petro chemical - Ethanol*	Pulp, paper and board
Oilseeds	Fish processing	*Petro Chemical - Biodiesel*	Paper and board products
Sugarbeets	Potato processing	Fertiliser industry	Printing and publishing
Vegetables - open ground	Vegetable processing	Chemical industry - end products	Re-production of media
Vegetables - glass	Fruit processing	*Chemical industry - PLA*	Glass, stone industry
Mushrooms	Dairy processing	Rubber industry	Base metal industry
FlowerBulbs	Animal feeding stuffs	Synthetic industry - other	Metal castings, forgings, fastenings, springs, et cetera
Potplants	Oils and fats processing	*Synthetic industry - PLA*	Machine industry
Nursery	Grain milling		Electrical equipment for industry, batteries, et cetera
Flowers - open ground	Starch processing	Extraction of oil and gas	Office machinery and computer equipment

Agricultural industry	**Processing industry**	**Chemical and oil/gas industry**	**Other industry and services**
Flowers - glass	Flour processing	Extraction other mining	Other electrical equipment, nes
Fruits	Sugar industry	Petroleum, coke processing	Telecommunication etc equipment, electronic capital goods
Cattle	Cacao, chocolate and sugar processing industry		Instrument engineering
Fattening calves	Miscellaneous foods		Motor vehicles and parts
Dairy cows	Coffee and tea processing		Shipbuilding and repairing
Pigs	Beverage industry		Railways and aerospace equipment manufacturing and repairing
Poultry	Tobacco industry		Other vehicles
Eggs	*Biorefinery*		Furniture
Other livestock			Other goods nes
Wool			Recycling
Gardening			Electricity production
Agricultural service			Water supply
Forestry			Terrain preparation for construction
Fishery			53 Burgerlijke en utiliteitsbouw
			54 Grond-, water- en wegenbouw
			55 Bouwinstallatie
			56 Bouwafwerking
			57 Verhuur van bouw- en sloopmachines

Agricultural industry	**Processing industry**	**Chemical and oil/gas industry**	**Other industry and services**
			Car wholesale distribution
			Car retail distribution
			Car service and pomps
			Wholesale distribution
			Retail distribution
			Hotels, catering, public houses, et cetera
			Public transport services
			Good transport services
			Transport by pipes
			Sea transport
			Sea transport
			Inland transport
			Air transport
			Road and other inland transport services
			Sea transport services
			Air transport services
			Travel agencies
			Postal services and telecommunications
			Bank services
			Insurance
			Finance services
			Estate agents
			Renting of movables

Agricultural industry	Processing industry	Chemical and oil/gas industry	Other industry and services
			Distribution and repair of vehicles, filling stations and other goods
			Computing services
			Research and development
			Legal and accoun-tancy services
			Engineering offices
			Advertising
			Employment agency
			Extraction of stone, clay, sand and gravel
			Other professional services
			Public administration - national government
			Public administration - local government
			Other administration and social security
			Defence
			Primary education
			Secondary education
			Tertiary education
			Health services
			Public welfare services
			Environmental private organisation
			Environmental public organisation

Agricultural industry	**Processing industry**	**Chemical and oil/gas industry**	**Other industry and services**
			Recreational and welfare services
			Gambling services
			Other services
			Domestic services
			Goods and services nes

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