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Meat consumption, production and land use: model implementation and scenarios

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G.B. Woltjer

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Abstract
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This report discusses simulations with the LEITAP model about opportunities to reduce land use as a consequence of changing meat consumption and production. In order to be able to generate plausible simulation results, the LEITAP model had to be adjusted. These changes are discussed in the first part of the report. The next part discusses the simulation experiments and their results. Finally, we discuss shortly where we stand with this type of analyses and what steps could be taken to improve on the quality of this type of analysis.

Keywords: model implementation, land use, meat consumption, meat production

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Preface

This working document reports the progress in the development of the general equilibrium model LEITAP for the use in the analysis of the international consumption, production, trade and land use effects of changes in meat and dairy consumption. Important steps have been set, i.e. tackling indirect consumption, substitution of biofuel byproducts in animal feeding, splitting out the animal feeding sector and first steps in the design of a better consumption function and the inclusion of physical quantity information in the model. The Chapters 4 and 5 that interesting results can be generated with this model, but also that further improvements are desirable. Especially the modelling of animal feeding and indirect consumption should be further improved. This requires including quantity information into the model in order to take care of energy consistency in feeding and food consumption. First steps have been made during 2009 and 2010, and hopefully we are able to finish this work in 2011 and 2012.

Recently it has been decided to rename the name of the LEITAP model towards MAGNET, (Modular Applied GeNeral Equilibrium Toolbox), because the development of a good general equilibrium model cannot be done in only one institution. The future of MAGNET is in a consortium approach, and this requires taking the name of a specific institution out of the name. Combined with the new name also the quality and versioning control will be improved; something required if other partners have to be able to use and extend the model. For this reason, the structure of the quality control as described in Chapter 2 of this document will be changed during the next year, although a lot of elements of the approach will be taken over in the new methodology. To make a difference between the new and old modelling structure, we keep the name LEITAP in this working document. Future developments of the model will take place in the new MAGNET structure.

I hope and expect that this working document will provide useful insights into the way in which a general equilibrium model can be used in analysing changes in meat and dairy consumption. The results in this document are not final, but provide good insights into the type of results that can be generated with a general equilibrium model. The simulation results discussed in Chapter 5 provide already a lot of information that provide useful insights about the complexity of the food and feed chains.

This report has been written by Geert Woltjer, but Section 3.4 on alternatives for the current consumption function has been written by Le Chen (LEI Wageningen UR). I am very grateful for her effort in this context. Her work will be the starting point for the implementation of an improved consumption function in the near future.

Geert Woltjer

Contents

Summary

This working document discusses important steps made to make the general equilibrium model LEITAP suitable for the analysis of the effects of changes in meat and dairy production for worldwide land use, trade, production, and consumption. Chapter 2 discusses the quality control of the model and database, and Chapter 3 the improvements of the model. In Chapter 4 a simple baseline is developed, while Chapter 5 discusses the policy experiments done with the model that are done with the improved model for the PBL-report 'The Protein Puzzle' (Westhoek *et al.*,2011).

The policy experiments provide some interesting results that require further investigation. We divide these conclusions in consequences of meat consumption reduction and increases in land and feed productivity. But first a general conclusion is important: the GTAP database, after splitting out the animal feed sector, is largely consistent with the stylized facts of animal feeding and production.

Reduction in EU27 meat consumption

With respect to a reduction in EU27 meat consumption, the following results our found. First, a reduction in meat consumption in Europe increases fossil energy demand because the reduction in expenditures on meat consumption free up income that are used for buying other commodities that require more fossil energy than the production of meat products.

Second, the reduction of meat consumption in the EU27 has large effects on EU27 livestock production, but much smaller effects on EU27 land use. This is because the Common Agricultural Policy (CAP) subsidizes the use of land. From the perspective of biodiversity this may not be a bad result: extensification of European agriculture implies less abandoned land and more opportunities for agricultural biodiversity, while outside Europe the smaller increase in land use may have significant effects on biodiversity reduction.

Third, the reduction of animal production in Europe gives a relatively large effect on worldwide demand for arable products by the livestock sector, because European production is relatively crop intensive compared with the world average.

Fourth, agricultural income per worker and the price of agricultural products in the EU27 is reduced a lot. The reduction in meat demand in the EU27 reduces the pressure on land and increases the outflow of labour from agriculture. Because farmers are not inclined the sector automatically when demand decreases, the reward for farming, i.e. agricultural income per worker, will decrease. As a consequence, the cost price of crop products in the EU27 is reduced.

Fifth, the price and income effects of meat consumption reduction in the EU27 are smaller in the long term, because the pressure on agricultural income per worker will be diminished when the adjustment process of agricultural labour towards less agricultural workers has been accomplished.

Sixth, the reduction in the price of crops and to a lesser extend livestock products, generates an increase in demand. As an indication, arable production is reduced only with $1.3 billion (0.65% of world production value), because the use of arable products in biofuel production is increased by $0.6 billion and consumption of arable products is increased by $ 3.5 billion.

Seventh, the use of biofuel byproducts in animal feeding implies that the reduction in crop demand for animal feeding is less than would be the case otherwise. While crops specifically grown for animal feeding can be reduced easily, the part of animal feeding that is supplied by byproducts will not be reduced much, even though the profitability of the main products may be reduced as a consequence of lower by-product prices.

In summary, the total land use effect of the reduction in the consumption of livestock products is relatively small compared with the reduction in consumption.

Increase in global land productivity
With respect to an increase in global land productivity, the following conclusions emerge. First, agricultural consumption increases as a consequences of the land productivity driven reduction in agricultural prices.

Second, only about a third of the increase in land productivity is translated into higher production per hectare. The reduction in land prices and the assumed increase in land productivity make land inputs relatively cheap and therefore extensification compensates part of the increase in land productivity.

Third, the land use effects of an increase in land productivity are even smaller than the production effects; also the increased consumption as a consequence of lower agricultural prices reduces the decrease in land use.

Fourth, because the EU-policy generates an incentive to keep land into agricultural production, the land use effects are smaller than in the rest of the world. Because the costs of land including the subsidies are also relatively small, the effect on cost price of a productivity increase is small in the EU compared with the rest of the world. Therefore, the rest of the world gets a comparative advantage and production is increased in the rest of the world at the cost of the EU27.

Fifth, the increase in land productivity is assumed to have only small effects on the productivity of the other production factors, because the model assumes that per economically effective unit of land the same amounts of production factor are used. As an alternative we could assume that the increase in land productivity also needs less capital and labour, and in that case the effect on cost price is much stronger.

In summary, also the increase in land productivity generates much smaller land use effects than you would expect because of consumption and production technology effects.

Increase in feeding efficiency
With respect to increases in feeding efficiency, the conclusions are similar to those for increases in land productivity. One feed-specific conclusions emerges: increases in feeding efficiency reduce the demand for land and therefore also the price of land. Both arable feed inputs and grassland are used more extensively as a consequence.

Model improvements
The simulation experiments give important feedback about required improvements in the model. First, the CES function as standardly used in general equilibrium models is not a good representation of the substitution process for feed because it doesn't guarantee energy and protein balances in animal feeding are satisfied.

Second, the modelling of biofuel byproducts shows the different effects of byproducts compared with purpose-grown animal feed. In reality there are more byproducts than only in biofuel production, for example with the production of vegetable oils. This should also be included in the model.

Third, the consumption effects of changes in product prices are important. These effects require also insight in the energy and protein balances of human food consumption. Inclusion of these balances may have important consequences for the size of the consumption effects of price changes.

In summary, the simulation results probably give correct qualitative results. In order to get a better insights in the quantitative plausibility of the simulation results in first instance some important elements of the model have to be improved. For most of these improvements information about supply and use tables in physical quantities is required. Important steps towards this goal have been set during the last year, but the final implementation is one of the high priority issues for the near future.

1 Introduction

The ministry of Economic Affairs, Agriculture & Innovation (EL&I) has large ambitions to develop sustainable animal production and consumption systems. Insights into the effects of meat consumption and production are also important for biodiversity policy. The Environmental Assessment Agency of the Netherlands (PBL) has two spearheads where animal production and consumption play a crucial role:

- nature, water and the green environment, focused on international biodiversity;
- sustainable development, with a focus on preservation of international production and consumption chains.

In this context PBL investigates sustainable protein chains, both qualitative and quantitative. They want to investigate the effects of Dutch, EU and global food consumption on for example worldwide biodiversity and greenhouse gasses. Policy options to reduce greenhouse gasses and biodiversity have to be evaluated, and shifts of costs to other regions in the world have to be evaluated. In order to these investigations PBL has their IMAGE and GLOBIO models to calculate land use, biodiversity and greenhouse gasses based on production information from other models. LEITAP is one of the models that will be used as input for the models IMAGE and GLOBIO. PBL uses results of a general equilibrium model like LEITAP to run simulations for their quantitative analysis.

A general equilibrium model like LEITAP is the only instrument that is able to tackle all international interdependencies, including land supply, trade, consumption and production. On the other hand, a general equilibrium model requires so much calculation time that only a limited number of sectors and regions can be handled, while the database required for such a model requires a lot of compromises. Furthermore, not all complexities can be included in such a model. The basic structure of general equilibrium models is relatively standard and straightforward, where the standard GTAP model is a good example of such a model. This model has been the starting point for the development of the LEITAP model. This model has been developed to focus more on the effects of the introduction of biofuels and to investigate European agricultural policies more in detail. To analyse the effects of biofuel policies, ethanol and biodiesel production and their byproducts have been separated out from the GTAP database, while substitution between different types of energies has been incorporated in the model. To investigate EU agricultural policies, a CAP budget has been modelled, where tax rates on land are adjusted in such a manner that the payment per hectare remains the same. Also second pillar policies, like investment subsidies, subsidies on extension and agro-environmental policies have been modelled in a stylized way.

The analysis of the effects of meat and dairy consumption and production requires new additions to the LEITAP database and model. First, in the GTAP database primary agricultural products are only for a small part bought directly as agricultural products. A lot of agricultural products are bought at the service sector, who buys it from the processing industry who buys it from the primary agricultural producers. This implies that a change in the private consumption of meat takes only a part of all private meat consumption, where a large part of the consumption is combined with a lot of other commodities. In order to synchronize a lot of tricks had to be found (Section 3.1), while for a long-term solution information about use and supply from FAO has to be used to improve the consistency in behaviour (Section 3.4). In order to analyse the reaction of the consumers on different policies and price changes, consumption behaviour has to be modelled better. For this reason, an overview of approaches to modelling consumption has been provided (Section 3.6). In order to analyse the effects of changes in meat and dairy production and consumption also the feeding of animals is an important topic. In the standard GTAP production structure, fixed coefficients are used, implying that the diet can not react to price changes of different feed components and changes in labour and capital costs, while it is very plausible that this happens. For this reason intensification in the animal sectors is modelled (Section 3.2), where special attention is given to biofuel byproducts like DDGS and oil cakes that can be very important feed inputs in an economy that is developing towards more biofuel production (Section 3.3).

The development of models for PBL requires that the quality of the modelling procedures is guaranteed. As an important step into this direction, all database adjustments have been automatized and programmed, while for the model and database system together a versioning system has been introduced. Chapter 2 describes these quality elements of the modelling and database system.

The purpose of the whole modelling exercise is to get a better instrument to project and analyse the effects of different policy options in the meat and dairy consumption and production. In order to have a point of reference, a baseline towards 2030 has been developed (Chapter 4). The policy experiments are discussed in Chapter 5. These policy experiments are part of the PBL-report "Meat, fish and dairy: consequences and choices" (forthcoming), where a descriptive analysis of the current situation of the environmental effects of meat, fish and dairy consumption and production is combined with an analysis of options to enhance the sustainability of global food supply. The results obtained by the LEITAP model are compared in this PBL-study with the results from the IMPACT model of IFPRI (see Chapter 7 of the PBL-report (Westhoek *et al.*,2011)). The focus of the PBL-report is on the applicability of the results of the two models, while the focus in Chapter 5 of this report is to analyse the plausibility and causality of the simulation results obtained from the adjusted LEITAP-model.

2 Quality control of the LEITAP modelling system

The version of LEITAP that was available at the start of the year included a lot of information where the precise source of the data and the precise calculations made were not easy to track. Because for the simulations in this project information had to be added, while more reliability checks were also required, the system of the initialization of the data had to be improved. We have chosen for a stepwise approach, where all steps are as much as possible automated. In doing this we required that updating the data in the future should also be simplified as much as possible. For this reason we tried to develop procedures that could use the LEI database system in development, called Metabase, to generate the data. In a stepwise procedure we generate the database, while we version and document the LEITAP programming system as much as possible.

In this chapter we first describe the stepwise procedure to create the database, and then the versioning system to document the LEITAP modelling system.

2.1 Steps into database generation

The starting point of the LEITAP database generation is the GTAP database. At this moment the 2001 database, but when a reliable 2004 database is available we will switch to that. Some information to the database is added before we aggregate it to our own aggregation, and some information after aggregating to the new aggregation. Because we call the GTAP aggregation step 1, we call the preparations before this GTAP aggregation step 0, and count all steps afterwards till the last step.

Step 0. Splitting biofuels from GTAP dataset

We add the biofuels ethanol and biodiesel before aggregation, and when we are able to split the animal feed sector also the feeding sector will be splitted off before we add the animal feed to it. The splitting of biofuels is introduced consistent with Taheripour *et al.* (2007). In the South and Central American countries ethanol is made from sugar cane, in the EU from wheat, and in the rest of the world from maize. Biodiesel is made from vegetable oils, all over the world. In contrast with Taheripour *et al.* (2007) all biofuels are assumed to be blended with crude oil in the petrol industry.

To standardize the whole procedure, a batch file “spitall.bat” is made that calls the batch files that prepare splitting off each biofuel (i.e. ethanol1.bat, ethanol2.bat, and biodiesel.bat), then splits the biofuel with the GEMPACK supplied program splitbat.bat, and copies the information to the next input directory. In preparing the weights information about for example trade flows and production is translated into weights that can be used in the splitting program. Consistent with Taheripour *et al*. a specific batch file is called that adjust the GTAP database for vegetable oils in Malaysia. Finally, a batch file “additive.bat” is called that transfers all demand for biofuels to the petroleum sector.

In order to have a starting point for generating biofuels of all types in all countries, a small amount of biofuel is split off in all countries, also when there is no production in 2001, the year of the database. This initial values provide starting points, where the levels of biofuels can be increased in initializing the database for 2007.

At this moment biofuel trade is only modelled to a very limited extent. The trade flows included by Taheripour *et al.* (2007) are in, but further adjustment have not been made. It is on our priority list to implement recent trade patterns into the database.

In summary, the process to include biofuels into the database is completed automated, although the programmer must check for error messages, and the steps can be traced. But the assumptions about trade and production technologies are based on rough indicators from Taheripour *et al.*, and could be refined.

Step 1. Aggregation to LEITAP aggregation with GTAPAgg

The next step is the aggregation of the GTAP regions and sectors towards the regions and sectors used in the project. This is managed by project-specific batch file, for example 0000FlexAgg.bat. The program uses the standard file Data-agg.bat supplied by GTAP, and gives a project-specific aggregation file, for example EURALIS_IIIBF_29_08_09.txt, as an input. This aggregation file can be changed to change aggregation. The batch file copies the results towards the relevant directories.

Step 2. Post-aggregation database adjustments

In the 2001 database there are some specific problems that require correction. For example, in some regions sugar can be produced without sugar cane or beet, vegetable oils can be produced without oil seeds, and dairy products can be produced without milk. For this reason, we adjust the database in such a way that at least 80% of the primary products (i.e. sugar cane and beet, oil seeds and milk) are used for the production of the secondary product (i.e. sugar, oils and dairy), and that at least 30% of the intermediate inputs of the secondary product consists of the primary product. The adjustment takes place by using a number of sectors as intermediate. For example, if milk is used in the service sector, while the service sector is delivering to the dairy industry, then we reduce milk deliveries to the service industry to increase deliveries to the dairy industry, while we compensate this with deliveries from the service industry to the dairy industry. This keeps the balances correct. In the cases when this type of adjustment is not sufficient possible, then we make smaller adjustments than the 80% and 30% above.

Also the database adjustment is steered by a batch file, in this case MILKSUGOILSADJUST.bat.

Step 3. Adding the LEITAP-specific information

The LEITAP model is more complex than the standard GTAP model. As a consequence extra information has to be added. This adding of information is managed through a model-specific batch file, for example LeitapAgg.bat, that calls the program stored in the file LEITAPagg.tab. This program combines the data created in step 2 with coefficients defined at the GTAP aggregation in LEIDATA files, and some aggregation specific information stored in a model specific file, for example MODELSPECIFIC.HAR. The model specific batch file calls all the standard routines and only differs in using a model specific data file. This makes again a lot of the data assumptions transparent. In many cases the size of coefficients is based on intuition, and not on econometric estimates.

The challenge is to fill the model-specific data file, and to have reasonable data for the LEIDATA files. For example, the land use and quantity data information is based derived from FAO data. This information is stored in the database program Metabase at LEI. In order transform this information into GTAP format mappings between GTAP and FAO sectors and regions have to be developed. A first step into this direction has been made, but a lot of improvements are required to make the system more complete and reliable. If it works, then updates of new data will become much easier.

At this moment we have a mapping to allocate arable land and crop quantities of FAO to the GTAP aggregation. The results are stored in the LEIDATA files by copying the data from metabase into the LEIDATA files. The procedure in Metabase is automatic through a GAMS program called DemoFaoGtapProdLand.gms. This is a start to automate the whole procedure from raw data to data used into the model.

Data on the amount of available land and corrections of marginal and average productivity is provided by PBL. The amount of available land for different scenarios is delivered on the IMAGE aggregation and imported directly into the model specific file. The marginal divided by average productivity of land is supplied by PBL in the form of characteristics of grid cells added. This is information is summarized in the form of function relating amount of land and marginal/average productivity. This function is estimated using EVIEWS through the program createdata.prg with the database store avmarg.wf1. To use this program, first a Delphi program RenamePBLDataFilesProject is used to rename the files from PBL into files with the LEITAP region names included, and then the results are stored into the matrix aaresults as defined in the database avamarg.wf1. This can be copied directly into the modelspecific data file.

Because information about biofuels is available in millions of tons or liters, we had to implement a procedure to transform the values in the GTAP database into physical quantities. As discussed, physical quantities of agricultural products are derived from the FAO database through procedures implemented in the Metabase database. Based on this information and information about energy efficiencies of agricultural crops it is possible to calculate the physical quantities of energy in the initial 2001 database we have created.

First, we have to define what quantities are behind the value data about the feedstock that goes into biofuels. This we do by assuming that the price of the feedstock when used in biofuels is the same as the market price of the feedstock. So, if the value of wheat production is 200 and if 2 ton of wheat are produced, then the price of wheat is 100. If 1 dollar of wheat is used in the production of ethanol, then with a price of 100, 0.01 ton wheat is used in the production of ethanol.

Second, we have to transform physical quantities into energy values. For this we use the following energy efficiencies (Table 2.1).

Table 2.1 Transforming physical quantities into energy values

Product	**Energy content in MJ per kg**
Wheat	8
Grain	8
Vegetable Oils	14
Sugar Cane	2
Crude oil	42
Biodiesel	39
Ethanol	27

Finally, the energy values used in the production of biodiesel and ethanol have to be transferred towards physical quantities of ethanol and biodiesel. This generates a possibility to convert the biofuel feedstocks in kg ethanol and biodiesel, and if useful to convert the biofuels into energy equivalents of crude oil. This last step is done in determining the shock: for biodiesel a shock of 1 Mtoe crude oil equivalents equals a shock of 42/39 Mton of biodiesel, and 42/27 Mton shock of ethanol. In case shocks would be known in mln liters instead of mln kg, a conversion factor is required to transform liters in kg. 1 liter of ethanol is 0.789 kg, and 1 liter of biodiesel is 0.88 kg.
In summary, although the generation of the data from the available files is automated, a lot of pre-processing is done in a relatively complicated way. The challenge is to create automated and traceable procedures to go from the raw data towards data used in the LEITAP program. This is accomplished for some parts of the database, but we are still far from this ideal situation.[1]

[1] But others, like the people in Purdue generating the GTAP database, also didn't reach this stage yet.

Step 4. Adding Byproducts

The next step is to add byproducts. We follow here the information used in the GTAPBIO database, that shows that about 30% of the value of the energy creating inputs used in biofuel production (i.e. wheat, maize and vegetable oils excluding palm oil) is the value of the byproducts. A program to initialize the database that the byproducts can be introduced is run through the batch file MAKEBYPRODDATABASE.bat.

The batch file MAKEBYPRODDATABASE.bat calls first the program stored in makebyproducts.tab. This program uses a file Extrasets.har where the byproducts are defined and it is also defined with which inputs in which products they are related. This information is integrated in the database, where a lot of new sets have to be defined because byproducts are not produced in their own sector but in the sector of the main product (for example DDGS is produced in the ethanol sector) while they are traded in their own sector. So, all sets related with production don't include byproducts, while the sets related with trade include them. This is a technical problem that is completely solved by the program makebyproducts.tab.

The only problem left is from which sectors the byproducts are split and in which sectors the byproducts are used. Because the byproducts are feed inputs, we split the byproducts from the general feed sector "ofd". To prevent distortions into this sector, we split only small amounts of byproducts from this sector, and will increase them through running the model. The byproducts are sold to the livestock sectors, where the value of "ofd" used in these sectors determines the distribution of the byproducts over the sectors.

After creating small numbers for the byproducts in the database, these numbers have to be blown up till 30% of the input values where they are related to. The batch file MAKEBYPRODDATABASE.bat starts for this reason a batch file called ByproductInitialization.bat. This is just running the LEITAP model and shocking the levels of byproduct production to the required levels. We prevent substitution between byproducts and unprocessed feed inputs like wheat or vegetable oilseeds, because we want to use these products as substitutes during the simulation exercises. Therefore, we use the sector ofd as a direct substitute of biofuel byproducts in initializing the database. In order to prevent large distortions in the database, the static version of the model with only substitution possibilities in feed inputs between ofd and the byproducts is used, with a very elasticity of substitution of 100. This guarantees that the price effect of the substitution of the byproducts and ofd is limited, so the distortions in the original database are as small as possible.

In summary, the byproducts are split from the sector "other feed and food" (ofd) in small amounts and distributed over the livestock sectors according to their share of "ofd" use. After initialization the required amounts of byproducts are created by running the model and shocking byproduct production, forcing the model to substitute ofd with the byproducts. This minimizes the distortions created in the database when including the byproducts.

Step 5. Creating Baseline data and parameters

To run a baseline scenario data about growth and production are required. GDP and population growth are taken from USDA (http://www.ers.usda.gov/Data/Macroeconomics/#BaselineMacroTables), where a spreadsheet template is used to convert these data towards GTAP aggregation. The data are available on a yearly base till 2030, and all data are imported in a GEMPACK data file (BaselineData.HAR). Also data from the International Energy Agency (IEA) about crude oil production are imported into this file. All these data are on a GTAP regional aggregation, creating the possibility for automatic aggregation. Data that are not region specific like the definition of the countries in the EU, are stored in a model specific file like AggregationSpecific.har. This implies that the batch file steering the creation of the baseline data is also aggregation specific, for example MakeBaselineData.bat.

Through the aggregation specific batch file the program stored in MakeBaselineData.tab creates the shock files for the database. In the future, this program can be somewhat further generalized, limiting the number of data that have to be stored in the aggregation specific data file. The program creates not only the shock files, but also the period-specific parameter files that are used in the baseline. For example, the elasticities and commodities in the feed nests are different for the initialization period till 2007 and afterwards. This guarantees that all data, including scenario specific parameter files, used for the baseline are generated automatically in a structured way.

Step 6. Making the baseline and updating the database till 2007
To go towards 2007 we update run a scenario with the variables that from 2001 to 2007 where GDP, population and crude oil, ethanol and biodiesel production are shocked. Also milk quota changes, tariff changes as a consequence of EU-policies and extension of the EU till 27 member states are implemented in this period. Production subsidies are being decoupled from production and coupled to land in the period 2004-2007. In order to prevent disturbances generated by fast increases in biofuels and their byproducts, we implement very high elasticities of substitution in the feed nest, and include only ofd and the biofuels in this feed nest, and don't allow for substitution in the fuel nest between crude oil and biofuels.

This generates a database with correct GDP, population, crude oil, ethanol and biodiesel production in 2007, that can be used as a starting point for simulations. For this project we start with policies in 2010, and so update the database till 2010, where we only shock GDP, population and crude oil production, having a constant subsidy budget for biofuel subsidies.

For the prediction periods, where differences in scenarios emerge, we shock endogenize GDP and crude oil production by first running a calibration scenario with GDP and crude oil production exogenous (Base_GDPExogenous), saving the technologies that are endogenous in this calibration run. Then we rerun the same scenario with technologies exogenous and GDP and crude oil production endogenous (Base). This Base run generates the same simulation, but when we make scenarios derived from this Base scenario, we can include the effects on GDP and crude oil production in these scenarios.

In the baseline scenario we keep the real budget for biofuel subsidies (direct and indirect) and the nominal first pillar CAP budget constant (with an assumed inflation rate of 2% per year).
In summary, we use the updating procedure of the database till 2007 to get crude oil production, biofuel production, GDP, population and some tariffs correct. The rest is determined by the model. For the period after 2007 only population, GDP and crude oil production are calibrated based on external sources, while the rest is determined by the model.

2.2 Versioning system

The LEITAP modelling system has to be put under a versioning system, called TurtoiseSVN. The whole directory generating and storing the data, and the baseline and reference scenario definitions are stored into this system. Also the programs that manage the flow of scenarios and the program used to analyse the results are stored and regularly updated to the most recent version. All versions are saved into this system.

When a new version of the LEITAP modelling system is uploaded into the TurtoiseSVN repository, as much as possible the changes are documented. This creates a log of all the changes automatically, while also the TurtoiseSVN system has some instruments to compare the files that have been changed between different versions. For the runs documented in Chapters 4 and 5, we use version

43, after using the versioning system for four months. This shows that the changes are documented and saved regularly.

The versioning system is only meant for the general development of LEITAP, not to store results of specific projects. For this purpose a special drive is reserved, where all the scenario definitions, programs and results are stored. This makes the results both reproducible and it is easy to read old scenario results.

2.3 Conclusion

Important steps have been made to improve the management of the LEITAP modelling system. All steps to create the database at LEI are reproducible, as far as processing from some input data is concerned. Some of the input processing is also programmed in some way, but quality control of these steps is still under development. Especially the use of Metabase promises important improvements and standardization in the processing from raw data towards the data used in the modelling system. An important aspect is also documentation of the quality and meaning of the data used from other databases, like the GTAP database and the FAO database. This requires further efforts.

3 Model and database improvements

In order to simulate the effects of different policy options, the standard LEITAP model had to be extended in several ways. This chapter describes the adjustments and adds a literature review about consumption functions that was not essential for the current experiments, but will be an important focal point for future improvements of the model.

3.1 Indirect demand for food

Only part of the primary agricultural sector produces products that are directly consumed by the private consumers in the model. Most primary products are processed and then sold to the service sector. The service sector sells a composite product that includes transport, health care, restaurants, etc. to the consumer. In the model the income elasticity of the service sector is much higher than of the primary agricultural sectors. This higher income elasticity is correct for most elements of the service sector, but gives problems for the demand of primary agricultural products that are bought by the service sector. In the model it is assumed that the percentage change of the inputs of a sector equals the percentage change of the output. So, if the demand for services increases with 1%, also the demand for meat increases with 1%, while in practice the share of the food component in the total service sector will decrease. So, because the income elasticity of the service sector is much higher than the income elasticity of the primary food sectors, while a lot of demand is going through non-food sectors, it is obvious that demand for primary food will be too high. For cattle (including processing) about 55% of production is going into intermediate production, although more than half of it is from cattle into cattle or other animal products. Of the intermediate deliveries to other sectors, about 65% goes into industry(25%) and services (40%). The income elasticity for services is more than one, while for cattle meat this is less than a quarter of it. Because probably this demand develops in the same direction as the direct consumption of primary agriculture, it is important to correct these elasticities.

We have decided to make adjustments in the following way. We assume that the percentage change of primary food commodities is leading for behaviour of the input coefficients of these commodities in other sectors. This implies that if the percentage change in consumption in for example the service industry is higher than for wheat, we adjust the input-output coefficient for wheat with the difference in percentage change in consumption:

```
coefficient (parameter) (all,i,TRAD_COMM) (all,j,TRAD_COMM1) dum(i,j);
formula (initial) (all,i,TRAD_COMM) (all,j,TRAD_COMM1) dum(i,j)=0;
formula (initial) (all,i,FOOD_COMM) (all,j,SEROIND_COMM) dum(i,j)=1;
formula (initial) dum("milk","dairy")=1;

Equation AF1_FOOD_TRAD
# Technical change is used to equalize direct and indirect demand#
(all,i,TRAD_COMM) (all,j,TRAD_COMM1) (all,r,REG)
    af(i,j,r) = dum(i,j)*[qp(j,r)-qp(i,r)]+
    (1-dum(i,j))*[afcom(i) + afsec(j) + afreg(r) + afall(i,j,r)
            + DUM_I_LAND(i)*ALANDFACT*aland(j,r)
            + ASCALE(i,j,r)*aknreg(r)];
```

Where af is the percentage change in technology, i.e. percentage change in the input coefficient, qp(j,r) is the percentage change of private consumption for the sector for which the input-coefficients are adjusted, qp(i,r) is the percentage change of the consumption of the food commodity that is used as an input in sector j, and all the factors starting with a represent real changes in technology.

The dummy determines if the consumption of the input is used to change the input-coefficients of the sectors, or the standard factors, like the general technological change is used. At this moment we assume that all food-inputs of industry and services are consumption related, but this can be changed easily. It is obvious that the consumption relation should not be applied to sectors that use primary goods in the production process, like feed related items in livestock, or biofuel inputs in ethanol or biodiesel production. Because for the dairy industry it is obvious that demand is consumption related, we apply the consumption elasticities in this sector (milk into dairy). But for example the sector ofd (i.e. other feed and food), including 60% consumer goods but also animal feeding, we don't like to relate technology in a direct way with consumption.

This method has the advantage that indirect consumption becomes consistent with direct consumption, but may be dangerous if inputs are involved that are used for other purposes than consumption. For example, if wheat would be used in chemical industry, it may be that this is really a technical input coefficient, and not an indirect way to consume the primary input. A lot of research is required to get into more empirically based technological change and adjustments of consumption. Especially the sector ofd should be split in order to separate consumption effects from technology effects.

Conclusion
The method to correct for indirect consumption seems to give an improvement compared with the old method where implicit technological change modelled also consumption behaviour. But a lot of theoretical and empirical details have to be worked out. Perhaps it is better to adjust the database in such a manner that indirect private consumption of primary agricultural products is allocated to the direct private consumption of primary agricultural products. This activity is not a trivial one, and requires coupling of the GTAP database with information about supply and use tables of FAO.

3.2 Modelling intensification in livestock

In the livestock sector there is an opportunity to substitute between crops (concentrates) and grass (roughage). This is not possible without limits. Intensification in livestock is in many cases related with using more concentrates at the cost of roughage. The marginal benefit of using more concentrates decreases, and efficient use of concentrates depends on management skills, the use and type of stable and also the type of animals used (i.e. capital). This implies that there is a combination of capital and skilled labour required to intensify. There is a substitution possibility between grass and a combination of capital, labour and concentrates. Again, the substitution possibility between capital and labour, and concentrates will be small, where the substitution possibility between skilled labour/capital and unskilled labour will be relatively high. Based on this line, feed substitution can be modelled as in Figure 3.1.

The value added energy nest (VAEN) consists of a feed land nest (FEEDLAND) and a non-land value-added nest (NLVAEN). The substitution elasticities is set at this moment 0.05 for the crops, and 0.1 for milk and cattle. These are much lower than they used to be, because it seems substitution possibilities are limited. For the sector "other animal products", that includes pork and chicken, land is not an important production factor, so we reduced this elasticity to zero.

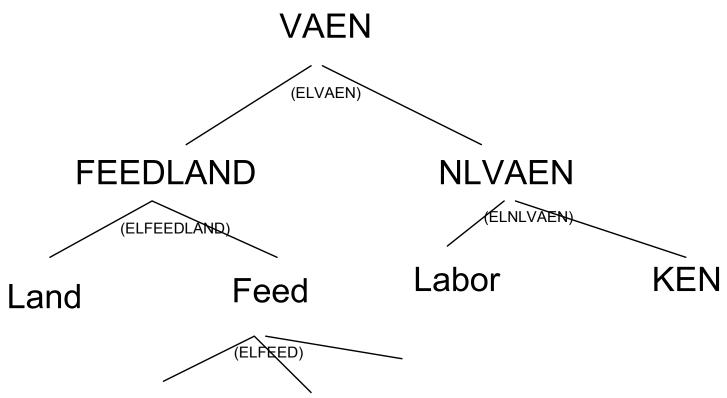

Figure 3.1. The role of feed in the value added nest

The substitution between land and animal feed represents intensification of livestock production. If less grassland is used in the livestock sector, then more feed has to be bought on the market. Because roughage from grassland is a different product than feed from crops, a very high substitution elasticity is not to be expected. We take a substitution elasticity of 0.2 as a rough indication of the available substitution possibilities. This means that a 1% increase in the price of feed of crops with a fixed price of feed from roughage results in 0.2% less feed per unit of roughage used. If the change is small, the dollar value of total feed remains roughly the same, i.e. one dollar of roughage is assumed to be equivalent with one dollar of feed from crops at pre-change prices.

The substitution elasticities between different types of feed may differ a lot. Especially, the substitution elasticities between high energy respectively high protein feed may be very high. Therefore, we extended the feednest with an extra layer: high energy feed (HEFEED), composed of for example grain and wheat, and high protein feed (HPFEED), composed of compound feed, oil cake and DDGS. The feed not included in these two nests are directly in the feed nest (Figure 3.2).

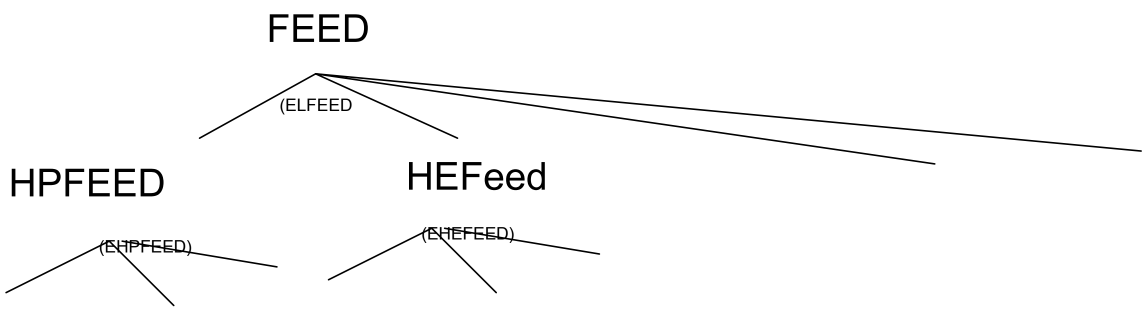

Figure 3.2. The nest structure describing substitution between feed components

In first instance we combined the vegetable oils, oil cakes, BDBP and DDGS in the high protein nest, and included other food and feed, maize and wheat in the high energy feed nest, with ofdfeed in the general feed nest. Although the system seemed nice in first instance, important problems became obvious when we did run the model. More processed sectors have less real feed per dollar than the less processed energy and proteins. As a consequence, when for example oilseeds became more expensive, the percentage increase in the price of the processed product was less, giving a competitive advantage to the processed sectors because they used less agricultural products. This implied a reduction in land use needed for feeding only because of the way the products were defined. As a consequence, we had to dig into a pragmatic solution for this problem.

The solution we took is to group the primary commodities into HPFEED, and the processed commodities into HEFeed, both with a high elasticity of substitution of 15. For the top feed nest, we used a smaller elasticity of substitution of 2. In this nest the other feed and food sector (ofd) is included next to the compound sectors HPFEED and HEFEED. In this way products with a comparative feeding value were grouped together with a high elasticity of substitution, while the commodities with a diverse feeding value were much smaller.

The solution provided above worked well for normal situations, but gave a problem during the simulations from 2001 to 2010, because during this period the biofuel production increased from almost zero to very significant levels. As a consequence, the byproduct production increased a lot, and this required a much higher elasticity of substitution and at the same time more commodities to substitute with. Therefore, in this initialization period we use an HPFEED elasticity of substitution of 100, with the other feed and food (ofd) sector included in the nest. So, in this case we used the ofd sector as an important substitute for DDGS and BDBP, taking for granted the effect on land use this has. Because in this initialization period total feeding is not changed as fundamentally as we do in the simulation experiments, the bias generated in this way is not extremely high: only a small part of ofd is reduced to be replaced by BDBP and DDGS in this period.

The description above shows that we made some progress into modelling animal feeding, but that we are still far away from the optimal way of modelling. Behind these problems is also a more fundamental problem: the CES (Constant Elasticity of Substitution) nests standardly used in general equilibrium models like GTAP and LEITAP don't guarantee that the animals will have enough energy and proteins. This could be solved by adding a linear equation that determines the amount of feed and protein that should be directly related with the production of the livestock sector. Differences between the energy and protein generated with the diet according to the CES nest and the amount required by the animals could be accommodated by adjusting one of the productivity parameters, for example the feed productivity parameter, or even the feed land productivity parameter. Discussion with specialists in this field is required for this, while the lack of precision in the data limits the opportunity for really fine-tuning the model.

In summary, we have developed a system to model animal feeding that allows for substitution between biofuel byproducts and other feed components, and that prevents that feeding components with completely different feeding values can be substituted too easily. But a lot of steps have to be made before the feeding sector is modelled in a really satisfactory manner.

3.3 Biofuel byproducts as feed inputs

For a lot of oil products animal feed is a by-product. This implies that the standard procedure in the GTAP model is not correct. For example, if demand for feed increases, then demand for products from the vegetable oils sector in GTAP (vol) will increase. The vegetable oil sector produces both vegetable oils and oil cakes. Only the oil cakes are used for feed. Oil cake and oil production is a combined production, although a limited amount of substitution is possible. For the moment, this problem is not solved.

Next to this problem, the rise of biofuel production has important consequences for animal feeding, because animal feed is a byproduct of a lot of biofuels. For the biodiesel production we explicitly model the production of an oil-cake type of byproduct. The production of this BioDiesel ByProduct (BDBP) depends on the production of oil seeds (and biodiesel) through the following formula:

```
Equation qoby1_BDBP (all,b,BP_COMM) (all,j,TRAD_COMM1) (all,r,REG)
   qoby(b,j,r)=sum{i,TRAD_COMM1,INPBYPROD(i,b,j)*qf(i,j,r)};
```

This formula tells that the production growth of by-product b equals growth of the use of input i in sector j, where for the vegetable oil sector i is oil seeds, and j is the biodiesel sector.

In order to make everything consistent, the zero profit condition needs two outputs. The value of the by-product is included in the second line:

Equation PF1_TOP_TRAD1 VFATOT(j ,r)*(ps(j,r) + ao(j,r))
+**sum{**b,BP_COMM,BYPRODUCTS(b,j,r)*(ps(b,r))**}** **(added for byproducts)**
= **sum{**i,TOP_COMM, VFA(i,j ,r) * **[**pf(i,j,r) - af(i,j,r)**]}**

In initializing the database we assume that 20% of the value of vegetable oil use in biodiesel and 30% of the value of wheat and maize use in ethanol production equals the value of the byproducts. We do this in two steps, by first splitting about 1/7 of the target production of byproducts, and then shocking the production of byproducts with 600%.

3.4 A first step into generating GTAP consistent data with Metabase

One of the challenges is to get quantity data consistent with the GTAP database, so we can use them in a consistent way in the model. In order to get a consistent result, we create in the programming language GAMS a program that maps information from FAO to the GTAP aggregation. We have included quantities and prices on the production of paddy rice, wheat, maize and other grains, vegetable oils, plant-based fibres, sugar cane and beet, vegetables, fruits and nuts, and other grains. It seems that in general the quantities are more reliable than prices, but we compared the values (calculated as FAO-quantity x FAO-price) with the information in the GTAP database. Table 3.1 shows an example.

Table 3.1. FAO versus GTAP values of wheat production in 2001

Country	Price	GTAP	FAO	FAO/GTAP
ita	159	1054.35	1022.601	0.969887
moz	149	0.0815	0.22422	2.751166
bgd	147	277.9718	245.5295	0.883289
rom	145	952.1957	1127.1	1.183685
ind	140	14438.12	9723.272	0.673444
irl	133	69.7916	102.2574	1.465183
esp	132	603.3803	659.1633	1.092451
grc	131	156.0928	288.1152	1.845794
mex	131	585.0541	429.4456	0.734027
tur	127	1751.542	2411.608	1.376849
chn	127	9728.989	11908.76	1.224049
pol	123	1220.685	1145.063	0.93805
prt	123	50.0772	18.84475	0.376314
arg	122	2686.119	1883.12	0.701056
ury	122	198.1979	17.4991	0.088291
aus	120	2361.796	2915.637	1.2345
lux	120	22.8677	6.502088	0.284335
fin	118	37.9269	57.91021	1.52689
xsa	118	2003.708	2570.034	1.282639
gbr	117	1524.917	1350.344	0.885519
svn	117	50.2569	21.2682	0.42319

It is obvious that the differences are large, although some are in the neighbourhood of each other. This may be caused both by the way production values are calculated in GTAP as by the quality of especially the FAO-prices. Even for wheat, that seems to be a relatively simple commodity, there are a lot of problems: Table 3.1 shows that FAO values are sometimes much lower and sometimes much higher than the GTAP values. For correct calculations of feed intake and use of area it seems better to use the quantity data of FAO than to depend on a general value conversion where you don't know what is behind it. But there remains a large challenge to try to improve on the available information and to correct the database for this. This requires complete recalculation of the database, and is therefore not possible within the current database.

One of the important problems with the FAO prices is that they are not completely consistent, and they are at the farm gate, implying that also the output subsidies have to be correctly implemented in the GTAP database. The FAO describes the construction of the prices as follows:

> "The term "price received by farmers" in the present series refers to the national average prices of individual commodities comprising all grades, kinds and varieties received by farmers when they participate in their capacity as sellers of their own products at the farm gate or first-point-of-sale. In actual practice it has been noted that (a) data might not always refer to the same selling points depending on the prevailing institutional set-up in the countries, (b) different practices prevail in regard to sale of individual commodities, (c) methods of arriving at national averages also differ from one country to another, and (d) as many countries do not collect producer prices, unit values used in the compilation of national accounts aggregates has been taken as the nearest approximation. In few cases, countries supplied wholesale prices. Such exceptions, wherever available, are documented in the country notes. A comparison of data among countries therefore should be considered with these limitations in mind."
> (http://www.fao.org/waicent/faostat/agricult/prodpric-e.htm)

Procedure to digest the FAO data
After creating the data in the database, we put them at this moment in an excel sheet that make the data consistent with a vertical lookup function. This automatically checks its consistency. Then we copy them as header in the Leidata that are used by the LEITAPAgg program. We add maize explicitly as a sector in order to be able to make a difference between maize and other sectors in the GTAP sector "other cereals". This is needed because IMAGE combines the non-maize cereals in "other cereals" with wheat, and separates out "maize" as a separate sector. In the LEITAPAgg program we can calculate the non-wheat, non-maize, non-rice cereals as a separate sector. We don't use this in the GTAP program, but have now the opportunity to adjust percentage changes calculated in GTAP to percentage changes consistent with the IMAGE model before we send them to IMAGE.

We use the quantity data for different purposes. At this moment the main use is the determination of the energy content in biofuels. In doing this we assume that the average price of the input is also the price when the input is used for biofuel production. This is not always the case; in further research this has to be investigated more deeply. In the future it would be useful to check also the energy and protein content of animal feeding. At this moment not enough data are included to that in a good manner.

3.5 Splitting out the animal feed sector

In analysing the database, it showed that animal feed is divided over a lot of sectors. For a lot of sectors like oils and oil seeds it may not be a bad idea to assume that the division of feed demand and other demand over countries is more or less the same. For example, in making vegetable oils, oil cakes are a by-product and therefore produced together in fixed proportions that will not differ very much between countries (perhaps with the exception of palm oil that has much less byproducts than other types of vegetable oils). But the sector ofd, i.e. other food and feed, is very heterogeneous. It includes animal feed, but also for example fruit juices and preserved fish. The countries where fish is produced may differ a lot from those where animal feed is produced, while the inputs required for its production are completely different. For this reason it is a good idea to split this sector out.

It is also a good idea from the perspective of the last section. If we assume that a lot of feed is a by-product, we should model demand for these byproducts explicitly through this feed sector. Because the sector ofd delivers in value terms ten till fifteen times as much to the animal sectors as the vegetable oil sector, we miss most of the essence if we do not split out the animal feed sector. For this reason we have been making some important steps to accomplish this, but we have not been able to simulate already with the split-out sector.

In first instance we were looking for the correct products in this sector, but this was an extremely difficult to task. For this reason, we just looked at the deliveries of the ofd sector to the animal sectors, and used this information to split the sector. This works relatively well for splitting out the deliveries, but not for the trade patterns. Therefore, we had to make a mapping between the trade statistics and the ofd sector, and make decisions about what part was animal feed. This information is used to create the weights in trade (Table 3.2 & 3.3).

Table 3.2. Definition of the other feed and food (ofd) sector

25	Ofd	Other Food: prepared and preserved fish or vegetables, fruit juices and vegetable juices, prepared and preserved fruit and nuts, all cereal flours, groats, meal and pellets of wheat, cereal groats, meal and pellets n.e.c., other cereal grain products (including corn flakes), other vegetable flours and meals, mixes and doughs for the preparation of bakers' wares, starches and starch products; sugars and sugar syrups n.e.c., preparations used in animal feeding, bakery products, cocoa, chocolate and sugar confectionery, macaroni, noodles, couscous and similar farinaceous products, food products n.e.c.

Table 3.3. Definition of the other feed and food (ofd) sector by reference to the CPC (Central Commodity Classification)

25	Ofd	212	Prepared and preserved fish
		213	Prepared and preserved vegetables
		214	Fruit juices and vegetable juices
		215	Prepared and preserved fruit and nuts
		2311	Wheat or meslin flour
		2312	Cereal flours other than of wheat or meslin
		2313	Groats, meal and pellets of wheat
		2314	Cereal groats, meal and pellets n.e.c.
		2315	Other cereal grain products (including corn flakes)
		2317	Other vegetable flours and meals
		2318	Mixes and doughs for the preparation of bakers' wares
		232	Starches and starch products; sugars and sugar syrups n.e.c.
		233	Preparations used in animal feeding
		234	Bakery products
		236	Cocoa, chocolate and sugar confectionery
		237	Macaroni, noodles, couscous and similar farinaceous products
		239	Food products n.e.c.

Although the description of the GTAP sectors above shows the importance of splitting the sector in an processed animal feed sector and a processed food sector, the problems in getting correct input-output coefficient for feed, and to map the trade data in a correct way, made it very complex to finish the splitting in time. Because splitting is extremely important to get reasonable results a first attempt has been made to do this.

The method of splitting is as follows. First, we allocate all ofd going into the animal sectors to feed. Then we use the program Splitcom to split the sector consistent with this information. With the weights created automatically in this way, we force adjustments of input-output coefficients by creating a new weight factor, where the weight of wheat, other grains, vegetable oils and oilseeds is multiplied by 50 for the feed sector, while the weight of the other inputs is divided by 10.[2] This guarantees that the type of inputs used in compound feed get a higher percentage of inputs. The end result is that about 80% of net inputs into the created ofdfeed sector is primary agriculture or vegetable oils (i.e. oil cakes).

Although this split is a first step in the right direction, further efforts are required to put more empirical information into the splitting process, or even dividing the animal sector in its components. At least trade information and more specific information about processing should be used in the splitting process. Also the vegetable oil sector should be split into two sectors, one oil cakes and the other the real vegetable oils. A co-product definition should be used as is used in the biodiesel sector now. This will be one of the challenges left for the year 2010.

3.6 A literature review relevant for future improvements of the consumption function

3.6.1 General: models of consumer behaviour

Part of the project is about changing consumer behaviour with a focus on food. This requires that food consumption is modelled in a suitable way. In this context two characteristics are important: for the baseline projections it is very important to know how food consumption changes when income per capita rises. For food consumption experiments, we first thought that it would be important to model the substitution between food categories in a correct manner, but in the end the focus of the experiments was on changing consumption outside the model. For this reason, this chapter discusses shortly the current consumption function in LEITAP, and then investigates alternative consumption function approaches. For the moment, no alternative will be implemented, both because it is a fundamental and labour intensive decision, and because it was not necessary to do the simulations in the current project.

The standard consumption as used in GTAP and LEITAP is a so-called Constant Difference of Elasticity (CDE) function. In the CDE function two parameters per commodity, i.e. a substitution and income parameter, determine own price, income and cross-price elasticities.

While the income elasticities in the CDE function are more or less fixed, in the real world the income elasticities depend on the level of income: poor countries have higher income elasticities for food

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[2] The weights don't tell how much exactly goes to the different sectors, because the Splitcom program has to satisfy a large number of balance requirements. For example, in this case 8 000 mln dollar of wheat goes still into the ofd sector, while 18 000 mln dollar goes into the ofdfeed sector. In practice this means that enough corn may go into the production of corn flakes as part of the new ofd sector. Although the weights chosen are arbitrary, the effect of these weights is less arbitrary through the balance conditions. Without additional empirical information, we don't know what input-output coefficients are the right ones.

than rich countries. For this reason, in the LEITAP model the income elasticities of the CDE are made dynamically dependent on purchasing power corrected real GDP per capita, but the other characteristics of the CDE approach remain intact. Income elasticities of demand for agricultural and food commodities are drawn based on the World Food Model that was developed by FAO in 2003. Other income and own-price elasticities derive from a variety of sources, none of which involve econometric estimation using the CDE form.

The calibration of the CDE function on income and own price elasticities implies that no information on cross price elasticities is used in calibrating the function, and in practice these cross price elasticities are extremely small. In the real world, you may assume that the cross price elasticity between different meat types is high, while the cross price elasticity between meat and electricity is very low. This differentiation is not possible in the CDE function. For this reason, it may be useful to search for alternative specifications of consumption functions. This chapter will provide an overview of some alternatives. For the moment we decided not to implement alternatives, because all experiments that were planned force consumption changes and is not using instruments to change consumer behaviour.

Although correct modelling of consumption behaviour is essential if experiments with tax or subsidy changes, or fundamental changes between relative prices are at stake, we have decided to wait to tackle this problem. The main reason is that we have decided to force changes in consumption behaviour on the model, instead of designing policy instruments for this. Another reason behind this decision is that it is very doubtful if a consumption function can describe real world changes in preferences anyhow, because all consumption functions assume consistent behaviour, where a lot of policies are focused on changing the pattern of consumption.

Nevertheless, we made a literature overview of income and substitution elasticities and different consumption functions. This may be useful for improvements in the consumption function of the LEITAP model in the future.

This section reviews seven models applied in the studies collected:
- Rotterdam model;
- Translog model;
- Almost Ideal Demand System;
- Linear Approximate / Almost Ideal Demand System;
- Linear Expenditure System – Almost Ideal Demand System;
- Quadratic Almost Ideal Demand System;
- Working-leser model.

3.6.2 Rotterdam model

This demand model was developed by Theil (1965) and Barten (1964) and has been used frequently to test economic theory. The model works in differentials. Theoretical restrictions are applied directly to the parameters.

The Rotterdam model, due to Barten (1964) and Theil (1965), takes the form

$$w_i d\log q_i = \theta_i d\log Q + \sum\nolimits_j \pi_{ij} d\log p_j \qquad i = 1,2,...,n \tag{3.6.1}$$

where w_i is the average budget share of commodity i; p_i and q_i are the price and quantity of good i, respectively; $d\log p_i$ and $d\log q_i$ represent dp_i/p_i and dq_i/q_i, respectively; $d\log Q$ is an index number for the change in real income:

$$d\log Q = \sum_i w_i d\log q_i \quad (3.6.2)$$

Demand parameters θ_i and π_{ij} are given by

$$\theta_i = p_i(\partial q_i / \partial m)\,,\ \pi_{ij} = (p_i p_j / m)s_{ij}\,,\ s_{ij} = \partial q_i / \partial p_j + q_j \partial q_i / \partial m \quad (3.6.3)$$

where m is budget and s_{ij} is the (i, j)th element of the Slutsky substation matrix, parameter θ_i is the marginal budget share of commodity i, and π_{ij} is a compensated price effect. The constraints of demand theory can be directly applied to the Rotterdam parameters:

Adding-up: $\sum_i \theta_i = 1\,,\ \sum_i \pi_{ij} = 0$ (3.6.4)

Homogeneity: $\sum_j \pi_{ij} = 0$, and (3.6.5)

Slutsky Symmetry: $\pi_{ij} = \pi_{ji}$ (3.6.6)

The Rotterdam is a particular parameterization of a system of differential demand equations, where demand parameters θ_i's and π_{ij}'s are assumed to be constant.

3.6.3 Translog model

This modelling system is known as a flexible functional form. The indirect translog model approximates the indirect utility function by quadratic form in the logarithms of the price-to-expenditure ratios. These demand equations are homogenous of degree zero. A limitation in this model is the large number of parameters to be estimated.

According to Christensen, *et al.* (1975), the use of direct and indirect translog utility functions allows to test the additivity and homotheticity on direct and indirect demand functions.

The *direct utility function U* is:

$$\ln U = \ln U(X_1, X_2, ..., X_m) \quad (3.6.7)$$

where X_i is the quantity consumed of the ith commodity. The consumer maximizes utility subject to the budget constraint:

$$\sum p_i X_i = M \quad (3.6.8)$$

where p_i is the price of the ith commodity and M is the value of total expenditure.

The first-order conditions for a maximum of utility can be written as:

$$\frac{\partial \ln U}{\partial \ln X_j} = \mu \frac{p_j X_j}{U} \qquad j = 1,2,...,m \quad (3.6.9)$$

where μ is the marginal utility of income. From the budget constraint we obtain:

$$\frac{\mu}{U} = \frac{1}{M} \sum \frac{\partial \ln U}{\partial \ln X_i} \tag{3.6.10}$$

so that:

$$\frac{\partial \ln U}{\partial \ln X_j} = \frac{p_j X_j}{M} \sum \frac{\partial \ln U}{\partial \ln X_i} \qquad j = 1,2,\ldots,m \tag{3.6.11}$$

The negative of the logarithm of the direct utility function is represented here by a function quadratic in the logarithms of the quantities consumed:

$$-\ln U = \alpha_0 + \sum \alpha_i \ln X_i + \frac{1}{2} \sum \sum \beta_{ij} \ln X_i \ln X_j \tag{3.6.12}$$

Using this form for the utility function we obtain:

$$\alpha_j + \sum \beta_{ji} \ln X_i = \frac{p_j X_j}{M} \sum (\alpha_k + \sum \beta_{ki} \ln X_i) \qquad j = 1,2,\ldots,m \tag{3.6.13}$$

We let $\alpha_M = \sum \alpha_k$ and $\beta_{Mi} = \sum \beta_{ki}$ ($i = 1,2,\ldots,m$), so that

$$\frac{p_j X_j}{M} = \frac{\alpha_j + \sum \beta_{ji} \ln X_i}{\alpha_M + \sum \beta_{Mi} \ln X_i} \qquad j = 1,2,\ldots,m \tag{3.6.14}$$

The budget constraint implies that:

$$\sum \frac{p_i X_i}{M} = 1 \tag{3.6.15}$$

The *indirect utility function V* is:

$$\ln V = \ln V\left(\frac{p_1}{M}, \frac{p_2}{M}, \ldots, \frac{p_m}{M}\right) \tag{3.6.16}$$

The budget share for the *j*th commodity from Roy's identify is:

$$\frac{p_j X_j}{M} = -\frac{\partial \ln V}{\partial \ln p_j} \Bigg/ \frac{\partial \ln V}{\partial \ln M} \qquad j = 1,2,\ldots,m \tag{3.6.17}$$

The indirect utility function is a function quadratic in the logarithms of the ratios of prices to the value of total expenditure:

$$\ln V = \alpha_0 + \sum \alpha_i \ln \frac{p_i}{M} + \frac{1}{2} \sum \sum \beta_{ij} \ln \frac{p_i}{M} \ln \frac{p_j}{M} \tag{3.6.18}$$

Using this form for the utility function we obtain:

$$\frac{\partial \ln V}{\partial \ln p_j} = \alpha_j + \sum \beta_{ji} \ln \frac{p_i}{M} \qquad j = 1,2,...,m \qquad (3.6.19)$$

$$-\frac{\partial \ln V}{\partial \ln M} = \sum (\alpha_k + \sum \beta_{ki} \ln \frac{p_i}{M}) \qquad (3.6.20)$$

If we let $\alpha_M = \sum \alpha_k$ and $\beta_{Mi} = \sum \beta_{ki}$ ($i = 1,2,...,m$), we have:

$$\frac{p_j X_j}{M} = \frac{\alpha_j + \sum \beta_{ji} \ln \frac{p_i}{M}}{\alpha_M + \sum \beta_{Mi} \ln \frac{p_i}{M}} \qquad j = 1,2,...,m \qquad (3.6.21)$$

3.6.4 Almost Ideal Demand System

The almost ideal demand system (AIDS) model presented here is developed by Deaton and Muellbauer (1980) which is of comparable generality to the Rotterdam and translog models.

The expenditure function defines the minimum expenditure necessary to attain a specific utility level at given prices. This function *c(u,p)* for utility *u* and price vector *p* is shown below:

$$\log c(u,p) = (1-u)\log\{a(p)\} + u \log\{b(p)\} \qquad (3.6.22)$$

where *u* lies between 0 (subsistence) and 1 (bliss) so that the positive linearly homogeneous functions *a(p)* and *b(p)* can be regarded as the costs of subsistence and bliss, respectively.

Next, functional forms for *loga(p)* and *logb(p)* are specified. For the resulting cost function to be a flexible functional form, it must possess enough parameters so that at any single point its derivatives $\partial c/\partial p_i$, $\partial c/\partial u$, $\partial^2 c/\partial p_i \partial p_j$, $\partial^2 c/\partial u \partial p_i$, and $\partial^2 c/\partial u^2$ can be set equal to those of an arbitrary cost function. We take

$$\log a(p) = a_0 + \sum_k \alpha_k \log p_k + \frac{1}{2}\sum_k \sum_j \gamma_{kj}^* \log p_k \log p_j \qquad (3.6.23)$$

$$\log b(p) = \log a(p) + \beta_0 \prod_k p_k^{\beta_k} \qquad (3.6.24)$$

So that the AIDS cost function is written:

$$\log c(u,p) = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2}\sum_k \sum_j \gamma_{kj}^* \log p_k \log p_j + u\beta_0 \prod_k p_k^{\beta_k} \qquad (3.6.25)$$

where α_i, β_i, and γ_{ij}^* are parameters. It can easily be checked that *c(u,p)* is linearly homogeneous in *p* (as it must be to be a valid representation of preferences) provided that

$$\sum_i \alpha_i = 1, \sum_j \gamma_{kj}^* = \sum_k \gamma_{kj}^* = \sum_j \beta_j = 0 .$$

It is also straightforward to check that (3.6.25) has enough parameters for it to be a flexible functional form provided it is borne in mind that, since utility is ordinal, we can always choose a normalization such that, at a point, $\partial^2 \log c / \partial u^2 = 0$. The choice of the functions *a(p)* and *b(p)* in (3.6.23) and (3.6.24)is governed partly by the need for a flexible functional form. However, the main justification is that this particular choice leads to a system of demand functions with the desirable properties which will be demonstrated below.

The demand functions can be derived directly from equation (3.6.25). It is a fundamental property of the cost function that its price derivatives are the quantities demanded: $\partial c(u,p) / \partial p_i = q_i$. Multiplying both sides by $p_i / c(u,p)$ we find

$$\frac{\partial \log c(u,p)}{\partial \log p_i} = \frac{p_i q_i}{c(u,p)} = w_i \tag{3.6.26}$$

where w_i is the budget share of good *i*. Hence, logarithmic differentiation of (3.6.26) gives the budget shares as a function of prices and utility:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i u \beta_0 \prod p_k^{\beta_k} \tag{3.6.27}$$

where

$$\gamma_{ij} = \frac{1}{2}(\gamma_{ij}^* + \gamma_{ji}^*) \tag{3.6.28}$$

For a utility-maximizing consumer, total expenditure *x* is equal to *c(u,p)* and this equality can be inverted to give *u* as a function of *p* and *x*, the indirect utility function. If we do this for (3.6.25) and substitute the result into (3.6.27) we have the budget shares as a function of *p* and *x*; these are the AIDS demand functions in budget share form:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\{x / P\} \tag{3.6.29}$$

where *P* is a price index defined by

$$\log P = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_j \sum_k \gamma_{kj} \log p_k \log p_j \tag{3.6.30}$$

The restrictions on the parameters of (3.6.25) plus equation (3.6.28) imply restrictions on the parameters of the AIDS equation (3.6.29). We take these in three sets

$$\sum_{i=1}^n \alpha_i = 1, \sum_{i=1}^n \gamma_{ij} = 0, \sum_{i=1}^n \beta_i = 0 \tag{3.6.31}$$

$$\sum_j \gamma_{ij} = 0 \tag{3.6.32}$$

$$\gamma_{ij} = \gamma_{ji} \tag{3.6.33}$$

Provided (3.6.31), (3.6.32), (3.6.33) hold, equation (3.6.29) represents a system of demand functions which add up to total expenditure ($\sum w_i = 1$), are homogeneous of degree zero in prices and total expenditure taken together, and which satisfy slutsky symmetry. Given these, the AIDS is simply interpreted: in the absence of changes in relative prices and "real" expenditure (*x/P*) the budget shares are constant and this is the natural starting point for predictions using the model. Changes in relative prices work through the terms γ_{ij}; each γ_{ij} represents 10^2 times the effect on the *i*th budget share of a 1 percent increase in the *j*th price with (*x/P*) held constant. Changes in real expenditure operate through the β_i coefficients; these add to zero and are positive for luxuries and negative for necessities.

The AIDS model can be aggregated over households. For details, please see Deaton and Muellbauer (1980).

3.6.5 Linear Approximate/Almost Ideal Demand System

The linear approximate, almost ideal demand system (LA/AIDS) model presented here is applied by Cashin (1991) to estimate Australian demand for meat between 1967 and 1990.

In Cashin's model, following the AIDS model developed by Deaton and Muellbauer (1980), the general form of the budget shares is:

$$W_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\{x/P\} \tag{3.6.34}$$

In Deaton and Muellbauer (1980), they used a nonlinear price index P that is defined as:

$$\log P = \alpha_0 + \sum_i \alpha_i \log p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \log p_i \log p_j \tag{3.6.35}$$

Rather than use this inherently nonlinear price index, Cashin (1991) used the linear approximate (LA/AIDS) form, with P being approximated by Stone's (1953) geometric price index ($\log P = \sum_i W_i \log p_i$). According to Cashine (1991), in general, the results obtained with the AIDS model have been found to differ only slightly from those obtained when the LA/AIDS version is estimated.

Restrictions on the parameters of equation (3.6.34) and (3.6.35) are the same as restrictions from AIDS model (see equations (3.6.31), (3.6.32), (3.6.33).

The expenditure and price elasticities for the model are given by:

$$\eta_i = 1 + \frac{\beta_i}{W_i} \tag{3.6.36}$$

$$\varepsilon_{ii} = -1 + \frac{\gamma_{ii}}{W_i} - \beta_i \tag{3.6.37}$$

$$\delta_{ii} = -1 + \frac{\gamma_{ii}}{W_i} + W_i \tag{3.6.38}$$

$$\varepsilon_{ij} = \frac{\gamma_{ij}}{W_i} - \beta_i\left(\frac{W_j}{W_i}\right) \tag{3.6.39}$$

$$\delta_{ij} = \frac{\gamma_{ij}}{W_i} + W_j \tag{3.6.40}$$

where η denotes the expenditure elasticities, ε denotes the Marshallian (uncompensated) price elasticities and δ denotes the Hicksian (compensated) price elasticities. Finally, the Allen elasticities of substitution (σ) are given by

$$\sigma_{ii} = \frac{\delta_{ii}}{W_i} = 1 + \frac{\gamma_{ii}}{W_i^2} - \frac{1}{W_i} \tag{3.6.41}$$

$$\sigma_{ij} = \frac{\delta_{ij}}{W_j} = 1 + \frac{\gamma_{ij}}{W_i W_j} \qquad i \neq j \tag{3.6.42}$$

3.6.6 Linear Expenditure System – Almost Ideal Demand System

The LES-AIDS model presented here is applied by Fan et. al. (1995) to estimate a complete demand system of Chinese rural households using pooled provincial and time-series data from 1982-90.

This model assumes that the consumer's utility maximization decision can be decomposed into two separate steps. In the first stage, total expenditure is allocated over broad groups of goods. In the second stage, group expenditures are allocated over individual commodities.

Weak separability of the direct utility function over broad groups of goods is both a necessary and sufficient condition for estimating the second stage of the two-stage budgeting procedure. Given a weakly separable utility function in a partition of commodities into N groups (N>2), price aggregation is possible if and only if the direct utility function is strongly separable into generalized Gorman polar forms, homothetically separable forms, or a combination of the two forms (Gorman). Homothetically separable utility functions are generally considered undesirable for empirical demand analysis. Hence, we choose a strongly separable function of indirect utility functions, with each group function corresponding to a specific group of commodities, and with each group function taking the generalized Gorman polar form.

The functional form chosen for the first stage is a linear expenditure system (LES). The advantage of the LES is that it is simple and it provides an intuitive economic interpretation, despite its strong separability assumption. The separability assumption is not overly restrictive for such commodities as food, housing, or clothing. The LES functional form is:

$$P_I Q_I = P_I R_I + B_I \left(E - \sum\nolimits_J P_J R_J \right) \tag{3.6.43}$$

Where $P_I Q_I$ (P_I and Q_I are aggregated price and quantity indices for commodities within group I) is expenditure allocated to group I, E is household total expenditure, and R_I and B_I are parameters to be estimated. This expenditure function can be interpreted as follows. First, the consumer purchases the minimum required quantities of each commodity group, R_I, costing $P_I R_I$. The consumer then distributes the remaining expenditures ($E-\Sigma P_J R_J$) over all commodities in fixed proportions, B_I (the marginal budget share of commodity group I). Hence, $P_I R_I$ and ($E-\Sigma P_J R_J$) can be interpreted as subsistence and supernumerary expenditures, respectively.

The uncompensated own- and cross- price elasticities associated with equation (3.6.43) are

$$\eta_{II} = (1 - B_I)P_I R_I / (P_I Q_I) - 1 \qquad (3.6.44)$$

and

$$\eta_{IJ} = -B_I (P_J R_J) / (P_I Q_I) \qquad (3.6.45)$$

The expenditure elasticities are

$$\varepsilon_i = B_I E / (P_I Q_I) \qquad (3.6.46)$$

The Almost Ideal Demand System (AIDS), developed by Deaton and Muellbauer, is used for second-stage demand estimation. The AIDS model satisfies the axioms of choice exactly, allows consistent aggregation of individual demands to market demands, and does not impose additive preferences. The model has been applied to both aggregate- and micro-level data. The share equation for the AIDS model is

$$W_{i,I} = \alpha_{i,I} + \sum_{j,I} \gamma_{ij,I} \log p_{j,I} + \beta_{i,I} \log \frac{E_I}{P_I} \qquad (3.6.47)$$

Where $w_{i,I}$ is the budget share of good *i* in commodity group *I*, $p_{j,I}$ is the price of commodity *j* in group *I*, E_I is the *I*th group's total expenditure, and P_I is the *I*th group price index.

$$\log P_I = \alpha_{o,I} + \sum_{j,I} \alpha_{j,I} \log p_{j,I} + 1/2 \sum_{i,I} \sum_{j,I} \gamma_{ij,I} \log p_{i,I} \log p_{j,I} \qquad (3.6.48)$$

With the following restrictions:

$$\sum_{j,I} \alpha_{j,I} = 1, \sum_{i,I} \beta_{i,I} = 0, \sum_{i,I} \gamma_{ij,I} = 0 \text{ (adding up)} \qquad (3.6.49)$$

$$\sum_{j,I} \gamma_{ij,I} = 0 \text{ (homogeneity)}; \gamma_{ij,I} = \gamma_{ji,I} \text{ (symmetry).} \qquad (3.6.50)$$

Following Blanciforti, Green, and King, conditional uncompensated price elasticity of commodity *i* with respect to commodity *j*s price, in the same group for the AIDS model, is

$$\eta_{ij,I} = \delta_{ij,I} + \frac{\gamma_{ij,I}}{w_{i,I}} - \frac{\beta_{i,I}\alpha_{i,I}}{w_{i,I}} - \frac{\beta_{i,I}}{w_{i,I}} \sum_{j,I} \gamma_{ij,I} \ln p_{j,I} \qquad (3.6.51)$$

Where $\delta_{ij,I} = -1$ if $i = j$, and $\delta_{ij,I} = 0$ otherwise. The conditional expenditure elasticity is

$$\varepsilon_{i,I} = 1 + \frac{\beta_{i,I}}{w_{i,I}} \qquad (3.6.52)$$

Unconditional price elasticities within the same group and unconditional expenditure elasticities can be calculated as

$$\eta_{ij} = \eta_{ij,I} + \varepsilon_{i,I} w_{j,I} (1 + \eta_{II}) \qquad (3.6.53)$$

and

$$\varepsilon_i = \varepsilon_{i,I} \varepsilon_I \qquad (3.6.54)$$

3.6.7 Quadratic Almost Ideal Demand System

The quadratic AIDS model is developed by Banks *et al.* (1997). It has properties of both a flexible functional form and a nonlinear Engel function. The indirect utility function has the form:

$$\ln V = \left\{ \left[\frac{\ln X - \ln a(\mathbf{p})}{b(\mathbf{p})} \right]^{-1} + \lambda(\mathbf{p}) \right\}^{-1} \tag{3.6.55}$$

where *V* is indirect utility, *X* is expenditure, the term $[\ln X - \ln a(\mathbf{p})]/b(\mathbf{p})$ is the indirect utility function of a PIGLOG demand system (i.e. a system with budget shares linear in log total expenditure), and the extra term λ is a differentiable, homogeneous function of degree zero of price ***p***.

We let:

$$\ln a(\mathbf{p}) = \alpha_0 + \sum_k \alpha_k \ln p_k + \frac{1}{2}\sum_j \sum_k \gamma_{kj} \ln p_k \ln p_j \tag{3.6.56}$$

$$b(\mathbf{p}) = \prod_k p_k^{\beta^k} \tag{3.6.57}$$

$$\lambda(\mathbf{p}) = \sum_k \lambda_k \ln p_k \tag{3.6.58}$$

Using Roy's identify, the budget shares are given by:

$$w_i = \alpha_i + \sum_k \gamma_{ik} \ln p_k + \beta_i \ln\left(\frac{x}{a(\mathbf{p})}\right) + \frac{\lambda_i}{b(\mathbf{p})}\left[\ln\left(\frac{X}{a(\mathbf{p})}\right)\right]^2 \tag{3.6.59}$$

When all the λ's are zero, the quadratic AIDS reduces to AIDS model.

3.6.8 Working-leser model

The Working-leser model presented here is applied in a FAO paper by Chern et. al. (2003) to analyse food consumption patterns in Japan and to conduct an econometric analysis of Japan's food demand structure.

Below we briefly present the structure of this model.

The Working-Leser food demand function is:

$$w_i = \alpha_0 + \alpha_i \log x + \sum_j \beta_{ij} \log p_j + \sum_k \gamma_{ik} H_k + \varepsilon_i \tag{3.4.60}$$

where (*i, j*) represents the 11 food items; w_i is the expenditure share of food *i* among the 11 food items; p_j is the price of food j; and *x* is the total expenditure of all food items included in the model.

H_k includes dummy variables where *k* is 25:
AGE = log age of household head;
SIZE = log of household size;
WE = number of wage earners;

BABY = number of children aged five years or under;
PRIM = number of children aged between 6 and 12 years;
HIGH = number of children aged between 13 and 18 years;
M = dummy variables for month (M1,…, M10);5
REG = dummy variables for region (REG1, .., REG9).

∑i's are random disturbances assumed with zero mean and constant variance. This model can be estimated for each food item by the ordinary least squares (OLS).

Demand elasticity formulae for Working-Leser model

The expenditure elasticity (e_i) can be expressed as:

$$e_i = 1 + \left(\frac{\alpha_i}{w_i} \right) \tag{3.6.61}$$

Taking a derivative of Equation 2.7.1 with respect to *log(p$_j$)* yields, uncompensated own (*j=i*) and cross (*j≠ i*) price elasticities (e_{ij}) are as follows:

$$e_{ij} = -\delta_{ij} + \left(\frac{\beta_{ij}}{w_i} \right) \qquad \forall i, j = 1,...,n \tag{3.6.62}$$

where δ_{ij} is the Kronecker delta that is unity if *i=j* and zero otherwise. In this study, expenditure, own-price and cross-price elasticities are evaluated at sample means.

Income elasticity in the Working-Leser model

Since the Working-Leser model uses total expenditures for the group of food items included in the model, it does not provide a direct estimate of income elasticity. In order to estimate income elasticity, the following Engel function is estimated:

$$\log x = \alpha_0 + \alpha_1 \log X + \beta \log P + \sum_k \gamma_k H_k + \varepsilon \tag{3.6.63}$$

where *x* is total expenditures of the food included in the model; *X* is total expenditures of food and non-food consumer goods and services; *P* is Laspeyres price index for the eleven foods; and other demographic and dummy variables are the same as previously defined. Remaining variables are the same as those in (3.4.). Income elasticity can be estimated from (3.4.) and (3.6.63). From (3.4.), the expenditure elasticity, $e_i = \frac{\partial q_i}{\partial x} \frac{x}{q_i}$, can be estimated. From (3.6.63), the responsiveness of expenditure on food items by income change, $s = \frac{\partial x}{\partial X} \frac{X}{x}$, can be derived. Hence, income elasticity is estimated as follows:

$$e_{i(income)} = e_i s = \left(\frac{\partial q_i}{\partial x} \frac{x}{q_i} \right) \left(\frac{\partial x}{\partial X} \frac{X}{x} \right) = \frac{\partial q_i}{\partial X} \frac{X}{q_i} \tag{3.6.64}$$

3.6.9 Some findings on model comparison

This section reviewed 7 models that are used to estimate demand system. In terms of model development, Rotterdam model and the AIDS model have particular long histories and are often applied in consumer demand systems modelling. The Rotterdam model and the AIDS model use similar linearized forms which make comparison of the two models possible.

Conclusions of many studies that compare these two models are mostly country specific. For example, Alston and Chalfant (1993) compared LA/AIDS with the Rotterdam model using data on food consumption in the United States from 1967-88. They concluded that in an application to the demand for meat, their test rejected the LA/AIDS model but not the Rotterdam model. Taljaard *et al.* (2006) concluded that LA/AIDS model fit better for South African meat demand.

Using Monte Carlo techniques, Barnett and Seck (2007) seek to determine which model performs better in terms of its ability to recover the true elasticities of demand. They found:
1. Both the Rotterdam and the fully nonlinear AIDS models perform well when substitution among goods is low. The higher the level of aggregation, the lower the elasticity of substitution among aggregates.
2. When substitution among all goods is very high, the nonlinear AIDS model performs better than the Rotterdam.
3. The Rotterdam model appears better at recovering the true elasticities, when exact aggregation within weakly separable branches of a utility tree.

3.6.10 Demand elasticities from a literature review conducted by USDA

For the results of model simulations, the size of elasticities is extremely important. Economic Research Service (ERS) of United States Department of Agriculture (USDA) has conducted a literature review over elasticities for major commodities and countries to provide a foundation for more accurate research on production, consumption, and trade. Their review presents demand elasticities from academic and government research conducted in the United States on consumer demand, as published in working papers, dissertations, and peer-reviewed journals and as presented at professional conferences in the United States. The most fully covered countries are the United States and China, and the greatest number of demand studies are for vegetables, fruits, and grocery products such as coffee and ketchup. The demand elasticities include the income elasticity, the expenditure elasticity, the own-price elasticity, and the cross-price elasticity (see Table 3.4).

Table 3.4 Elasticities (mean) collected by USDA on China and the United States.

China	Expenditure elas.	own price elas.	Income elas.	US	Expenditure elas.	own price elas.	Income elas.
Nonfood	1.417			Nonfood		-0.990	1.160
Food	1.071	-0.856		Food		-0.400	0.360
Fish	0.963	-0.426		Fish	0.789	-0.287	0.121
Meat	0.719	-0.373	0.264	Meat	0.933	-0.325	0.110
Pork	0.970	-0.423	0.253	Pork	0.686	-0.827	1.083
Beef	1.192	-0.579		Beef	1.349	-1.086	2.719
Poultry	1.156	-0.666	0.328	Poultry	0.819	-0.561	
Dairy	1.094	-0.093		Dairy	0.748	-0.703	0.117
Milk	1.436	-1.185		Milk		-0.180	

Income elasticity and own-price elasticity of 114 countries estimated by USDA
USDA has estimated food budget shares and income and price elasticities using 1996 data for nine major consumption groups and eight food subgroups across 114 countries. The broad groups include food, beverage, and tobacco; clothing and footwear; education; gross rent, fuel, and power;

house furnishings and operations; medical care; recreation; transport and communications; and other items. Food subgroups include bread and cereals, meat, fish, dairy products, fats and oils, fruit and vegetables, beverages and tobacco, and other food products (Tables 3.5 - 3.7).

Table 3.5 Food budget shares for selected countries in 1996

Country	Beverages, tobacco	Breads, cereals	Meat	Fish	Dairy	Fats, oils	Fruits, vegetables	Other foods	Total Food Expenditure
				Percent of total food expenditures					*expenditures*
Argentina	15.02	14.59	26.13	1.39	12.67	3.46	17.22	9.51	32.79
Australia	25.24	13.50	16.91	3.11	9.67	1.65	18.34	11.56	15.07
Austria	23.72	13.45	20.98	1.64	11.29	3.80	14.10	11.01	13.53
Belgium	21.06	10.78	24.72	6.06	10.96	3.87	12.38	10.16	14.36
Brazil	12.32	16.80	24.54	2.31	14.04	3.62	14.83	11.55	22.71
Bulgaria	12.35	17.07	19.68	0.81	13.94	3.49	24.78	7.89	30.70
Canada	29.48	11.43	16.46	2.65	11.19	2.11	18.12	8.57	11.68
Chile	13.41	21.48	21.79	2.06	11.19	4.60	17.33	8.13	22.96
Czech	28.09	10.25	21.27	1.76	11.63	4.03	12.38	10.59	25.00
Denmark	28.81	8.93	20.38	2.04	11.12	2.16	11.93	14.65	14.02
Egypt	9.25	24.65	23.62	4.56	10.10	8.36	12.53	6.92	48.08
Estonia	21.39	16.08	20.26	2.97	13.17	4.73	10.18	11.21	33.45
Finland	31.45	11.44	15.16	2.85	12.57	1.96	13.45	11.12	14.67
France	21.36	10.89	24.92	4.75	11.80	2.85	12.39	11.05	15.34
Germany	28.25	14.87	20.30	1.87	7.11	2.27	8.28	17.05	13.09
Greece	24.56	7.25	16.03	4.53	13.58	5.37	17.27	11.40	21.17
Hungary	23.58	10.91	20.48	0.77	12.76	4.73	12.67	14.09	22.54
Iceland	27.41	11.87	16.45	5.05	11.56	1.62	10.83	15.23	18.90
Ireland	37.33	9.51	16.38	1.97	10.09	2.74	13.42	8.56	16.59
Italy	16.18	11.32	23.58	5.40	13.90	3.86	19.14	6.61	16.59
Japan	23.15	22.28	7.82	17.02	4.79	0.66	12.79	11.49	14.88
Kenya	15.49	32.49	5.13	0.43	15.08	2.64	17.57	11.17	45.82
Latvia	18.92	12.89	18.87	3.05	14.89	4.29	17.80	9.30	41.76
Lithuania	19.88	12.92	20.67	3.47	14.10	4.83	11.98	12.15	40.42
Luxembourg	43.12	8.88	18.30	2.26	7.83	1.88	11.64	6.09	17.08
Mexico	18.88	21.67	17.33	3.12	10.88	2.30	13.00	12.82	26.63
Netherlands	24.00	12.36	18.67	2.16	12.61	2.21	15.72	12.27	13.29
New Zealand	32.93	12.62	13.87	1.74	9.20	2.28	16.85	10.51	15.19
Norway	29.99	7.70	16.35	4.85	12.79	1.52	11.06	15.73	15.98
Peru	9.23	21.30	22.18	4.65	9.62	3.70	21.37	7.95	30.31
Poland	26.53	10.33	21.24	1.55	8.35	3.44	14.49	14.07	30.65

Country	Beverages, tobacco	Breads, cereals	Meat	Fish	Dairy	Fats, oils	Fruits, vegetables	Other foods	Total Food Expenditure
Portugal	21.49	13.06	22.40	12.18	8.53	3.65	14.50	4.18	23.23
Romania	13.47	14.62	24.34	0.80	12.82	5.71	20.61	7.63	45.26
Russia	15.46	14.26	22.92	4.13	13.27	4.26	16.24	9.47	34.35
Slovakia	25.44	10.04	20.56	1.68	13.86	4.57	13.43	10.40	32.06
Slovenia	24.13	10.08	22.13	1.90	11.41	2.98	17.21	10.16	21.34
Spain	17.70	12.47	23.98	10.32	11.60	4.77	13.82	5.35	17.52
Sweden	27.47	11.42	15.18	4.37	11.71	2.29	14.44	13.12	13.26
Switzerland	26.18	10.73	16.52	1.81	15.16	1.97	17.02	10.60	14.57
Turkey	9.47	20.34	13.55	1.01	12.84	8.42	23.23	11.14	32.60
United Kingdom	47.53	8.31	12.57	2.25	6.88	1.27	12.02	9.16	16.37
United States	28.71	11.39	19.58	1.19	8.59	1.77	14.66	14.11	9.73

Source: Seale *et al.*, 2003.

Table 3.6 Unconditional income elasticities for food subgroup of selected countries in 1996

	Beverages, tobacco	Breads, cereals	Meat	Fish	Dairy	Fats, oils	Fruits, vegetables	Other foods
Argentina	0.670	0.246	0.549	0.604	0.587	0.290	0.432	0.547
Australia	0.388	0.143	0.318	0.350	0.340	0.168	0.250	0.317
Austria	0.404	0.153	0.330	0.364	0.353	0.178	0.260	0.329
Belgium	0.424	0.163	0.345	0.381	0.369	0.188	0.273	0.344
Brazil	0.877	0.404	0.663	0.747	0.718	0.429	0.533	0.661
Bulgaria	0.872	0.401	0.662	0.745	0.716	0.426	0.532	0.660
Canada	0.376	0.155	0.302	0.335	0.324	0.174	0.240	0.301
Chile	0.824	0.379	0.625	0.704	0.676	0.403	0.502	0.622
Czech Republic	0.638	0.272	0.507	0.564	0.545	0.300	0.404	0.506
Denmark	0.322	0.124	0.262	0.289	0.281	0.143	0.207	0.261
Egypt	0.898	0.411	0.685	0.770	0.741	0.438	0.550	0.683
Estonia	0.776	0.345	0.606	0.678	0.654	0.374	0.485	0.604
Finland	0.521	0.217	0.418	0.464	0.448	0.242	0.332	0.417
France	0.431	0.159	0.353	0.389	0.377	0.187	0.278	0.352
Germany	0.402	0.153	0.328	0.362	0.351	0.177	0.259	0.327
Greece	0.597	0.233	0.485	0.535	0.519	0.267	0.383	0.483
Hungary	0.745	0.337	0.576	0.645	0.622	0.362	0.462	0.574
Iceland	0.326	0.118	0.268	0.294	0.286	0.140	0.210	0.267
Ireland	0.578	0.245	0.461	0.512	0.495	0.271	0.367	0.460
Italy	0.417	0.160	0.340	0.375	0.364	0.185	0.268	0.339

	Beverages, tobacco	Breads, cereals	Meat	Fish	Dairy	Fats, oils	Fruits, vegetables	Other foods
Japan	0.388	0.160	0.312	0.345	0.334	0.179	0.247	0.311
Kenya	1.618	0.583	0.808	0.975	0.906	0.596	0.665	0.805
Latvia	0.878	0.404	0.665	0.749	0.720	0.430	0.535	0.662
Lithuania	0.829	0.373	0.644	0.721	0.695	0.401	0.516	0.642
Luxembourg	0.159	0.040	0.133	0.146	0.142	0.057	0.104	0.133
Mexico	0.807	0.360	0.630	0.704	0.679	0.389	0.504	0.628
Netherlands	0.466	0.185	0.378	0.418	0.405	0.211	0.299	0.377
New Zealand	0.523	0.217	0.419	0.465	0.450	0.242	0.333	0.418
Norway	0.426	0.170	0.344	0.381	0.369	0.193	0.272	0.343
Peru	0.944	0.439	0.699	0.792	0.759	0.462	0.564	0.697
Poland	0.798	0.361	0.617	0.692	0.666	0.388	0.495	0.615
Portugal	0.577	0.217	0.471	0.519	0.504	0.253	0.371	0.470
Romania	0.812	0.355	0.640	0.714	0.689	0.388	0.511	0.638
Russia	0.873	0.403	0.657	0.742	0.712	0.428	0.529	0.655
Slovakia	0.759	0.338	0.593	0.663	0.639	0.366	0.474	0.591
Slovenia	0.649	0.277	0.516	0.574	0.555	0.305	0.411	0.515
Spain	0.580	0.232	0.470	0.519	0.503	0.263	0.372	0.468
Sweden	0.477	0.197	0.384	0.425	0.411	0.221	0.304	0.382
Switzerland	0.330	0.112	0.273	0.300	0.291	0.137	0.214	0.272
Turkey	0.826	0.364	0.648	0.723	0.698	0.396	0.518	0.646
United Kingdom	0.432	0.169	0.351	0.387	0.375	0.194	0.277	0.350
United States	0.134	0.050	0.110	0.121	0.117	0.059	0.086	0.109

Source: Seale *et al.*, 2003.

Table 3.7 Unconditional own-price elasticities for food subgroup of selected countries in 1996

	Beverages, tobacco	Breads, cereals	Meat	Fish	Dairy	Fats, oils	Fruits, vegetables	Other foods
Argentina	-0.542	-0.199	-0.444	-0.489	-0.474	-0.235	-0.349	-0.443
Australia	-0.314	-0.115	-0.257	-0.283	-0.275	-0.136	-0.202	-0.256
Austria	-0.327	-0.124	-0.267	-0.294	-0.285	-0.144	-0.210	-0.266
Belgium	-0.343	-0.132	-0.279	-0.308	-0.299	-0.152	-0.220	-0.278
Brazil	-0.709	-0.327	-0.536	-0.604	-0.581	-0.347	-0.431	-0.534
Bulgaria	-0.705	-0.324	-0.535	-0.603	-0.579	-0.345	-0.430	-0.533
Canada	-0.304	-0.125	-0.245	-0.271	-0.262	-0.140	-0.194	-0.244
Chile	-0.666	-0.307	-0.505	-0.569	-0.547	-0.326	-0.406	-0.503
Czech Republic	-0.516	-0.220	-0.410	-0.456	-0.441	-0.243	-0.326	-0.409

	Beverages, tobacco	Breads, cereals	Meat	Fish	Dairy	Fats, oils	Fruits, vegetables	Other foods
Denmark	-0.260	-0.100	-0.212	-0.234	-0.227	-0.116	-0.167	-0.211
Egypt	-0.726	-0.332	-0.554	-0.623	-0.599	-0.354	-0.445	-0.552
Estonia	-0.628	-0.279	-0.490	-0.548	-0.529	-0.302	-0.392	-0.489
Finland	-0.422	-0.176	-0.338	-0.375	-0.363	-0.196	-0.268	-0.337
France	-0.348	-0.129	-0.286	-0.314	-0.305	-0.152	-0.225	-0.285
Germany	-0.325	-0.124	-0.265	-0.292	-0.284	-0.143	-0.209	-0.264
Greece	-0.482	-0.188	-0.392	-0.433	-0.420	-0.216	-0.310	-0.391
Hungary	-0.603	-0.272	-0.466	-0.522	-0.503	-0.293	-0.373	-0.464
Iceland	-0.264	-0.096	-0.216	-0.238	-0.231	-0.114	-0.170	-0.216
Ireland	-0.468	-0.198	-0.373	-0.414	-0.401	-0.219	-0.297	-0.372
Italy	-0.337	-0.129	-0.275	-0.303	-0.294	-0.150	-0.217	-0.274
Japan	-0.314	-0.129	-0.252	-0.279	-0.270	-0.145	-0.200	-0.251
Kenya	-1.309	-0.471	-0.654	-0.788	-0.733	-0.482	-0.538	-0.651
Latvia	-0.710	-0.327	-0.537	-0.606	-0.582	-0.348	-0.432	-0.536
Lithuania	-0.671	-0.301	-0.521	-0.583	-0.562	-0.325	-0.417	-0.519
Luxembourg	-0.128	-0.032	-0.108	-0.118	-0.115	-0.046	-0.084	-0.108
Mexico	-0.653	-0.291	-0.510	-0.570	-0.549	-0.315	-0.408	-0.508
Netherlands	-0.377	-0.149	-0.306	-0.338	-0.327	-0.170	-0.242	-0.305
New Zealand	-0.423	-0.176	-0.339	-0.376	-0.364	-0.196	-0.269	-0.338
Norway	-0.344	-0.138	-0.278	-0.308	-0.298	-0.156	-0.220	-0.277
Peru	-0.764	-0.355	-0.565	-0.641	-0.614	-0.374	-0.456	-0.563
Poland	-0.646	-0.292	-0.499	-0.559	-0.539	-0.313	-0.400	-0.498
Portugal	-0.466	-0.176	-0.381	-0.420	-0.408	-0.205	-0.300	-0.380
Romania	-0.657	-0.287	-0.518	-0.577	-0.557	-0.314	-0.413	-0.516
Russia	-0.706	-0.326	-0.532	-0.600	-0.576	-0.346	-0.428	-0.530
Slovakia	-0.614	-0.273	-0.480	-0.536	-0.517	-0.296	-0.384	-0.478
Slovenia	-0.525	-0.224	-0.418	-0.464	-0.449	-0.247	-0.332	-0.416
Spain	-0.469	-0.187	-0.380	-0.420	-0.407	-0.213	-0.300	-0.379
Sweden	-0.386	-0.159	-0.310	-0.344	-0.333	-0.178	-0.246	-0.309
Switzerland	-0.267	-0.091	-0.221	-0.242	-0.236	-0.111	-0.173	-0.220
Turkey	-0.668	-0.294	-0.524	-0.585	-0.564	-0.320	-0.419	-0.522
United Kingdom	-0.349	-0.137	-0.284	-0.313	-0.304	-0.157	-0.224	-0.283
United States	-0.108	-0.040	-0.089	-0.098	-0.095	-0.047	-0.070	-0.088

Source: Seale *et al.*, 2003.

3.6.11 Conclusion on consumption modelling and elasticities

The overview of modelling approaches for consumption shows that none of the approaches explicitly includes calorie restrictions in the model. The most flexible approach seems to be the Quadratic Almost Ideal Demand System, but such a consumption function requires a lot of information. For the moment the implementation of an improved consumption function did not have the first priority, but this large investment is needed if you would like to have more reliable projections of consumption.

The overview of the elasticities from USDA shows estimates of income and price elasticities, but these differ from those used by FAO or in the current LEITAP model. Furthermore, they don't provide information for changes in these elasticities when real GDP per capita changes, as happens in the scenarios in this report. For this reason, the choice of elasticities requires further investigation, and this is much related with the way in which consumption is modelled. The current relatively ad hoc approach of income adjusted CDE functions will be kept till it is possible to come to a significantly better consumption function.

3.7 Conclusion

Some improvements in standardizing and improvement of input data, splitting out sectors that are too aggregated, and improving the modelling of animal feeding, including the use of byproducts, have been made. For the consumption function an overview has been made of different types of consumption functions and some income and price elasticities have been presented. This is a starting point for the development of a better consumption module in the LEITAP model.

The extensions to the LEITAP model have been important first steps towards improving the suitability of the model to analyse the global effects of changes in consumption and production of meat and dairy. Handling indirect food demand through correction of input-output coefficients, modelling substitution possibilities between roughage and concentrates, modelling substitution possibilities between different feed components, including biofuel byproducts, and splitting out the animal feed sector from the broad GTAP sector “other feed and food” were very important steps in improving the model.

Despite these extension, important steps still have to be made. The logic of animal feeding and consumption behaviour requires also calorie and protein inputs are consistent with feed requirements. This implies that quantities of food and feed have to be taken into account explicitly. For this reason, important steps towards the inclusion of quantity data from FAO have been made. Regretfully, this work was much more difficult and time consuming than expected. As a consequences, the benefits of this work could not be implemented in the current model version. Also the work on the consumption function is a good starting point for future improvements of the model, but was too complicated to be really implemented in the current version of the model.

In summary, important steps towards model improvement have been made. These improvements make the model more reliable for the analysis of food consumption and production. Chapters 4 and 5 would not have been very useful without this work. But very important steps, especially with respect to the inclusion of quantity data into the model, have still to be made.

4 The baseline

4.1 The sources of the baseline

The base year database

The current projections are based on the 2001 GTAP database, where some information about current land use is added, based on FAO-data. At this moment there is a 2004 database available, but the first version didn't have the required quality for agricultural analysis. We will investigate to what extend the recent release of an improved version of the 2004 database is sufficient for our purposes.

For the simulations we will use 2010 as a base year. This implies that we have to run the model towards 2010 to make a database for 2010, where we use some information of 2010 to guide the model run. In any case, we use GDP, population, and crude oil production with their most recent available estimates. Also ethanol and biodiesel production is updated till this year. We extend the EU with the new member states. We adjust for EU-policy changes in the period between the base year and 2010. This includes decoupling and the sugar reforms.

USDA Population and GDP projections

The USDA published population and GPD projections till 2030 (http://www.ers.usda.gov/Data/Macroeconomics/#BaselineMacroTables). Their population projections are based on detailed international projections from the US Census Bureau (Census Bureau International Population Database, to be found in http://www.census.gov/ipc/www/idb/estandproj.php). The GDP series starts with the 2005 U.S. dollar GDP series derived from the latest edition of the World Bank's *World Development Indicators* and is filled in using other data sources such as Oxford Economic Forecasting, Global Insight, Project Link, and the International Monetary Fund's *International Financial Statistics*. Conversion to dollars is based on a fixed 2005 exchange rate. The advantage of using the USDA series is that they are available at a low aggregation level, i.e. 190 countries and 34 regions of the world, are consistent and easily accessible.

Based on the USDA population projections and the GDP projections it is assumed that labour supply follows population and that capital growth equals GDP growth. This last assumption is consistent with the stylized facts of economic growth, one of which is that the capital-output ratio is roughly constant over time. For natural resource growth it is assumed that it is 25% of GDP growth. Available land is based on information from the IMAGE model that is derived from FAO projections.

Based on the GDP projections, technology is calibrated in the model. This calibrated technology is used in all simulations. In the calibration procedure it is assumed that different sectors have different rates of productivity growth. The relative sectoral growth rates are based on Kets and Lejour (2003) who have examined the historical developments in sectoral total factor productivity in OECD countries between 1970 and 1990. This implies that primary agriculture has a much faster growth rate than services and even than a lot of industrial sectors. Next to the decisions about the distribution of technology over sectors, also decisions had to be made about the distribution of this productivity over different production factors. We assume that changes in productivity are mainly labour saving, but also intermediate inputs and natural resource saving. It is a stylized fact of economic growth history that capital intensity does not change, which implies a zero increase in capital productivity. Improvements in capital goods generate savings in the other production factors.

IEA Crude oil production projections
In the World Energy Outlook 2009 the International Energy Agency (IEA) suggests that crude oil prices will rise to 120 dollars per barrel. For the moment we don't follow this projection directly, but use the IEA projections of crude oil production and make the projections of energy prices based on the structure of the LEITAP model. If the crude oil price in 2001 is about 21 dollar, then the crude oil price in our simulations is about 70 dollars per barrel in 2030.

FAO/PBL land productivity projections
Land productivity projections are based on FAO projections till 2030 as used in the study World Agriculture: Towards 2015/2030 - An FAO Perspective (Bruinsma, 2003). These projections are made consistent with the IMAGE land use database, and include adjustments for the quality of land that is used consistent with the IMAGE land allocation and climate model.

Policy assumptions
For the baseline we implement only a limited number of policies that are certain to be implemented until 2030. We assume that the nominal EU budget remains constant with 2% inflation. So, the real budget is reduced with 2% a year. We implemented a cattle market reform in the period 2001-2004, a milk reform in the period 2004-2007, and a sugar reform in the period 2007-2010. In the period 2001-2004 the EU is extended till 25 EU-members, and in the period 2004-2007 with two other EU-member (Bulgaria and Rumania). In the period 2004-2007 a type of decoupling is modelled, implemented as allocation of first pillar subsidies to land and equalizing the subsidy rate on land rates over sectors.

It is assumed that sugar quota are active during the whole simulation period, while milk quota are abolished in 2013. This is done by increasing the quota by 6% in the period 2007-2010, and abolishing them completely afterwards.

For the Netherlands the sector "oap", i.e. pork and chicken, is made exogenous because the size of the sector is determined by the manure policy, a policy that is specific for the Netherlands with its high pork density.

4.2 A short characterization of the baseline

For the macroeconomic simulations we use an aggregation with maximum consistency between the IMAGE model and LEITAP. Most countries of the EU27 are separated out. Only Bulgaria-Rumania, Belgium-Luxemburg, Cyprus-Malta and the Baltic countries are taken together. The rest of the world is divided into 23 regions, where large countries like the US, Canada, Japan, Brazil, China and India are separated out.

In the sketch below, we will aggregate information to the world, the EU15 (EU member states in 2000), the EU12 (new EU member states), High Income countries (USA, Canada, Australia, New Zealand), Central and South America, Asia, Africa and the Rest of the World (Russia, Turkey, and the rest of Europe).

GDP and population
Tables 4.1 and 4.2 show the assumptions about population and welfare growth between 2001 and 2030, according to the USDA database. We see in general a decrease in the growth rate of population, where population is decreasing in the EU12 and after 2020 also in the EU15. Population growth in Africa remains very high, but decreases gradually.

Table 4.1 Yearly percentage population growth rate in the baseline

	World	EU15	EU12	HighInc	C&SAmer	Asia	Africa	ROW
2001-2004	1.21	0.27	-0.17	0.97	1.37	1.20	2.21	0.06
2004-2007	1.19	0.23	-0.16	0.95	1.33	1.18	2.15	0.08
2007-2010	1.17	0.19	-0.16	0.92	1.26	1.16	2.11	0.06
2010-2013	1.14	0.14	-0.18	0.89	1.20	1.13	2.06	0.03
2013-2020	1.05	0.07	-0.26	0.85	1.08	1.01	1.94	-0.04
2020-2030	0.87	-0.04	-0.43	0.80	0.88	0.79	1.75	-0.16
2001-2030	1.04	0.09	-0.28	0.87	1.10	1.00	1.96	-0.04

Source: LEITAP, based on USDA.

Table 4.2 Yearly percentage growth rate of GDP per capita in the baseline

	World	EU15	EU12	HighInc	C&SAmer	Asia	Africa	ROW
2001-2004	1.55	1.18	4.27	1.64	1.18	2.74	2.17	4.06
2004-2007	2.44	2.18	5.88	1.71	3.63	4.07	3.32	5.12
2007-2010	0.57	0.23	4.42	-0.37	2.10	2.15	3.49	2.82
2010-2013	2.29	1.95	4.30	2.10	2.81	3.48	3.19	3.51
2013-2020	2.33	1.90	3.69	2.03	2.93	3.53	2.76	3.67
2020-2030	2.70	1.95	3.62	1.99	3.04	4.17	2.74	3.90
2001-2030	2.20	1.70	4.09	1.70	2.76	3.57	2.87	3.83

Source: LEITAP, based on USDA.

With respect to GDP per capita (Table 4.2) it is assumed that high income countries show less growth than low income countries, where Africa is catching up much less than Asia because of its faster population growth and political instability. The new EU members are able to catch up from about 25% towards almost 50% of EU15 purchasing power corrected GDP per capita.

Agricultural production

Agricultural production is determined by the LEITAP model. The location of production is determined by a combination of demand and supply factors. In general, arable production is growing less than GDP, because agricultural consumption is not very income elastic. For some commodities, like rice and wheat, the income elasticity of consumption is even negative. Because of differences in consumption growth, land availability and differences in the development of labour and capital cost (where the assumption that productivity growth is faster in agriculture than in the average economy is important) arable production is mainly taking place outside Western Europe (see Table 4.3 & 4.4).

Table 4.3 Yearly percentage growth rate of arable production per capita in the baseline

	World	EU15	EU12	HighInc	C&SAmer	Asia	Africa	ROW
2001-2004	1.64	1.18	1.91	1.80	0.70	1.90	1.31	4.86
2004-2007	1.52	1.37	1.68	0.62	2.84	1.55	1.71	4.04
2007-2010	0.12	-1.07	0.84	-1.75	1.14	0.34	2.03	1.40
2010-2013	0.75	0.33	0.81	1.43	1.34	0.60	1.53	2.16
2013-2020	0.46	0.14	0.63	0.87	1.00	0.35	0.98	1.88
2020-2030	0.61	-0.07	0.92	1.48	1.13	0.44	1.14	1.67
2001-2030	0.74	0.19	1.01	0.93	1.25	0.69	1.31	2.31

Source: LEITAP.

Table 4.4 Percentage growth of arable land in the baseline

	World	EU15	EU12	HighInc	C&SAmer	Asia	Africa	ROW
2001-2004	7.28	6.70	10.51	8.63	4.87	6.02	6.07	13.15
2004-2007	5.41	-7.64	4.35	3.27	10.19	4.60	8.36	10.22
2007-2010	1.68	-1.69	0.44	-5.01	5.07	2.42	8.26	-0.08
2010-2013	3.61	-0.74	0.23	5.69	4.74	1.50	7.80	3.16
2013-2020	5.93	-1.88	-1.45	9.02	8.03	1.68	14.08	5.95
2020-2030	12.99	-2.45	-1.57	27.57	14.30	5.33	22.35	6.73
2001-2030	42.59	-7.97	12.60	56.63	57.01	23.47	87.22	45.37

Source: LEITAP.

As a consequence of this distribution of production, land use growth is also distributed unequally over the world. We see a decline in agricultural land use in the EU15 (5% in 30 years, see Table 4.5), and a fast increase in land use in the rest of the world outside Asia.

Table 4.5 Percentage growth of total agricultural land in the baseline

	World	EU15	EU12	HighInc	C&SAmer	Asia	Africa	ROW
2001-2004	2.21	0.88	14.20	2.63	0.87	2.33	0.53	7.44
2004-2007	2.90	-0.65	2.05	0.91	5.86	1.73	3.76	7.67
2007-2010	0.01	-1.13	0.30	-3.60	1.70	-0.14	3.23	-1.18
2010-2013	1.88	-0.44	0.08	2.33	2.07	0.11	5.10	1.51
2013-2020	2.33	-1.41	-1.04	2.41	2.45	-1.02	8.79	2.34
2020-2030	5.03	-2.13	-2.29	8.58	2.54	-0.37	14.79	1.76
2001-2030	15.19	-4.80	13.12	13.59	16.45	2.62	41.32	20.85

Source: LEITAP.

An important background of the land productivity growth is the growth in production per hectare. This production per hectare is especially fast in the livestock sectors, showing an intensification of production. This intensification in livestock also explains partly why more arable land is needed for production (Table 4.6 & 4.7).

Table 4.6 Percentage growth of exogenous land productivity in livestock in the baseline

	World	EU15	EU12	HighInc	C&SAmer	Asia	Africa	ROW
2001-2004	10.29	0.51	0.58	7.75	9.14	9.49	16.67	8.61
2004-2007	10.52	0.51	0.58	7.90	9.16	9.56	16.91	8.66
2007-2010	10.75	0.51	0.58	8.05	9.19	9.63	17.15	8.71
2010-2013	7.79	0.15	1.42	5.90	6.86	7.69	10.81	6.86
2013-2020	19.46	0.36	3.37	14.55	16.79	19.01	27.27	16.85
2020-2030	21.43	-1.00	12.85	17.44	21.63	23.08	22.66	23.77
2001-2030	111.09	1.03	20.37	78.96	97.47	107.42	176.42	98.26

Source: LEITAP.

Table 4.7 Percentage growth of exogenous land productivity of arable land in the baseline

	World	EU15	EU12	HighInc	C&SAmer	Asia	Africa	ROW
2001-2004	3.42	1.53	1.14	3.30	2.78	3.46	4.71	3.86
2004-2007	3.44	1.55	1.15	3.33	2.80	3.48	4.72	3.90
2007-2010	3.47	1.57	1.15	3.37	2.81	3.51	4.73	3.94
2010-2013	3.37	1.81	1.85	3.40	2.96	3.76	4.26	2.16
2013-2020	8.13	4.31	4.39	8.20	7.09	9.09	10.26	5.14
2020-2030	11.77	5.21	8.76	12.17	10.84	12.83	14.34	7.88
2001-2030	38.30	17.01	19.65	38.47	32.76	41.52	50.95	29.97

Source: LEITAP.

4.3 Technological change in the baseline

Technological change is one of the fundamental drivers of economic change. For this reason, it is important to get a better grasp on the changes in technology, and especially input coefficients, implicit in the combination of GDP per capital developments and the distribution of technology over production factors and sectors.

Table 4.8 suggests that the average cost price of services increases with 11%, while the cost price of arable production is reduced with 60%. Although also in services the volume of inputs per unit of output is reduced, the price of the inputs increases more than the reduction in its volume. This is explains why the cost price of services increases. This is for example the case with labour, where the real wage increases more than the volume used per unit of product in services is reduced.

Table 4.8 Cost price development of firms in the world

	Arable	Livestock	Industries	Services
Value	-59	-46	-23	11
Volume	-48	-31	-28	-13

Source: LEITAP.

Table 4.9 provides an impression for the period 2001-2030 of the change in input requirements per unit of product of different groups of inputs in the different sectors. This provides averages over groups of sectors in the world. In arable production and industries labour saving technological change is very high, while also savings on the inputs of industries and services are high (Table 4.10 & 4.11).

Table 4.9 Average worldwide percentage change in input cost per sector (2001-2030)

	Arable	Livestock	Industries	Services
Land	-29	-19	0	0
Labour	-68	-50	-64	-43
Capital	-3	7	-16	23
Natural Res.	0	0	-43	0
Arable	-9	-24	-23	-50
Livestock	-62	-24	-47	-39
Industries	-65	-48	-6	-22
Services	-61	-44	-61	-2

Source: LEITAP.

Table 4.10 Average worldwide percentage change in cost price per region and sector (2001-2030)

	Arable	Livestock	Industries	Services	ALL_COMM
World	-59	-46	-23	11	-4
EU15	-37	-30	-18	10	0
EU12	-44	-45	-16	11	-4
HighInc	-41	-36	-18	5	-2
C&SAmer	-55	-49	-10	12	0
Asia	-68	-57	-31	14	-10
Africa	-54	-42	21	12	6
RusTurRestEUR	-63	-53	2	46	25

Source: LEITAP.

Table 4.11 Percentage change in the volume of input use per unit of product (2001-2030)

	Arable	Livestock	Industries	Services	ALL_COMM
World	-48	-31	-28	-13	-17
EU15	-35	-21	-23	-9	-12
EU12	-41	-26	-22	-12	-14
HighInc	-34	-22	-24	-12	-13
C&SAmer	-45	-27	-25	-15	-16
Asia	-52	-39	-31	-16	-20
Africa	-48	-33	-27	-16	-20
RusTurRestEUR	-58	-43	-38	-19	-23

Source: LEITAP.

If we compare cost price developments in different regions, then we see that Asia and Central and South America are creating a comparative advantage in arable production, while Asia is even better in industries. We find the effects of these cost price developments partly back in the development of export volumes (Table 4.12). But we have to be aware that not only cost price development is relevant, also connections with the right markets. For example, the integration of the EU12 in the EU generates much larger increases in exports than can be based on cost price development only, while Africa performs worse than could be expected based on cost price development, because Africa doesn't have trade relationships with the growing markets. And this lack of relevant trade relationships depends on the ability to produce the right products.

Table 4.12 Percentage change in exports volume at world prices (2001-2030) (Ref)

	Arable	Livestock	Industries	Services	ALL_COMM
World	0	0	0	0	0
EU15	-14	-22	29	191	72
EU12	149	389	64	136	88
HighInc	15	-7	45	205	89
C&SAmer	58	281	82	195	102
Asia	143	233	399	110	340
Africa	110	124	125	113	120
RusTurRestEUR	254	530	154	71	136

Source: LEITAP.

The EU15 is losing market share in agriculture because of smaller decreases of cost price than in other regions of the world. This is caused by the assumed catching up effect of GDP per capita: a fast increase in technology is assumed to increase wages in general and therefore the relative cost of services. Because technological change is faster in agriculture than in for example services the reduction in cost because of technological change is higher than the increase in cost because of rising wages. As a consequence, economies with a lot of technological change generate a comparative advantage in agricultural products.

Table 4.13 Percentage change in production volume (2001-2030)

	Arable	Livestock	Industries	Services	ALL_COMM
World	49	55	146	123	133
EU15	-5	-4	24	65	52
EU12	11	30	97	173	131
HighInc	31	36	69	101	93
C&SAmer	68	88	133	195	165
Asia	49	89	292	192	231
Africa	134	169	201	267	240
RusTurRestEUR	70	63	167	168	171

Source: LEITAP.

The development of the price of GDP (Table 4.14) indicates the development of the real exchange rate of countries. For example, the EU15, South and Central America, but especially Africa and the rest of the world, increase their real exchange rate. The reasons behind this are very complex, including differences in technological change for sectors focused on the domestic market compared with international sectors.

Table 4.14 Percentage change in the price of GDP (2001-2030)

World	EU15	EU12	HighInc	C&SAmer	Asia	Africa	RusTurRestEUR
-0.55	2.89	-3.18	-0.75	1.84	-6.15	12.9	31.6

Source: LEITAP.

Interesting information can also be provided by the change in input costs of the different inputs. We see that everywhere the cost of land per unit of product is reduced as a consequence of land productivity increases with stable or lightly decreasing land prices per hectare, but that in Africa the assumed fast productivity increase of land has only small effects on the cost of land per unit of product as a consequence of large land price increases. In Africa the cost of service inputs is compensated by productivity increases, in contrast with the situation in other regions of the world (Table 4.15 & 4.16).

Table 4.15 Percentage change in costs of different inputs in different regions (2001-2030)

	Land	Labour	Capital	Nat. Res	Arable	Livestock	Industries	Services
World	-13	1	13	398	-68	-65	-22	0
EU15	-54	12	11	62	-56	-59	-24	7
EU12	-72	18	35	67	-76	-75	-24	15
HighInc	-50	6	8	262	-57	-57	-28	3
C&SAmer	-50	19	11	334	-67	-69	-27	9
Asia	-26	-6	19	325	-80	-72	-27	-4
Africa	-2	10	18	552	-61	-62	-19	0
RusTurRestEUR	-39	29	50	259	-80	-76	-3	38

Source: LEITAP.

Table 4.16 Percentage change in input use per unit of output in different regions (2001-2030)

	Land	Labour	Capital	NatlRes	Arable	Livestock	Industries	Services
World	-52	-50	9	-39	-41	-41	-4	-10
EU15	-45	-32	9	-23	-31	-40	-16	-2
EU12	-57	-60	28	-42	-57	-54	-13	5
HighInc	-50	-34	8	-37	-29	-33	-13	-3
C&SAmer	-52	-49	11	-49	-37	-39	-19	-3
Asia	-66	-69	12	-53	-60	-51	-1	-16
Africa	-57	-54	15	-57	-29	-36	-20	-11
RusTurRestEUR	-57	-62	9	-49	-59	-55	-16	-7

Source: LEITAP.

4.4 The reference scenario

As a point of reference in the policy experiments that will be discussed in Chapter 5 we will not use the baseline, but the baseline with one additional policy implemented: milk quota abolition. It is standard practice at LEI to have a baseline without milk quota abolition, but to add milk quota abolition when doing reference scenarios. Sometimes also uncertain policy changes like a WTO agreement are included in a reference scenario, but the disadvantage is that this is not an already agreed policy. Milk quota abolition has been more or less decided to be finished in 2013. For this reason, we increase the milk quota with 6% between 2010 and 2013 and then abolish them. The influence on the policy experiments is very small.

4.5 Conclusion

The baseline is a starting point for analysis. It is a best guess of the future without assuming too many changes. We have chosen for USDA macro assumptions, IEA crude oil production assumptions and FAO/PBL productivity projections. Especially predictions of future technological developments are very difficult, and it is important to make these assumptions explicit, as we have done in the last section. Such an overview may be a starting point for further thinking about the future, but for this report the baseline is just a starting point for doing policy experiments. This is the topic of the next chapter.

5 Policy experiments

5.1 Definition of the scenarios

Policy instruments focused on the reduction of the environmental effects of the consumption of animal products may be either focused on changing consumption behaviour or on measures to change production. The simulated scenarios have been defined by PBL and are described below, with a focus on the way they are implemented in the LEITAP model.

Consumption scenarios

For all consumption scenarios we target consumption of specific food categories by swapping the consumption (qp) with the tariff rate on this product (tp). This implies that for the same amount of expenditure a different amount of real consumption is possible. To compensate for this, we change all other tariffs on consumption expenditures, in order to keep real expenditures constant. We do this by the following formula:

equation tpcorr1 (**all**,r,REG)   **Sum{**i,TRAD_COMM,VPA(i,r)* **[**tpcorr(r)+tpcorrswap(r)+tp(i,r)**]}**=0;

where VPA is the value of private consumption at agent prices as defined in the model, tpcorr is the correction tariff that is the same for all products, and tp is the changed products specific tariffs, that are exogenous for all products except for the products where consumption is shocked. So, tpcorr makes the tariff adjustment income neutral by being added to all formulas where the consumption tariffs are calculated. If tpcorr is exogenous (and therefore tpcorrswap endogenous) then the mechanism is switched off because tpcorrswap is used in no other equation; if you swap these two variables, then the mechanism is activated. Be aware that using the tariffs is not meant as the imposition of taxes in the real world, but only a trick to model the change in consumption behaviour.

WHO-conform diet (Ref_WHODiet). In this scenario diets (especially of meat and dairy) are changed to the level the WHO advices. PBL supplies 2001 data about required change in consumption of all food products to conform to the World Health Organization advices. PBL decides on which information this is based: calories, protein, fat, kg, etc. Then during the scenario consumption per capita has changed. The shock of food consumption per capita in the period 2010-2013 is composed of two components. First the reversion of the change in food consumption per capita between 2001 and 2010. And then the percentage change that is required to make 2001 per capita consumption consistent with the WHO advices. So, total food consumption should increase with the shock needed to go from 2010 per capita food consumption to WHO per capita food consumption and the growth of the population. After 2013 food consumption only grows with population.

If we would have the real consumption data for 2010 (or another year), we could calibrate the model on that, and therefore increase the realism of the size of the shock. But this is something for future research. This scenario is only implemented for diet change in the EU27.

From red to white meat (Ref_CattleRed40). In this scenario it is assumed that consumers go from the less efficient cattle meat to the more efficient chicken and pork meat. We reduce the consumption of cattle meat with 40%, and let the model determine the change in consumption. In the future it would be better to calculate the total diet change, but this requires better information about relative prices and food conversion factors.

Reduced food waste (Ref_EUFoodWasteRed15, Ref_GlobalFoodWasteRed15). The idea is that consumers and producers throw less food away. As a consequence you need less food for the same consumption level. We implement for private consumption a taste shift for all food commodities by 15% as a consequence of this increased efficiency. This taste shift implies that for each commodity the utility of the commodity is the same with 15% less consumption. Because for consumption of livestock products indirect consumption is coupled with private consumption, this shock will also reduce waste in indirect consumption of livestock products, like in restaurants. For arable products this indirect consumption is not taken into account.

As a consequence of this way of modelling the reduction of food waste, the consumer gets more value for the same amount of product. As a consequence the effective price for the consumer becomes lower, and depending on the price elasticity of consumption this will generate extra consumption.

The scenario has been implemented both for food waste reduction only in the EU27 and for food waste reduction on a global level.

Less consumption of animal products (Ref_EUAnimalsRed10/20/50). The idea of this group of scenarios is to investigate what the total effect of less animal consumption in the EU27 will be. The consumption of cattle, other animal products and milk is reduced with a certain percentage. We will run 10, 20 and 50% reductions. The indirect consumption, for example consumption of dairy products, is handled through an adjustment of the input-output coefficient of the dairy industry. This implies that the dairy industry uses less milk and substitutes this with some other inputs to produce food commodities that make the consumer happy.

Production scenarios

For the production scenarios we change in most cases the productivity parameters (all starting with an “a” in the model code).

Increase in feed efficiency (Ref_LivestockEff15). This can be modelled as an increase in efficiency of the feed input, the productivity of all inputs used in the land and feed nest are shocked with the same percentage, i.e. 15% for the period 2010-2020. Without substitution this would imply a decrease in feed use of 15%. But feed becomes also cheaper compared with other production factors. So, feed intake will increase. Furthermore, because livestock production as a whole becomes cheaper, demand for livestock products will also increase.

Increase in cropland productivity (Ref_CropLandProdGrowthInc40). The exogenous changes in land productivity of crops as supplied by PBL are multiplied by 1.4, except in the case these growth rates are negative. In that case cropland productivity growth is set at 0. This implies that less land is used per unit of crop. But land also becomes cheaper compared with other production factors, leading to an increase of land demand. Crops are also becoming cheaper, increasing demand for crops. So, the decrease in land demand will be less than the increase in land productivity.

Increase in land productivity (Ref_LandProdIncrease5).
This is modelled as an increase in land productivity for all sectors in the period 2010-2013, leading to less land demand. Because land in all uses becomes cheaper, land demand increases by substituting away from the use of other inputs. Because the products made with the land are becoming cheaper, demand for these products increases, increasing land demand further.

Animal friendly production (Ref_AnimalFriendlyOAPEU27)
This is modelled as a decrease in feeding efficiency for non-ruminant animals in the EU27. This implies more feed demand. The effects are in the opposite direction from an increase in feed efficiency. The changes are country specific in the range of 12 to 16%.

Organic production (Ref_OrganicEU27)
This is modelled as a decrease in land and feeding efficiency in the EU27. The change in feeding efficiency is the same as in the animal friendly production scenario. The decrease in land efficiency is modelled as a decrease in land productivity for crops of 5% compared with the baseline.

5.2 Discussion of results

In this section we will discuss the scenario results. Before doing this, we do a short reliability check on the database as we generated it by comparing it with some stylized facts. Then we focus on the scenarios, by discussing an example of each type of scenario in great detail and providing a summary of the results of the scenarios with a comparable methodology.

5.2.1 A short check on the 2007 data

We checked the data that we generated for 2007 roughly with the preliminary information available in the PBL-report 'The Protein Puzzle' (Chapter 4; Van Zeijts *et al.*, 2011). According to this report about 5 million km^2 of cropland and 35 million km^2 of grassland is used for animal feed. In the reference LEITAP database of 2007 we calculate that about 32% of arable land or about 4.4 million km^2 is used for animal feeding[3]. We calculate this by looking at the value share of input use in the feed sector and the animal sectors together in total production value of arable crops separated for each arable crop, and multiply this share with the land use of each arable crop sector. We assume that 80% of the value of the use of products of the GTAP vegetable oils sector in animal feeding is the value of oilseeds being used, implying that 20% is value added. Grassland is estimated at 36 million km^2. So, total land use for animal feeding is roughly consistent with the data in the report.

Also the cropland used for animal feeding in Europe, 62 mln ha out of 127 mln ha, calculated in the same way as the global land use for animal feeding, is roughly consistent with the information of the report (Section 4.1), that states that 67 out of 122 mln ha crop land is used for feed.

With respect to imports (see Van Zeijts *et al.* 2011, Chapter 3), the net import value of animal feed is about 11 billion euro's; the new ofdfeed sector imports about half of that, but also half of animal feeding in the EU is supplied directly by the primary agricultural sectors of which part is imported. Half of ofdfeed is coming from the USA and South America. 62% of the inputs in ofdfeed in these countries is vegetable oils and oilseeds. This percentage seems also roughly the same for the direct input use in the animal sector.

In summary, the database is not perfect, but roughly approximates the situation in the animal feeding sector as described in Van Zeijts *et al.* (2011).

5.2.2 The consumption scenarios

Twenty percent reduction of animal products in the EU27

We will investigate this scenario in more detail in order to improve understanding of the mechanisms involved in the model. In this scenario consumption of animal products in the EU27 is reduced with 20%. EU27 animal consumption is in 2020 about 20% of worldwide animal consumption.

Meat and dairy demand reduction increase other food demand and energy demand
When consumption per capita is reduced with 20% compared with the level in 2010 the difference is more than 20% in 2020 because in the reference scenario the consumption is increasing. In this case,

[3] See spreadsheet CheckAnimalFeeding.xls, available on request.

livestock consumption is more than 24% lower (see Table 5.1). As a consequence of the reduction in demand in the EU27 prices of animal products will decline, and therefore consumption outside the EU27 will increase, in this case with 0.51%. The total effect on world consumption is a decrease in livestock consumption of -4.44%.

Table 5.1 Percentage difference in private consumption in 2020 as a consequence of 20% reduction of consumption of animal products in the EU27 compared with 2010

	World	**EU27**	**World-EU27**
Primary Agriculture	-2.07	-15.97	0.38
Arable	0.45	2.45	0.24
Livestock	-4.43	-24.43	0.52
Rice	0.17	1.35	0.15
Wheat	0.56	8.53	0.38
Coarse grains	0.40	7.30	0.23
Oil seeds	0.27	1.67	0.21
Sugar	0.19	2.22	0.15
Horticulture	0.50	2.36	0.26
Other crops	0.75	2.39	0.29
Cattle meat	-5.08	-24.23	0.43
Pork/poultry	-4.35	-24.47	0.59
Milk and dairy	-6.73	-22.57	0.20
Sugar	0.32	2.49	0.08
Vegetable oils	0.70	2.15	0.23
Other food	0.59	2.69	0.06
Fish, beverages and tobacco	0.44	2.46	0.03
Forestry	0.28	3.15	0.07
Petroleum	0.34	3.13	-0.08
Gas	0.66	2.90	-0.08
Coal	0.32	2.68	-0.06
Electricity	0.72	3.60	-0.05
Chemical industry	0.66	3.19	-0.05
Other industries	0.70	3.35	-0.06
Services	0.31	1.73	-0.03

The reduction in livestock consumption is partly compensated by an increase in non-meat consumption, partly because after the reduction in meat consumption more income is left to buy other products, partly because the price of agricultural products is reduced. For most sectors this is about 0.5% on a worldwide level (only the price effect), and somewhere between 1% and 3% in Europe. The reduction in meat consumption in Europe is especially compensated by an increase in the use of grains, but in value terms the increase in fish, horticulture and other food (including canned food) is very important. About 80% of the reduction in expenditures on meat is compensated by expenditures on other food products.

The reduction in expenditures on animal products increases also the demand for services and industry as well as energy products in the EU27. The reduction of meat consumption generates an increase in energy demand in the EU27 that is not compensated by less energy demand in the rest of the world. As a consequence of this mechanism, the carbon greenhouse gasses may increase, although part of it may be compensated by an increased use of biofuels as a consequence of the price reduction of agricultural products.

Production effects

As a consequence of the reduction in meat consumption, also meat production is reduced. The percentage changes are not the same as for consumption, because both production and consumption are weighted with their market values, where production and consumption are in different regions. The change in production of arable crops is completely different from the developments in direct private consumption of arable crops because they are used also for the production of feed and biofuels. On a worldwide level the reduction in purchased animal feed use of 6.4% is more than could be expected from the reduction in livestock production of 4.6%. The reason is that the main part of animal production is reduced in the EU27 where livestock production is relatively intensive, and therefore uses more crops per unit of product than the world average (see Table 5.2a).

Table 5.2a Percentage difference in production in 2020 as a consequence of 20% reduction of consumption of animal products in the EU27 compared with 2010

	World	**EU27**	**World-EU27**
Primary Agriculture	-2.31	-10.53	-0.82
Arable	-0.08	4.73	-0.65
Livestock	-4.48	-18.42	-1.00
Biofuels	1.38	4.22	0.81
Rice	0.09	5.93	0.01
Wheat	-1.66	0.49	-2.00
Coarse grains	-1.63	-4.40	-1.22
Oil seeds	-0.27	6.54	-1.05
Sugar	0.11	1.43	-0.03
Horticulture	0.39	6.16	-0.20
Other crops	0.17	7.07	-1.50
Cattle meat	-3.97	-17.57	-1.33
Pork/poultry	-4.65	-17.80	-0.97
Milk and dairy	-6.43	-20.16	-0.68
Sugar	0.13	1.28	-0.08
Vegetable oils	-1.10	-1.93	-0.82
Animal feed	-6.53	-18.68	-2.92
Other food	0.43	2.47	-0.14
Fish, beverages and tobacco	0.40	2.03	-0.01
Forestry	0.07	0.10	0.07
Crude oil	0.01	-0.01	0.01
Petroleum	0.04	0.68	-0.07
Biodiesel	4.35	4.27	4.52
Ethanol	0.62	4.03	0.47
Gas	0.13	0.36	0.10
Coal	0.08	0.26	0.06
Electricity	0.21	1.00	0.01
Chemical industry	0.17	0.33	0.12
Other industries	0.16	0.15	0.16
Services	-0.02	0.02	-0.03
BDBP	4.40	4.23	4.74
DDGS	0.59	4.62	0.23
CGDS	-0.18	-0.14	-0.18

In production we see back that the reduced meat consumption increases total production of fossil energy a little bit, where the increase in biofuel production is not sufficient to supply all the extra energy needed. The increase in arable production in the EU27 is caused by the reduced pressure on land, increasing exports with 1.9% of production and reducing imports with 2.8% of production (Table 5.2b). This is caused by a reduction in the price of arable products with 9% compared with a price reduction in the rest of the world of 2%. This reduction in price is for a small part caused by lower land price, but for the main part because less labour is needed and therefore the reward for labour (and its coupled capital) is reduced (called wage in Table 5.2b).

Table 5.2b Effect of 20% reduction in animal consumption in the EU27

		EU27	World-EU27
Price production (market prices)	Arable	-9.3	-1.6
Price production (market prices)	Livestock	-10.8	-1.5
Land Price	Arable	-3.8	-1.7
Land Price	Livestock	-31.4	-1.8
Wage (nominal)	Arable	-15.8	-1.8
Wage (nominal)	Livestock	-18.9	-1.9

Land use effects
The effect on land use is much less than you would expect from the effects on production; a little bit more than half of the original effect (Table 5.3). Especially for Europe we see that the model predicts a small effect on land use, implying that the model predicts a large extensification effect for livestock production in the EU27 of 11%, while the effect on extensification in the rest of the world is relatively small. For crops the model predicts as a consequence of the Constant Elasticity of Transformation (CET) function a small intensification, which is not very plausible but requires further research to be solved. The reduced demand for labour as a consequence of smaller livestock production implies that wages are reduced making labour cheaper compared with land, and as a consequence intensification takes place. With respect to the CET function for land, the reduction in demand for grassland implies that the price of grassland is reduced relative to the price of cropland. This effect is smaller than the effect on the average land price, so cropland prices are reduced. The reduction in land price is smaller less than the reduction in wages and capital rentals. This explain the small increase in intensification. Because the EU-subsidies compensate changes in the market price for land to a large extend, the effect on the effective price of land for the users is relatively small.

Table 5.3 Percentage difference in land use in 2020 as a consequence of 20% reduction of consumption of animal products in the EU27 compared with 2010

	World	EU27	World-EU27
Primary Agriculture	-1.26	-1.62	-1.24
Arable	-0.99	2.49	-1.25
Livestock	-1.38	-7.92	-1.24
Rice	-0.04	4.42	-0.05
Wheat	-2.21	2.09	-2.62
Coarse grains	-1.14	-0.77	-1.17
Oil seeds	-0.81	6.72	-1.45
Sugar	0.11	2.35	-0.06
Horticulture	-0.17	5.25	-0.52
Other crops	-1.31	7.89	-1.46
Cattle meat	-1.55	-5.49	-1.50
Milk and dairy	-0.97	-9.39	-0.60

Outside the EU the model predicts a faster reduction in land use than the reduction in production. This effect seems to be mainly a composition effect. Production is reduced in the sectors and regions with a low production per hectare, and therefore land use is decreased faster than production, in arable production even two times as fast (Table 5.4).

Table 5.4 Percentage change in land use between 2010 and 2020

	World	EU27	World-EU27
Ref	4.17	-2.44	4.43
Ref_EUAnimalsRed20	2.86	-4.02	3.13

In summary, the total land use effect of the reduction in the consumption of livestock products is relatively small compared with the reduction in consumption. The reason is that outside the EU consumption of livestock products increases as a consequence of lower prices, while biofuel production and the consumption of non-animal food increases in the whole world. As an indication, arable production is reduced with $1.3 billion, while the use of arable products in biofuel production is increased by $0.6 billion and consumption of arable products is increased by $ 3.5 billion.

For Europe the model suggests extensification, making the reduction in land use in the EU small compared with the reduction in production. Outside the EU the extensification is much smaller. From the perspective of biodiversity this may not be a bad result: extensification of European agriculture implies less abandoned land and more opportunities for agricultural biodiversity, while outside Europe the smaller increase in land use may have significant effects on biodiversity reduction.

Price and income

It is obvious that the reduction in meat demand has consequences for agricultural income. Agricultural income in the model is the sum of the income from land, labour and capital. So, if the prices of these production factors are reduced agricultural income is reduced. With respect to land if land is rented, the increase in land rents may go to the land owner, so this part of the change in income may be overestimated. Table 5.5 shows that income per worker is reduced with 15%. Part of this is a consequence of the reduction in land prices of 10%, but the main part is just because people working in agriculture don't leave the sector that easily. Employment is reduced with 6% while production is reduced with 10%. This lack in mobility of agricultural labour explains the reduction in income per worker, but this mechanism also implies that in the very long term the effect on agricultural income per worker will disappear.

Table 5.5 Percentage difference in agricultural income and employment in 2020 as a consequence of 20% reduction of consumption of animal products in the EU27 compared with 2010

	World	EU27	World-EU27
Sectoral income real per worker	-3.14	-15.24	-1.96
Sectoral income, real at market prices	-4.99	-20.52	-2.77
Sectoral capital per worker	0.53	0.64	0.03
Sector employment, volume	-1.91	-6.22	-0.82
Land Prices per sector	-2.37	-10.21	-1.71

The decreases in agricultural income per worker and the reduction in land prices implies a reduction in agricultural prices. For Europe the prices of primary agricultural products are about 10% lower, while outside the EU prices are reduced with about 1.5% (Table 5.6). Also this effect is smaller in the long run than in the short run. For example, in 2030 EU prices are 6% lower and prices outside the EU 0.3% lower in the 20% EU-meat consumption reduction scenario than in the reference scenario.

Table 5.6 Percentage difference in agricultural prices in 2020 as a consequence of 20% reduction of consumption of animal products in the EU27 compared with 2010

	World	EU27	World-EU27
Primary Agriculture	-3.1	-10.7	-1.6
Arable	-2.5	-9.3	-1.6
Livestock	-3.4	-10.8	-1.5

In summary, the income and price effects of the reduction in meat consumption is significant in the short run, but becomes much smaller in the long run. In the very long run only the effect on land rents will remain, while the difference in reward for labour and capital will not differ fundamentally.

5.2.3 The other consumption reduction scenarios

The different consumption scenarios react more or less in the same way as the animals consumption reduction scenario (Table 5.7a,b,c). For the reduction of consumption of cattle meat with 40% the consumption of other animal products and milk products increases. About 16% of the value of the reduction in cattle meat consumption will be compensated by increased use of other animal products. This is implicit in the consumption function. For total livestock this scenario is comparable with a 10% reduction in total animal products consumption. For the food waste reduction scenarios and the WHO diet scenario the consumption reduction holds for all food products, although the reasons for doing this are different, and the size of the effect of a 15% reduction in food waste is about double of that of changing towards a more healthy diet according to the norms of the WHO.

Table 5.7a Consumption change in the EU27 for the consumption reduction scenarios

	Primary Agriculture	Arable	Livestock	Cattle meat	Pork/ poultry	Milk and dairy	Other food
Ref_CattleRed40	-9.2	1.5	-14.1	-43.0	3.4	1.7	1.4
Ref_WHODiet	-4.3	-1.9	-5.5	-5.0	-5.6	-3.2	-2.3
Ref_GlobalFoodWasteRed15	-7.4	-10.1	-6.2	-6.0	-6.3	-8.2	-8.3
Ref_EUFoodWasteRed15	-8.8	-11.0	-7.8	-7.9	-7.7	-8.5	-8.5
Ref_EUAnimalsRed10	-9.8	1.5	-15.0	-14.7	-15.0	-12.9	1.5
Ref_EUAnimalsRed20	-16.0	2.5	-24.4	-24.2	-24.5	-22.6	2.7
Ref_EUAnimalsRed50	-33.8	7.6	-52.8	-52.7	-52.8	-51.6	9.7

Table 5.7b Production change in the EU27 for the consumption reduction scenarios

	Primary Agriculture	Arable	Livestock	Cattle meat	Pork/ poultry	Milk and dairy	Other food
Ref_CattleRed40	-4.0	4.1	-8.1	-39.3	4.8	1.6	0.8
Ref_WHODiet	-3.3	-1.2	-4.4	-3.6	-4.3	-3.3	-2.7
Ref_GlobalFoodWasteRed15	-4.8	-5.7	-4.3	-4.4	-4.6	-5.7	-6.0
Ref_EUFoodWasteRed15	-2.6	-1.8	-3.0	-2.8	-3.0	-5.2	-4.6
Ref_EUAnimalsRed10	-6.5	2.8	-11.4	-10.5	-11.0	-11.6	-0.1
Ref_EUAnimalsRed20	-10.5	4.7	-18.4	-17.6	-17.8	-20.2	-0.2
Ref_EUAnimalsRed50	-22.3	11.7	-39.9	-40.4	-37.7	-46.1	2.3

Table 5.7c Land use change in the EU27 for the consumption reduction scenarios

	Primary Agriculture	Arable	Livestock	Cattle meat	Pork/ poultry	Milk and dairy
Ref_CattleRed40	-0.2	2.9	-5.1	-17.1	4.4	2.4
Ref_WHODiet	-0.8	-0.1	-1.9	-0.7	-4.3	-2.7
Ref_GlobalFoodWasteRed15	-1.5	-1.8	-1.0	-1.1	-4.4	-0.9
Ref_EUFoodWasteRed15	-0.6	-0.1	-1.4	-0.9	-2.9	-1.8
Ref_EUAnimalsRed10	-1.1	1.7	-5.3	-3.4	-10.5	-6.4
Ref_EUAnimalsRed20	-1.6	2.5	-7.9	-5.5	-16.6	-9.4
Ref_EUAnimalsRed50	-2.4	4.5	-12.8	-9.3	-34.4	-14.9

Outside the EU most scenarios generate an increase in food consumption because the reduction in demand generates a price decrease. Only the global food waste reduction has obviously a worldwide effect (Table 5.8a,b,c).

Table 5.8a Consumption change outside the EU27 for the consumption reduction scenarios

	Primary Agriculture	Arable	Livestock	Cattle meat	Pork/ poultry	Milk and dairy	Other food
Ref_CattleRed40	0.2	0.1	0.3	0.2	0.3	0.1	0.0
Ref_WHODiet	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Ref_GlobalFoodWasteRed15	-7.7	-9.6	-5.7	-6.0	-5.9	-7.1	-8.1
Ref_EUFoodWasteRed15	0.2	0.1	0.3	0.3	0.3	0.1	0.0
Ref_EUAnimalsRed10	0.2	0.1	0.3	0.3	0.4	0.1	0.0
Ref_EUAnimalsRed20	0.4	0.2	0.5	0.4	0.6	0.2	0.1
Ref_EUAnimalsRed50	0.7	0.4	1.0	0.8	1.1	0.3	0.1

Table 5.8b Production change outside the EU27 for the consumption reduction scenarios

	Primary Agriculture	Arable	Livestock	Cattle meat	Pork/ poultry	Milk and dairy	Other food
Ref_CattleRed40	-0.4	-0.2	-0.6	-1.2	-0.3	0.0	-0.1
Ref_WHODiet	-0.3	-0.3	-0.3	-0.4	-0.3	-0.3	-0.1
Ref_GlobalFoodWasteRed15	-3.8	-5.3	-2.2	-2.0	-2.5	-3.5	-5.5
Ref_EUFoodWasteRed15	-0.3	-0.4	-0.2	-0.3	-0.2	-0.1	-0.2
Ref_EUAnimalsRed10	-0.5	-0.4	-0.6	-0.8	-0.6	-0.5	-0.3
Ref_EUAnimalsRed20	-0.8	-0.7	-1.0	-1.3	-1.0	-0.7	-0.5
Ref_EUAnimalsRed50	-1.7	-1.4	-2.1	-2.5	-2.2	-1.2	-0.9

Table 5.8c Land use change outside the EU27 for the consumption reduction scenarios

	Primary Agriculture	Arable	Livestock	Cattle meat	Pork/ poultry	Milk and dairy
Ref_CattleRed40	-0.7	-0.4	-0.9	-1.3	-0.1	0.1
Ref_WHODiet	-0.4	-0.5	-0.4	-0.4	-0.2	-0.3
Ref_GlobalFoodWasteRed15	-3.7	-5.4	-3.0	-2.9	-1.6	-3.1
Ref_EUFoodWasteRed15	-0.5	-0.6	-0.4	-0.5	-0.1	-0.1
Ref_EUAnimalsRed10	-0.8	-0.8	-0.8	-0.9	-0.5	-0.4
Ref_EUAnimalsRed20	-1.2	-1.3	-1.2	-1.5	-0.8	-0.6
Ref_EUAnimalsRed50	-2.4	-2.5	-2.4	-2.9	-2.0	-1.2

If we look at the final land use effects of the different scenarios, we see that that animals reduction scenarios are roughly linear with respect to the percentage change in animal consumption. Compared with the WHODiet policy the food waste reduction of 15% looked more effective from the perspective of the change in food expenditures, but is about equally effective with respect to land use (Table 5.9).

Table 5.9 Land use change in the consumption reduction scenarios

	World		EU27	
	Arable	*Livestock*	*Arable*	*Livestock*
Ref_CattleRed40	-0.2	-1.0	2.9	-5.1
Ref_WHODiet	-0.4	-0.4	-0.1	-1.9
Ref_GlobalFoodWasteRed15	-5.1	-2.9	-1.8	-1.0
Ref_EUFoodWasteRed15	-0.5	-0.4	-0.1	-1.4
Ref_EUAnimalsRed10	-0.6	-0.9	1.6	-5.3
Ref_EUAnimalsRed20	-1.0	-1.4	2.5	-7.9
Ref_EUAnimalsRed50	-2.0	-2.6	4.5	-12.8

In general, the land use changes in the EU27 are small compared with the production changes. The reason behind this is the CAP, where we assume that decoupled subsidies are premiums per hectare that are in most cases a large percentage of the total land rents. As a consequence, the incentive to keep land into production is very high, generating extensification of land use.

5.2.4 The production scenarios

Increase in global land productivity of 5%

The increase in exogenous global land productivity translates for 85% in an increase in production per hectare (Table 5.10a). The increase in global land productivity also reduces cost price, and therefore increases demand, production and land use (Table 5.10b). Because the effective price of land use is reduced it becomes beneficial to increase land use by using less energy, labour and capital per effective unit of land. This extensification effect of an increase in land productivity is general, where we have to be aware that the combined effect of a productivity increase and extensification is always an increase in production per hectare.

For Europe the CAP policy that subsidizes land use, the effect of a productivity increase on land use is much smaller. Because the subsidy per hectare is almost the price of land and depends on keeping the land in good agricultural condition, farmers keep the freed land into production, although in a relatively extensive way. This explains why in the EU27 the exogenous 5% increase in land productivity reduces land effectively used per hectare by only 1%.

Table 5.10a Percentage change in production per ha

	World	EU27	World-EU27
AGRI_PRIM	4.3	1.0	4.6
Arable	5.0	1.2	5.3
Livestock	4.0	0.5	4.3

Table 5.10b Percentage change in land use

	World	EU27	World-EU27
AGRI_PRIM	-3.4	-1.1	-3.4
Arable	-3.9	-1.5	-4.0
Livestock	-3.1	-0.6	-3.2

Sometimes the change in production per hectare is more than the exogenous shock. This is mainly a composition effect, where countries and sectors with a high productivity per hectare increase more than the countries and sectors with a low productivity per ha.[4]

As a consequence of the reduction in land demand, the price of land is reduced (Table 5.11). We see that the reduction in land prices is almost the same in the EU and the rest of the world; about 7%. But the mechanism is different. While in most of the rest of the world the price elasticity of land supply is relatively high, this is much smaller in the EU27. In the EU27 farmers like to keep land into agricultural use, so land supply has to be reduced much less than in the rest of the world. To use agricultural land remains attractive because a subsidy is coupled to the land.

Table 5.11 Percentage change in land prices

	World	EU27	World-EU27
AGRI_PRIM	-6.8	-7.4	-6.8
Arable	-6.3	-6.5	-6.4
Livestock	-6.9	-9.3	-6.8

The increase in land productivity in combination with the reduced land price (and in Europe also the increased subsidy per effective unit of land, because the subsidy per ha remains the same), generates a reduction in agricultural prices (Table 5.12), although the effect on prices of processed food is much smaller. The EU uses much less of the increased land productivity for the reduction in land, but keeps a lot of agricultural land into production. The reduction in agricultural prices generates an increase in agricultural consumption of 0.8% outside the EU and 0.4% in the EU (Table 5.13).

Table 5.12 Percentage change in agricultural prices

	World	EU27	World-EU27
AGRI_PRIM	-3.2	-1.5	-3.5
Arable	-4.1	-2.2	-4.4
Livestock	-2.4	-1.2	-2.7

Table 5.13 Percentage change in agricultural consumption

	World	EU27	World-EU27
AGRI_PRIM	0.8	0.4	0.8
Arable	0.6	0.3	0.7
Livestock	0.9	0.4	1.0

The change in consumption is part of the explanation for the increase in agricultural production (Table 5.14). Because cost price in the EU is reduced less than in the rest of the world (because at agent prices land price is low as a consequence of the high CAP subsidies that are allocated to land), some agricultural production is shifted from the EU towards the rest of the world. The lower agricultural prices do not only generate more consumer demand, but also an increase in demand for biofuels. In our results this is effect is small compared with the total production change.

Table 5.14 Percentage change in agricultural production

	World	EU27	World-EU27
AGRI_PRIM	0.84	-0.19	1.02
Arable	0.92	-0.28	1.06
Livestock	0.76	-0.14	0.98
Biofuels	1.26	3.18	0.87

[4] For some regions, like Oceania, production even decreases while land efficiency increases for some reason a little bit, too.

The final effect on land use of the general land productivity increase of 5% can be found in Table 5.15.

Table 5.15 Percentage change in agricultural land use

	World	EU27	World-EU27
AGRI_PRIM	-3.4	-1.1	-3.5
Arable	-3.9	-1.5	-4.0
Livestock	-3.1	-0.6	-3.2

In conclusion, the effect of a global increase in land productivity on worldwide production, consumption and land use seems to be plausible. The increase in land productivity is assumed to have only small effects on the productivity of the other production factors, because the model assumes that per economically effective unit of land the same amounts of production factor are used. As an alternative we could assume that the increase in land productivity also needs less capital and labour, and in that case the effect on cost price is much stronger.

The EU-policy has a very specific effect on land use and cost price. Because the EU-policy generates an incentive to keep land into agricultural production, the land use effects are small. Because the costs of land including the subsidies are also relatively small, the effect on cost price of a productivity increase is small in the EU compared with the rest of the world. Therefore, the rest of the world gets a comparative advantage.

5.2.5 Sensitivity analysis of increase in global land productivity of 5%

The scenarios with the global land productivity increase show that especially the assumptions about the EU CAP policy and the assumption that land productivity increases a lot has important consequences for the effect of a global increase in land productivity of 5%. Table 5.16 shows that with fixed subsidies per dollar land rent instead of fixed subsidies per hectare arable land, land use becomes 2.75% lower. Grassland is using part of this freed up cropland. The total effect on EU-land use is -2.7% instead of -1.1%. The effect on worldwide land use of this difference is very small.

Table 5.16 Percentage change in land use when EU subsidy rates on land are fixed compared with the effect with the current CAP policy

	World	EU27	World-EU27
AGRI_PRIM	-0.02	-1.54	0.04
Arable	-0.07	-2.75	0.13
Livestock	0.00	0.31	-0.01

A second sensitivity experiment is the analysis of the effect of a 5% increase in productivity for land when this would also be applied to capital and labour. In this case the decrease in land use is less than if it would be only applied on land itself (Table 5.17). The effect is relatively small for the EU, but large for the rest of the world. The reason is the much larger reduction in agricultural prices, i.e. agricultural prices in the world are reduced with 6% instead of 3%. Worldwide agricultural consumption therefore increases with about 0.7%, implying an increase in land use (see Table 5.18).

Table 5.17 Percentage change in land use as a consequence of also having a 5% increase in capital and labour productivity

	World	EU27	World-EU27
AGRI_PRIM	0.53	0.10	0.55
Arable	0.61	0.11	0.64
Livestock	0.50	0.08	0.51

Table 5.18 Percentage change in price as a consequence of also having a 5% increase in capital and labour productivity

	World	EU27	World-EU27
AGRI_PRIM	-2.88	-2.98	-2.86
Arable	-3.09	-3.24	-3.07
Livestock	-2.73	-2.87	-2.69

5.2.6 Increase in global feed efficiency (Ref_LivestockEff15)

In this scenario feed productivity (including feed from land) of the livestock sector increases with 15%. This efficiency increase is added to the baseline productivity increase. In Table 5.19 we see that both feed demand and land use per unit of product decreases with less than 15%. Because feed becomes cheaper farmers put less effort in its most efficient use. We use an elasticity of 0.1 for this purpose while the effective price of feed changes with about 20%, implying an increase in feed use of about 2%. So, this does explain about half of the difference. The other part must be found somewhere else, probably through the change in composition of feed. BDBP and DDGS are co-products with biodiesel and ethanol. Therefore, their use will not change. Because total feed use is reduced because of the increase in feed efficiency, the share of BDBP and DDGS in total feed use will increase. In order to make this attractive, the prices of BDBP and DDGS will be reduced much more than the prices of the other feed components.

In order to investigate to what extend the composition effect plays an important role, we have compared the feed defined as a weighted aggregate of the composite inputs with the feed demand in the model. For example, the model tells that feed demand for cattle in Brazil between 2013 and 2020 increases with 5%, while the same number as the CES aggregate feed in the model tells that feed use increases only with 0.6%. This effect is very general, where the land use effects suggest that the number in the model (that is a CES aggregate of the consisting elements) is less correct than the model for feeding calculated outside the model. A CES aggregate is not an aggregate made by adding the components in a weighted way, but by something like a multiplicative function, for example $Agg=A1^{c}*A2^{1-c}$. So, if c is small then an increase in A1 has only a small effect on the aggregate. This is a fundamental consequence of the use of CES nests in calculating input demands, and is therefore something that cannot be changed without changing the general approach used in most general equilibrium models.

Table 5.19 Input use in livestock

		World	EU27	World-EU27
Grassland use per unit of ruminant livestock	Land	-8.3	-4.3	-9.0
Purchased Feed-use per unit of livestock	Feed	-11.5	-12.0	-11.4

As a consequence of the savings on feed the cost price of animal products decreases with about 7%. Therefore, private consumption increases with about 2.3%. Land and feed demand decrease with 2 percentage points less than would be the case without the consumption adjustment. For Europe, the effect on land use is much smaller, because of the agricultural policy that rewards keeping land into agricultural production.

An interesting thought exercise may be to look at the land use consequences of the feedstock efficiency increase scenario in km^2. Table 5.20 shows that the change in land for livestock is roughly 3 million km^2, i.e. about 8% of grassland area, while the reduction in arable production is 0.26 million km^2, i.e. about 5% of arable land used for feeding the animals. When we take into account that consumption is increased, with 2.3% for livestock and a little bit less than 1% for crops, the reduction in land use would already have been more than the 8% for grass and the 5% for arable land, i.e.

roughly 10.5% respectively 7.5%. What is left over of the 15% increase in livestock efficiency (i.e. 15-10.5 is about 4.5%), is a reduction in land use as a consequence of land becoming about 15% cheaper compared with the other production factors, and changes in the composition of land, where byproducts continue to be produced and are becoming a more important and a cheaper substitute for other feed.

Table 5.20 Effect of increase in feedstock efficiency of 15% on land use in km^2

	World	EU27	World-EU27
AGRI_PRIM	-3 264 517	-27 843	-3 236 674
Arable	-263 482	-4 348	-259 134
Livestock	-3 001 036	-23 496	-2 977 540

5.2.7 Other production scenarios

The animal friendly and organic production scenarios increase land use, because more land is needed for feeding the non-ruminant animals in the animal friendly scenario, and also more land is needed for arable production in the organic production scenario. Because the reduction in feed productivity is only for feed from crops, and the higher prices of meat generate a reduction in livestock production, grassland use in the livestock sector is reduced. The increase in feed prices increases also production cost in the ruminant animal sectors, generating a reduction in land demand also in these sectors. The price increases reduce consumption of agricultural products a little bit (Tables 5.21 - 5.24).

Table 5.21 Percentage change in land use in 2020 compared with reference scenario

		World	EU27	World-EU27
Ref_AnimalFriendlyOAPEU27	Primary agriculture	0.081	0.326	0.072
Ref_AnimalFriendlyOAPEU27	Arable	0.305	0.923	0.26
Ref_AnimalFriendlyOAPEU27	Livestock	-0.023	-0.589	-0.011
Ref_OrganicEU27	Primary agriculture	0.243	0.403	0.237
Ref_OrganicEU27	Arable	0.801	1.115	0.778
Ref_OrganicEU27	Livestock	-0.013	-0.688	0.001
Ref_CropLandProdGrowthInc40	Primary agriculture	-1.276	-0.41	-1.308
Ref_CropLandProdGrowthInc40	Arable	-3.297	-1.049	-3.462
Ref_CropLandProdGrowthInc40	Livestock	-0.347	0.57	-0.366

The faster growth in cropland productivity reduces land demand, reduces agricultural prices and increases therefore agricultural consumption.

Table 5.22 Percentage change in price in 2020 compared with reference scenario

		World	EU27	World-EU27
Ref_AnimalFriendlyOAPEU27	AGRI_PRIM	0.5	1.7	0.2
Ref_AnimalFriendlyOAPEU27	Arable	0.3	0.9	0.2
Ref_AnimalFriendlyOAPEU27	Livestock	0.6	2.2	0.3
Ref_OrganicEU27	AGRI_PRIM	1.3	4.5	0.7
Ref_OrganicEU27	Arable	1.5	7.3	0.8
Ref_OrganicEU27	Livestock	1.1	3.1	0.6
Ref_CropLandProdGrowthInc40	AGRI_PRIM	-1.8	-0.8	-2.0
Ref_CropLandProdGrowthInc40	Arable	-3.2	-1.4	-3.5
Ref_CropLandProdGrowthInc40	Livestock	-0.5	-0.5	-0.6

Table 5.23 Percentage change in private consumption in 2020 compared with reference scenario

		World	EU27	World-EU27
Ref_AnimalFriendlyOAPEU27	AGRI_PRIM	-0.1	-0.5	-0.1
Ref_AnimalFriendlyOAPEU27	Arable	0.0	0.0	0.0
Ref_AnimalFriendlyOAPEU27	Livestock	-0.2	-0.7	-0.1
Ref_OrganicEU27	AGRI_PRIM	-0.3	-0.9	-0.2
Ref_OrganicEU27	Arable	-0.2	-0.6	-0.1
Ref_OrganicEU27	Livestock	-0.4	-1.0	-0.2
Ref_CropLandProdGrowthInc40	AGRI_PRIM	0.3	0.2	0.3
Ref_CropLandProdGrowthInc40	Arable	0.5	0.2	0.5
Ref_CropLandProdGrowthInc40	Livestock	0.2	0.2	0.2

Table 5.24 Percentage change in production in 2020 compared with reference scenario

		World	EU27	World-EU27
Ref_AnimalFriendlyOAPEU27	AGRI_PRIM	-0.02	-0.61	0.09
Ref_AnimalFriendlyOAPEU27	Arable	0.19	1.16	0.07
Ref_AnimalFriendlyOAPEU27	Livestock	-0.22	-1.53	0.11
Ref_OrganicEU27	AGRI_PRIM	-0.18	-2.38	0.22
Ref_OrganicEU27	Arable	-0.01	-3.49	0.40
Ref_OrganicEU27	Livestock	-0.35	-1.81	0.02
Ref_CropLandProdGrowthInc40	AGRI_PRIM	0.42	-0.06	0.50
Ref_CropLandProdGrowthInc40	Arable	0.67	-0.48	0.81
Ref_CropLandProdGrowthInc40	Livestock	0.17	0.15	0.17

5.3 Conclusions

The simulations with the improved LEITAP model generate results that can be roughly explained. The composition of animal feeding seems to have an effect on total feed demand, but this is weighted with values, so it is not clear what it means with respect to energy and protein intake of the animals. If we don't believe in the land saving effects of changes in animal feed composition, i.e. don't believe in the savings on feed use that can be accomplished, it seems that the current estimates of the total land use effects of animal production and consumption scenarios may be a little bit too small, in the order of magnitude of 15% of the land use effects.

6 Conclusions and suggestions for further research

In this report we have discussed the introduction of a quality control system for the creation of the LEITAP database, and documented the implemented improvements of the model. We have investigated possibilities to improve on the consumption function, but have decided not to implement another consumption function because the focus of the project came on exogenous changes of the consumption instead of the search for instruments to change consumption behaviour. A baseline has been developed for a combination of projects, that is also the starting point in this project. With the created model instrument we were able to do some experiments on changes in meat consumption and production. In this report we explain the mechanisms that explain the mechanisms that generate the results, while PBL will publish the results of the model exercises from the perspective of the effectiveness of different policy options.

The LEITAP model has been improved significantly during this project. Splitting out the animal feed sector, modelling indirect consumption and inclusion of the substitution between grassland and animal feed as well different types of animal feed improve the realism of the model a lot. Nevertheless, a fundamental problem remains with the way animal feeding is modelled. It seems that the model underestimates the effect of animal feeding on the demand for land because the energy and protein balances are not guaranteed. Therefore, a fundamental effort to improve the way animal feeding is modelled would improve the results a lot. This process requires the inclusion of physical quantities in the model. A first step towards this goal has been made (see Section 3.4), but the final steps into this model development process have still to be made. The inclusion of physical quantity balances into the model is not only relevant for animal feeding, but also for improvements of the consumption function.

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