The MAGNET Model

Module description

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Preface

MAGNET (Modular Applied GeNeral Equilibrium Tool) is a global general equilibrium model. A distinguishing feature of the model is its modular structure, which allows the model structure to be tailored to the research question at hand. This manual describes each of the modules included in MAGNET. First-time users should refer to the 'Working with MAGNET' manual, which includes the interfaces for running MAGNET and a guide to analysing results. Each module is described in a dedicated chapter; these chapters are briefly described below.

The MAGNET consortium, led by LEI Wageningen UR, includes the Institute for Prospective Technological Studies (IPTS), which is an institute of the European Commission's Joint Research Centre (JRC) and the Thünen-Institute (TI).

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Module descriptions

Chapter 1 - Introducing the MAGNET model
The introduction describes MAGNET's origins and its underlying philosophy. There is a description of the logic of the MAGNET model directory structure and an outline of its content. Finally, there is a summary of key MAGNET coding conventions to ease the reading of GEMPACK code.

Chapter 2 - Adjustments and additions to the GTAP database
The chapter describes the aim and general approach used to construct a MAGNET database from a GTAP database and several other additional data sources. Available modules for adjustments to GTAP databases not requiring additional data are described with the required DSS settings.

Chapter 3 - Creating a baseline with MAGNET
The chapter describes the various data sources available within MAGNET for baseline construction. It also outlines the general approach for preparing these data for use with a specific model aggregation and time horizon.

Chapter 4 - Modelling around a GTAP core
The standard GTAP model forms the core of MAGNET. This chapter describes how this is reflected in the structure of the MAGNET code and provides a reading guide to the structure of the model code. It also describes how modules can be activated.

Chapter 5   Modified GTAP
This chapter describes the module MGTAP; more specifically, it describes the modifications made to standard GTAP so as to create a more robust and general model. This module must be activated if the user wishes to include any of the MAGNET modules.

Chapter 6 - A fully flexible production structure
A major extension of MAGNET is the introduction of a fully flexible production structure that can vary among sectors. This extension allows a user to tailor the modelling of production to the research question being addressed without requiring a change in model code.

Chapter 7 - Endogenous land supply
The module explains the land supply model. Understanding how land use changes over time and with different policies is a concern not only for agricultural analyses; it also features, for example, in the discussions on the effects of climate change. Innovative ways of modelling land were first developed in LEITAP and have been carried over into MAGNET. The endogenous land supply module allows land to shift in and out of the agriculture sector and accounts for the increasing costs of conversion as land becomes more scarce.

Chapter 8 - Allocation of land over sectors
Moving land from one use to another involves adjustments costs. To capture this effect, land is treated as a sluggish input in the GTAP model. Within the land module of MAGNET, alternative options of modelling the allocation of land are presented.

Chapter 9 - Consumption function correcting for real GDP changes
When performing long-term projections, incomes may change considerably and, as a consequence, the composition of consumption may also change. To capture such changes, this module was developed in such a way that elasticities are calibrated using ppp-corrected GDP per capita.

Chapter 10 -   Mobile Endowments and segmented mobile factor markets
The segmented mobile factors market module allows developments in agricultural and non-agricultural wages and capital returns to be modelled.

Chapter 11 — Production quota

Production quotas are an important part of agricultural policies. For example, they are one of the policy instruments employed in the EU Common Agricultural Policy. The production quota module allows the introduction of this policy instrument in MAGNET.

Chapter 12 — EU Common Agricultural Policy

The EU Common Agricultural Policy has implications for global markets and forms an important component of many analyses done with MAGNET. To capture the CAP in more detail, a dedicated module has been developed.

Chapter 13 — Biofuel directive

Policies to stimulate biofuel use and production are highly contested and are therefore the subject of many current analyses. In order to capture these specific policies, modules have been added to MAGNET to add biofuel sectors to the database and capture the key elements of policies.

Chapter 14 — Investment

The plain vanilla GTAP model is developed in principle for comparative-static analysis. MAGNET, however, is often used for long-term projections describing changes in the economy over time. This chapter describes an alternative investment specification designed to improve the standard GTAP investment specification, which at times causes improbable baselines or might even cause the model to fail for certain baseline shocks.

Chapter 15 — BTRQ

The bilateral tariff rate quota (BTRQ) module allows for the modelling of tariff rate quota on bilateral imports in MAGNET. Tariff rate quota emerged from the Uruguay Round Agreement on Agriculture as a new policy mechanism that ensures both tariffication and market access.

1 Introduction the MAGNET model

MAGNET (Modular Applied GeNeral Equilibrium Tool) is a global general equilibrium model. A distinguishing feature of the model is its modular design. Modularity allows modellers to tailor the model structure to fit the research question at hand. MAGNET is based on the LEITAP model, which has been used extensively in policy analyses. MAGNET offers more flexibility in model aggregation (definition of regions and sectors) and more options for changing a model's structure. The main purpose of MAGNET is to provide a globally applied general equilibrium modelling framework. With the standard GTAP model as the core around which MAGNET was developed, use of MAGNET requires, at a minimum, an understanding of the standard GTAP model and the ability to read GEMPACK code. Therefore, in the following MAGNET documentation, neither general equilibrium modelling nor the GTAP model is discussed. We do describe, for each of the extensions MAGNET makes to the standard GTAP model, the aim of the extension, the theory underlying the module, the additional data requirements needed to run the module and instructions on how to activate the module.

In this chapter, we describe the main coding conventions used in MAGNET in order to facilitate reading of the code. Documentation on how to run MAGNET from scratch is available in the last chapter. More information on how to adjust the MAGNET model for developers is available in several of the early chapters of this manual.

1.1 The origins of MAGNET

MAGNET was developed at LEI as a successor to LEITAP. The development of LEITAP started in 1996 based on the standard GTAP model. Because LEI is a policy-oriented research institute, model developments have been geared towards answering policy questions. With agricultural issues increasingly connected to other fields in matters concerning, for instance, bio-energy, sustainability and climate change, LEITAP became increasingly complex. Changes were made to the original GTAP code in the following areas:
– Differences in substitutability of land between sectors
– Imperfect mobility of labour between agricultural and non-agricultural sectors
– Output quotas for milk and sugar
– Endogenous land supply
– Biofuel sectors and the biofuel directive
– Modulation of the EU Common Agricultural Policy from first to second pillar measures
– Income elasticities dependent on GDP per capital
– International capital mobility for dynamic analyses.

The LEITAP model has been used to answer the questions of a diverse group of clients including: Dutch policymakers (Houtskoolschets), the European Commission (Scenar2020 I & II, Modulation) and the OECD (Compare long-run scenarios, Environmental Outlook).

The increasing complexity of LEITAP led to a corresponding increase in the costs associated with using the model. First, it increased the costs of changing model aggregations due to the use of external data, which needed to be manually adjusted when the aggregation was changed. The LEITAP aggregation also had a high level of detail (mainly at the EU level) which increased runtime even when the detail was not needed to answer a specific research question. A final issue was the high cost of training new staff members, who were discouraged by the increasing complexity of the model. To reduce the costs of using the model, LEI made a considerable investment in recoding the model, an effort that has resulted in MAGNET.

1.2 The philosophy underlying MAGNET

Experience gained with LEITAP guided the development of MAGNET. Development has been driven by the following key principles:

– A modular setup around a GTAP core: the modular setup has been designed such that model extensions can be switched on through choices in a single parameter file, sometimes in combination with changes to the closure file. This allows new users to start with GTAP and then add extensions as needed. For experienced users, it facilitates the tailoring of the model to the research question at hand and eases debugging when developing a model. The GTAP model was chosen as a basis for MAGNET not only because it is the premier CGE model, but also because the GTAP network provides a common background, which enables comparison across a wide variety of other CGE models developed from GTAP.

– Data are kept and processed at the lowest level of detail; all databases are kept in their original format and processed at the lowest level of detail to increase aggregation flexibility.

– All data changes and adjustments are coded in GEMPACK to enhance tractability and quality control. This approach also facilitates the updating of datasets, since the same code can be applied to the updates.

1.3 For whom is this manual intended?

This manual provides a description of the modules composing the MAGNET model. A separate manual ('Working with MAGNET') describes how to install the MAGNET system and provides a user guide to the tools and interfaces for running the MAGNET model.

With the standard GTAP model as the core around which MAGNET was developed, the use of MAGNET requires, at a minimum, an understanding of the standard GTAP model and the ability to read GEMPACK code. Therefore, in the following MAGNET documentation, neither general equilibrium modelling nor the GTAP model is discussed.

1.4 An outline of the GTAP core

The standard GTAP model (Version 6.2 of September 2003) was the starting point for developing MAGNET. GTAP is a general equilibrium model covering all sectors of the economy (agriculture, manufacturing and services) as opposed to partial equilibrium models such as CAPRI, which focuses on subsets of an economy. In addition, GTAP is a global model, covering all regions and major countries in the world, as opposed to a subset of regions or countries. A region may include several countries for which there are no individual country data.

Figure 1.1 provides a simplified graphical presentation of the GTAP model. The regional household supplies factors (land, skilled and unskilled labour, capital and natural resources) to the production sectors. By combining these factors with intermediate inputs from other sectors, commodities are produced. Produced commodities are either supplied to domestic markets to satisfy the demand for commodities by private households and governments, or exported.

For every region in the model there is a single representative household demanding consumption goods (including savings) on the behalf of the private household and the government. Total demand is determined by income earned from land, labour and capital, as well as income raised from taxes. The demand for goods is met by national producers or by imports. Each commodity is produced by one sector, while each sector produces just one commodity, that is, there is one producer of wheat, one producer of gas, one producer of wood products, etc.

The model includes trade between all regions in the model and accounts for trade barriers between regions via tariffs. These tariffs may drive a wedge between prices in regions, that is, the same product may be more expensive in one region than in another because of tariffs. Whereas

international trade is modelled by tracing all bilateral flows, international capital flows are governed by a global bank. This bank collects savings and uses them for international investments. Since savings are pooled by the global bank before being used for investments, it is not possible to trace bilateral capital flows.

Prices of goods, land, labour and capital in each region adjust to ensure that both national and international demand and supply are equal; hence the term general equilibrium model. Therefore, when a policy simulation is run, for example, to analyse the impacts of lowering tariffs between regions, the model computes consumption and trade (both imports and exports) by sector, as well as the price levels that ensure equilibrium in national and international markets.

More technical information on the standard GTAP model can be found in various publications. An overview of the model is available in Hertel (2012). An elaborate description of equations is provided by Hertel (1997), and updates of the model described in various technical papers are available at www.gtap.org. A good starting point for understanding the model is the graphical exposition in Brockmeier (2001). An excellent introduction to the GTAP model (and thus the core of the MAGNET model) is provided by the annual short courses organised by the GTAP centre in Purdue (see www.gtap.org for more information).
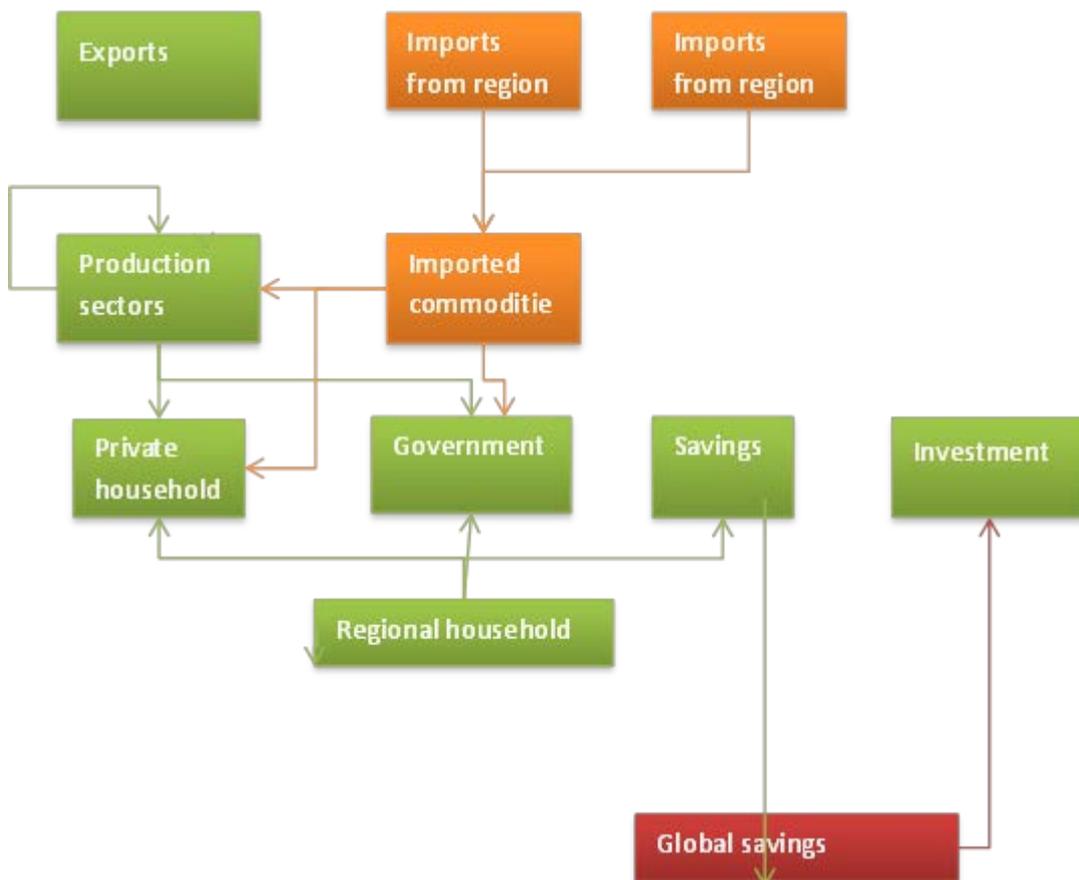
Figure 1.1   *A simplified representation of the GTAP model*

1.5 Extending the GTAP model in a modular fashion

As mentioned, a key feature of MAGNET is its modular design, which facilitates the addition of extensions. The standard GTAP model forms the core of the model. Extensions can be added to the GTAP model in a stepwise fashion as needed. This procedure simplifies the comparison of results across models and lowers entry costs for new modellers. The modular approach is facilitated by

dedicated software developed at LEI for coding (Gtree), running MAGNET (DSS) and analysing results (GEMSE-Analyst).

The standard GTAP model (version 6.2 of September 2003) forms the core of MAGNET. To allow easy entry into MAGNET, the GTAP core is preserved within MAGNET, that is, GTAP equations are left untouched when extensions are made except in the following cases: 1) changes made to set domains over which the equations apply and 2) when differentiation between sectors and commodities is needed in the event that one commodity is produced by more than one sector or a sector produces more than one commodity.

Using sets to alter the structure of the model implies that the same variable can be governed by different equations. It is sometimes helpful to place the standard GTAP equation next to a new MAGNET equation to grasp how a particular equation is changed in a specific module. The following two excerpts of the MAGNET code illustrate this use of sets. The first bit of code is the standard GTAP equation determining intermediate demand for inputs (qf):

```
# industry demands for intermediate inputs, including cgds #
(all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,GPROD_GREG)
  qf(i,j,r) = - af(i,j,r) + qo(j,r) - ao(j,r)
        - ESUBT(j) * [pf(i,j,r) - af(i,j,r) - ps(j,r) - ao(j,r)];
```

The only difference from the standard GTAP model is in the definition of the domain of the equation. The GTAP equation applies only to regions that are part of GPROD_REG, namely regions that have a GTAP production structure. Regions can also have a more elaborate and flexible production structure if they belong to the set CETPROD_REG; then the same variable qf is governed by the following equation:

```
Equation QF1_INP1_S1
# demands for endowment commodities (HT 34) #
(all,i,INP1_S1)(all,j,SECTORS_S1)(all,r,CETPROD_REG)
  qf(i,j,r)
    = 0*time+ if(CS_INP1_S1(i,j,r)>0,
  - af(i,j,r) + sum{k,SUB1_S1,qf(k,j,r)}
  - sum{k,SUB1_S1,EL_PROD(k,j,r)}
        * [pf(i,j,r) - af(i,j,r) - sum{k,SUB1_S1,pf(k,j,r)}]);
```

By using sets, it is possible to have different equations for the same variable coexisting in the model. GEMPACK allows empty sets, in which case the equations are effectively removed from the model. Therefore, if no regions are assigned to CETPROD_REG (the above equation), the model reverts to the standard GTAP specification.

The use of sets to create 'parallel universes' of different equations governing the same variable has the advantage that only the domain of GTAP equations needs to be changed. It also allows the development of new modules while allowing others to use the original code because, as long as the regional sets of the new modules are left empty, they do not affect model results. By using sets, we can also keep all code together, that is, an application with a standard GTAP production structure and one with an extended production structure can be run using the same code. Finally, having a single MAGNET model helps to prevent diverging developments that are hard to recombine.

A disadvantage of using sets is that a large number of sets need to be defined before running the model. To ease the burden of defining sets, definitions are defined through the choice parameters in the model defining stage in DSS. With DSS, it is also possible to reuse existing model choice files, thereby reducing the number of changes that need to be made.

1.6 Keep the model independent of a specific aggregation

A second key feature of MAGNET is its independence of a specific aggregation. Just as with the standard GTAP model, any aggregation of regions and sectors can be made and run within the model;

however, MAGNET simplifies the aggregation process. In MAGNET, additional data are processed at the aggregation level at which they are available. While the GTAP database aggregation is the starting point for MAGNET, extra commodities, endowments and countries can be added through the DSS interface. General sets for countries, endowments and sectors are defined at their lowest level of aggregation. For example, the ISO country classification is used as a common set for regions. By mapping all regional classifications in different databases to this common classification, procedures for aggregation or splitting regions from the original databases to the level that is used in the specific MAGNET database are largely automated. If region definitions for a database change, only the mapping from the ISO classification to those regions needs to be changed. The same holds for new variants of the GTAP database; adding a new database of GTAP that normally has a different regional aggregation only requires the addition of the new mapping to the ISO classification in order to make the system work.

1.7 All database adjustments need to be traceable

Data are key for policy-oriented modelling applications. Again, based on experiences gained from LEITAP, all database adjustments in MAGNET are coded in GEMPACK. This implies that all changes made to the source data are visible in the code. This allows the quality control of adjustments and eases the transfer of knowledge on database adjustments to other researchers. Coding all data adjustments also makes the use of data more flexible. For example, projections of GDP and population growth used in projections are aggregated to the chosen model aggregation and made period-specific using code. Maintaining full separation of code and data implies that only the input files defining the model aggregation and periods need to be changed to use these projections in a new project.

1.8 MAGNET directory structure

The directory structure of the MAGNET model has been designed to make it easy to find the base data, model assumptions, the accompanying model, the scenarios created, the dynamics implemented, any policies implemented, outcomes and the tools to analyse output. The directory structure is as follows:

BaseData	28-11-2011 20:28	File folder
CodeMainProgram	28-11-2011 20:28	File folder
CodeShocks	28-11-2011 20:28	File folder
CommandFiles	28-11-2011 20:28	File folder
GEMSE_Analist	28-11-2011 20:28	File folder
graphsettings	29-9-2011 1:15	File folder
Input data	28-11-2011 20:28	File folder
OutputData	28-11-2011 20:28	File folder
Scenarios	28-11-2011 20:28	File folder
Shocks	28-11-2011 20:28	File folder
Solutions	28-11-2011 20:28	File folder
Updates	28-11-2011 20:28	File folder

1.8.1 BaseData

The BaseData folder contains all the base data and assumptions that have been used to create the model. It has the following structure:

The subdirectories that are relevant when carrying out analyses with MAGNET are ModPar, Par, Sets and Views. The subdirectory **ModPar** contains all the choices that have been made regarding the behaviour of actors and the functioning of an economy in general (land market, factor markets, consumption, production, etc.). These parameters govern the structure of the model; hence the name ModPar (model parameters). The subdirectory **Par** contains the values for parameters used in the model, including, for example, substitution elasticities. To facilitate changes in a model's structure, the parameters of all available model options (even those not currently selected in model choices) are included. The subdirectory **Sets** contains the sets used in the model. Finally, the subdirectory **Views** contains all *ad valorem* rates of taxes, tariffs and subsidies and macroeconomic indicators, such as GDP, that can be calculated ex post from the model. The base data of the model can be found in BaseData_b.har.

All files containing the base data (model parameters file with extension prm, parameters file with extension prm, sets and view files with extension har) can be opened with the GEMPACK program ViewHAR. This is true for all data files (including shock data, solutions and updates discussed below).

1.8.2 CodeMainProgram

The CodeMainProgram folder contains the model code in gmp format, which is used in GTREE (the MAGNET default editor) to program MAGNET. GTREE compiles this code into the tablo format that is used by GEMPACK, the language in which GTAP and MAGNET are coded. The GEMPACK program TABMATE is used to compile the tablo code into Fortran code, which is automatically compiled into an executable named MAGNET.exe. This is the program used in simulations.

1.8.3 Shocks and CodeShocks

The Shocks folder contains, for the periods for which the model is run, data on the changes in macroeconomic drivers (GDP, population/labour, capital, technology and yields) that are underlying the baseline. Further coded manipulations of these data are contained in the folder CodeShocks. At a minimum, this code transfers the information on shocks to a simulation and period specific file in the subdirectory Calculated shocks of the Shocks directory. The code for any other policy shocks programed and imposed on the model are also be stored here. Similarly, any data to calculate shocks via a shock program (i.e. coded) will be included in the Shocks folder.

1.8.4 CommandFiles

The CommandFiles folder contains command files (with extension .cmf) that are split into four types in four subdirectories, and put together by DSS when running a scenario. The four types of files are:
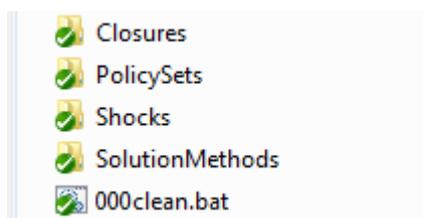
Model closures files determine which variables are exogenous and which are endogenous.
- PolicySets files may be used to define sets that are used in more than one shock file
- Shock files define policies and/or shocks to be implemented (designating that a specific variable should change by x%)
- SolutionMethods files define which solution method should be used and give the number of steps by which a model is to be solved.

1.8.5 Scenarios

The Scenarios folder stores the so-called answer files that have been created by the user in DSS to run different scenarios by name (naming is thus very important!). They contain all the settings that were previously specified. Once a scenario has been run, a subdirectory with the same name will be created. This subdirectory stores information on the scenario specification (in a cmf file) and additional information, including any error messages (in a log file). Errors are assembled automatically through the program Checkfile.exe, which is run through batch files generated by the DSS system and stored in a warning file (file extension .warn), which automatically pops-up when there were warnings or error messages during the simulation. Note that the warning file does not contain all messages, so if there is any doubt, please go to the log files that are created by GEMPACK and stored in the scenario subdirectory of the specific scenario.

1.8.6 Solutions

The solutions folder contains solution files for each scenario for the periods specified. The files are named after the command file with which they were run. DSS creates these names by combining the scenario name and the period over which a model is run. The standard solution file generated by GEMPACK is an .sl4 file which can be opened with the ViewSOL program. In the MAGNET program, the variables are also contained in a HAR file with the extension .SOL and have the same name as the .sl4 file. This file is used by GEMSE_Analyst, the software package created by LEI to analyse the solutions of MAGNET simulations. The .sol files can also be read with VIEWHAR. Files with the .slc extension contain the pre-simulation coefficient values. The default settings of AnalyseGE, another GEMPACK program with which solutions can be analysed, use these coefficients when evaluating equations. *This can cause divergences between the numbers computed by AnalyseGE and those found in the sl4 file.*

1.8.7 Updates

The updates folder contains updated versions (created after the model has been solved) of the base data files that were used at the beginning of a scenario. Specifically, the update.har files are the updated versions of the BaseData_b.har file, named after the scenario and period for which it was created. These files provide a starting point for multi-period simulations: the simulation for period t+1 initialises on the values in the update.har file of period t. Similarly, the directory also contains updates of tax rates (update_tax.har), and indicators derived from the base data file (update_view.har).

1.8.8 GEMSE_Analyst

This folder contains the GEMSE_Analyst program created by LEI to analyse the results of MAGNET simulations. The settings of the tables and graphs are stored in the 'graphsettings' folder, which can be found in the file below the GEMSE_Analyst folder, while the definitions of the variables in GEMSE_Analist are stored in the subdirectory Input data\Aggregatieconversie. The subdirectory Outputdata is for exporting results to Excel sheets or ASCI files.

1.9 MAGNET conventions

Key principles:
- The program code (TAB file) is split into a large number of plain text files (with the extension .gmp).
- Chapters and sections within code are visible through GTREE.

- Gtree compiles a single program code (TAB) file from the text files.
- Compilation to Fortran code through the GEMPACK programming language.
- Equations are named after variables, followed by a 1. Doing this systematically allows a program (VariableEquationMatching.exe) to link variables and equations to each other in order to check for closure problems.
- Keep code per module and sub-modules together in directories.
- Put code in logical order and use informative file names and GTREE regions.
- Code should be independent of aggregation (i.e. no hard coding of set elements).
- Make model choices independent of aggregation, that is, limit the number of aggregation specific sets and coefficients. In many cases, you can derive sets by a standardised method using a mapping defined in classifications.har in the database or by programming the code in modelstructure.gmp and magnetagg.gmp.

Naming conventions:
- In general, names are made consistent over the whole system from database to final program.
- Make names as intuitive as possible, but be aware that there is a limit to the size of names in GEMPACK (12 characters) and try to stay below this in order to be able to add prefixes to them when needed.
- The sets of the original GTAP database are identified by the addition of a 'G' (for GTAP): GREG, GTRAD_COMM, GTRAD_SECT, etc..
- Sets including added commodities can be identified by a 'D' (for disaggregated), namely at the lowest aggregation level at which everything is made consistent: DREG, DTRAD_COMM, DTRAD_SECT, etc.
- By splitting off extra regions, DREG will become bigger than GREG.
- The sets of the final aggregation are defined without a prefix, consistent with the GTAP naming convention: REG, TRAD_COMM, TRAD_SECT, etc.
- Similarly, GTAP coefficients have a prefix G, disaggregated coefficients have a prefix D, while the final aggregations have no prefix.
- Mappings are named after sets, with a 2 in between; for example, MCOM2DCOM is a mapping from MCOM to DCOM. If set names are too long to do this, make them shorter in a logical manner.
- Equations named after variables are appended with a 1. This allows the program VariableEquationMatching.exe to link variables and equations to each other in order to check for closure problems.

1.10   References

Brockmeier M. 2001. A Graphical Exposition of the GTAP Model. GTAP Technical Paper No. 8. Available from www.gtap.org under Resources – Technical Papers.
Hertel, T.W. (ed.) (1997). *Global Trade Analysis, Modelling and Applications*. Cambridge, Cambridge University Press.
Hertel, Thomas. (2012). *Global Applied General Equilibrium Analysis using the GTAP Framework*, GTAP Working Paper No. 66. Available at www.gtap.org.

2 Adjustments and additions to the GTAP database

Just as the standard GTAP model forms the core of the MAGNET model, the GTAP database forms the core of the MAGNET database. In addition to the GTAP database, the MAGNET database includes a series of other databases in support of MAGNET modules, such as the land use module, and for the construction of baselines.

This chapter describes the general approach used to adjust MAGNET databases, and possible database adjustments for the GTAP database. Databases and data adjustment procedures used for specific MAGNET model modules are described in chapters dedicated to those modules, for example a description of the land use data in MAGNET can be found in the module on endogenous land supply.

2.1 Aim

The data adjustment module in MAGNET can be used to:
- Improve the GTAP data as provided by the GTAP centre for specific research questions
- Add satellite accounts with additional data needed by MAGNET (e.g. land use data)
- Add additional accounts to the SAMs (e.g. adding biofuel sectors or adding new countries).

To maintain the flexibility of the system, all adjustments are made at the most disaggregated GTAP regional level. All adjustments are coded in GEMPACK for tractability.

2.2 Approach

In MAGNET, we include several additional datasets needed for extensions made to the standard GTAP model. These additional data are generally not provided in the same format as the GTAP database. We therefore need to process the data in order to make them compatible. A complicating factor is that the number of GTAP regions varies with each version of the GTAP database. To ease the updating process and to maintain compatibility with different GTAP database versions, we code the date processing procedures in GEMPACK.

The MAGNET database is constructed in three distinct steps: creation of a SAM, adjustment of the data and conversion of the SAM back to the standard GTAP database format.

2.2.1 Creating a SAM

Although the standard GTAP database is not in the form of a social accounting matrix (SAM), a SAM can be derived from it. Adjusting data in a SAM shows the economy-wide impacts of those adjustments and signals violations of balancing requirements. We therefore make all data adjustments after the data have been placed in a SAM format.

We create a SAM from a given GTAP database using an adjusted version of the code originally developed by Vitaly Kharitonov (Center for Global Trade Analysis, Purdue University) as a complement to the technical paper by McDonald, Thierfelder and Robinson (2007).

When creating the SAM, we create empty rows and columns for new commodities that we want to add to the database. In the next step, we fill these empty rows and columns with data while maintaining

the integrity of the SAM. Note that we do not use the SplitCom program to add sectors, since we prefer to maintain full control over the adjustments made to the database.

In the standard GTAP database, no distinction is made between commodities and sectors, that is, all sectors produce a single commodity. In MAGNET we allow for joint production: we allow a single sector to produce more than one commodity. To this end, we need to make a distinction between commodities and sectors and, consequently, there can be more commodities than sectors in the database.

In the MakeSAM code, we distinguish between GTRAD_COMM (traded commodities as defined in GTAP; 57 in total) and DTRAD_COMM (disaggregate traded commodities, including the original GTAP sectors). If the DTRAD_COMM set is equal to GTRAD_COMM, no commodities have been added. In the case where commodities have been added, DTRAD_COMM consists of all 57 original GTAP commodities plus any number of sectors added to the model. The code has been developed assuming that commodities will be added to the existing commodities. Therefore, when adding a commodity, the original sector name is maintained and one or more new sectors are added to the file.[1] This approach is enforced by defining GTRAD_COMM as a subset of DTRAD_COMM.

When adding a new commodity we need to decide how the new commodity is produced. Either we maintain the one-to-one relationship between sectors and commodities as in the standard GTAP database, or we introduce joint production. In the first case, we need to add a new sector to the standard GTAP sectors, that is, DTRAD_SECT includes the original sectors from GTRAD_SECT plus the new sector. If we add a new commodity as a case of joint production, we do not adjust DTRAD_SECT and so it will therefore have one less element than the DTRAD_COMM.

Allowing for joint production in the database requires an explicit decision to be made about how commodities and sectors are related to each other. This is expressed through mappings between commodities and sectors. Note that we can add multiple commodities and sectors to the model in one go. The new commodities and sectors will be added to the SAM with empty rows and columns. These are then filled with data in the next step when we add and adjust data. The process is similar when adding new sectors and commodities to the GTAP database; these are also added as empty rows and columns filled with data in the next step.

2.2.2   Modifying the GTAP database

The selected GTAP database can be modified in three ways. First, the data entries in the original GTAP database can be adjusted without any changes in the number of commodities or regions. An example of such an adjustment is the removal of land from non-ruminants (oap).

Second, satellite accounts can be added to the GTAP database to provide input for extensions to the standard GTAP model. These modules add new headers to the GTAP database without affecting the existing ones. An example of such an adjustment is the addition of land use data to allow the modelling of endogenous land supply. Another distinct set of satellite accounts is the creation of a separate dataset with data used to create projections compatible with the selected GTAP database.

Finally, new commodities, sectors, endowments or regions can be added to the GTAP database. These modules change the existing headers in the GTAP database by changing the number of elements in the standard GTAP sets and by changing the contents of the existing entries. An example of such a module is the addition of biofuel sectors and commodities.

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[1] Of course, you are free to rename the original sector when defining your model aggregation in the model definition step.

2.2.3   Making the MAGNET database

After modifying the data in a SAM format, the SAM is converted back to the standard GTAP database format. The resulting database is used to create a model aggregation (e.g. the GTAP database is aggregated by GTAPagg to a user-defined model aggregation).

2.2.4   Adjusting an aggregated database

As a matter of principle, almost all data adjustments are done at the most disaggregated level in order to maintain the maximum flexibility in model aggregations. There can be exceptions to this rule if data adjustments are relevant only to aggregated databases, namely when the user has defined specific regions and sectors to be used in the model. An example of such an adjustment is the removal of internal trade in aggregated regions (which is a choice offered in MAGNETagg).

2.3 Implementing general GTAP data adjustments through DSS

In order to adjust the (disaggregated) GTAP data, information in the Database tab in DSS is needed. See the chapter on DSS in the 'Working with MAGNET' manual for guidance on using the DSS Database tab. To implement the general GTAP database adjustments described above, choose the following settings in Database tab:

Choice	Selection to be made	Comment
GTAP database folder	Any GTAP database can be selected	
Files for extra data	Use list defined in standard scenario	
Choose includes	Include data adjustment procedures that you would like the implement	Check the documentation on data manipulations for the adjustments made by each include; here you also find any specific codes for new sectors, commodities, regions or factors.
Add sectors	Some modules require new sectors with specific codes; consult the documentation on data manipulations for details	Absence of a sector with the proper code can cause errors in the AddAndModifyData step
Add commodities	Some modules require new commodities with specific codes; consult the documentation on data manipulations for details	Absence of a commodity with the proper code can cause errors in the AddAndModifyData step
Add region	If modules for adding new regions are available, these need to be defined here with the proper code; consult the documentation on data manipulations for details	Absence of a region with the proper code can cause errors in the AddAndModifyData step
Add endowments	If modules for adding new factors are available, these need to be defined here with the proper code; consult the documentation on data manipulations for details	Absence of a factor with the proper code can cause errors in the AddAndModifyData step

2.4 Adjusting an aggregated database – removal of self-trade

2.4.1   Aim of removing self-trade

When aggregating regions, internal trade flows within these regions will occur. Therefore, all aggregated regions in the database (those starting with an x) have non-zero internal trade flows. However, even regions that appear to be single countries could have internal trade flows. In the V8 2007 database, Australia, Finland and Norway have non-zero internal trade. In some applications, it can be desirable to remove these internal trade flows, which is the purpose of the module removing self-trade.

2.4.2   Pros and cons of removing self-trade

The GTAP mailing list has contrasting opinions on whether or not internal trade flows in aggregated regions should be removed or not. In the case of MAGNET, we add the option of removing internal trade as an option to MAGNETagg. When setting-up a model structure in DSS, the user can decide whether this adjustment to the database should be implemented for a specific project.

Self-trade in the GTAP database is a result of aggregating more detailed data. It does reflect genuine cross-border trade flows. In the disaggregated database, self-trade appears for all aggregated regions and some countries due to a regional definition that, for example, includes several islands (as is the case of Australia).

Some argue that self-trade is hard to interpret since it suggests two different behavioural decisions for domestically produced commodities: one for domestic goods and one (Armington based) for goods imported from the own region. Removing self-trade results again in a single decision making process for domestic goods only.

Others argue that the imported goods from the own region represent genuine cross-border trade, and thus deserve to be treated differently from domestically produced goods that do not cross borders. Removing them from the database can mask important shifts in trade flows when, for example, high initial tariffs on imports from the own region are reduced. If self-trade is removed following the procedure below, the flows will no longer be affected by changes in tariffs. Therefore, in some cases (e.g. when aggregating Hong Kong and China), self-trade may be an important feature that should remain in the analysis.

The final conclusion seems to be that users need to decide on a case-by-case basis which approach is needed. The decision depends both on the policy issues being addressed and on the aggregation being used. With the increasing number of regions in the GTAP database, it seems advisable to keep all countries that are relevant to a project as separate regions, thereby avoiding most of the problems with self-trade.

2.4.3   Approach to removing self-trade

Removing self-trade is not as straightforward as shifting exports to domestic use. Cross-border trade flows are affected by tariffs and subsidies and require the use of transport services, all of which need to be accounted for in order to maintain a balanced database. Figure 2.1 presents the relationships between the various GTAP headers affected by self-trade.

The adjustments to the database should disturb the overall structure of the data as little as possible. For example, total expenditure by commodity (on domestic and imported) should not change, nor should the production of commodities.

The adjustments proceed in the following steps:
1.   Compute components of internal trade flows
    To be able to reallocate, we need to know the value of internal trade and related export tariffs, transport margins, import tariffs and source-generic import tariffs by intermediate and final demand category.
2.   Compute shares in trade flows
    Users of imports (intermediate and final demand) do not know the origin of their imports. It is assumed that each user's share in imports by commodity can be applied when reallocating self-trade (in other words, all users have the same mix in origins of their imports).
3.   Remove self-trade
    It is then possible to compute the changes in VIFM, VIFA, VIPM, VIPA, VIGM and VIGA which need to be removed from self-trade within import demand by users and set all entries related to self-trade to zero in VXMD, VXWD, VTWR, VIWS and VIMS.
4.   Increase domestic use of self-traded commodities
    Using the shares of users in imports by commodity, we can reallocate the amount of VXMD previously exported to domestic use to domestic demand in market prices (VDFM, VDPM and

VDGM). Reinterpreting tariffs as domestic taxes, we can also compute the changes in domestic demand at agents' prices. Note that the removal of self-trade can entail considerable changes in the domestic tax rate when tariffs on self-trade are high. After this step, total expenditures on domestic and imported goods are the same, apart from the absence of margins, which require some additional treatment.

5. Compute changes to trade margins

    Cross-border trade requires transport services (atp, otp and wtp are the margin commodities in GTAP). Demand for margin commodities has been reduced by setting the diagonal elements in VTWR to zero. This change needs to be matched by a reduction in supply of margin commodities by region, VST. Lacking better data, we proportionally reduce each country's supply of margin commodities to match the reduction in VTWR.

6. Increase trade in transport services

    Next, the amount of margin commodities previously supplied to VST needs to be absorbed. They are now consumed directly as transport services by the users previously demanding the self-trade (which included the costs of transport as a margin). This involves increasing imports of margins recorded in VIFM, VIFA, VIPM, VIPA, VIGM and VIGA. Note that there are no tariffs on transport services used as margins, but there are source-generic taxes on imported transport services by user. Increasing the demand for imported transport services by the value of the margins may therefore alter the implied tax on imported transport services.

7. Increase domestic consumption of transport services

    The final step is to add the computed self-trade margin commodities to domestic demand for transport services. This involves increasing demand for margin commodities in VDFM, VDFA, VDPM, VDPA, VDGM and VDGA. Again, note that since there are taxes on the use of domestic transport services, adding transport services with no taxes associated with it will alter the implied tax rate of use of domestic transport commodities.
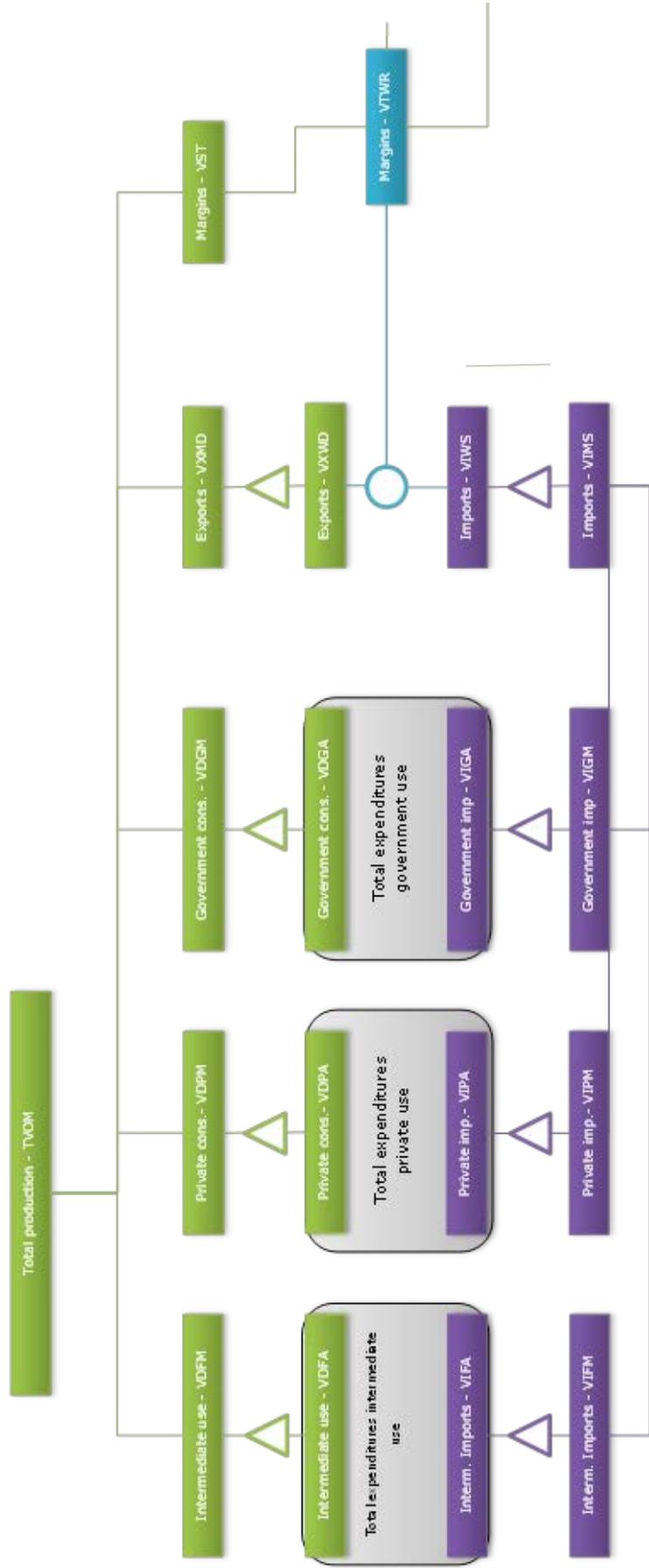
MAGNET

Figure 2.1: Relationships between headers involved in reallocating self-trade

2.5 Adjusting an aggregated database – removing negative savings

2.5.1 Aim of removing negative savings

The allocation of regional household income over private expenditures, government expenditures and savings is governed by a Cobb-Douglas utility function. A Cobb-Douglas function yields constant and non-negative consumption shares and therefore does not allow for the negative savings that occur in the disaggregated GTAP database. If negative savings persist in the aggregated database used for modelling, the data are inconsistent with the economic theory underpinning the model.

2.5.2 Pros and cons of removing negative savings

Negative savings indicate that a country's expenditures exceed its income. In the 2007 V8 database, there are 24 countries that have negative savings. Expenditures can exceed available income by 33%, as is the case for Nicaragua. Removing negative savings is a quick and, for some countries, a highly distorting fix. The real solution is therefore to alter the specification of saving behaviour in the model in order to capture empirically observed patterns.

2.5.3 Approach to removing negative savings

Removing negative savings is not straightforward, since the database needs to be balanced. We need to ensure that the budget constraint of each regional household is maintained. For example, expenditures need to match income earned in each region:

$$\text{PRIVEXP}(r) + \text{GOVEXP}(r) + \text{SAVE}(r) = \Sigma_e \text{VOM}(e,r) - \text{VDEP}(r) + \text{INDTAX}(r);$$

Verikios and Hanslow (1999) address this problem in version 4 of the GTAP database by offsetting the required increase in savings by a reduction in depreciation (VDEP) in regions with negative savings. This is an attractive way to adjust the accounts of regions with negative savings. This approach does require VDEP to be larger than the negative savings. Unfortunately, this condition is not satisfied in seven of the 24 regions in the V8 2007 database; we therefore cannot rely on this approach to accommodate negative savings.
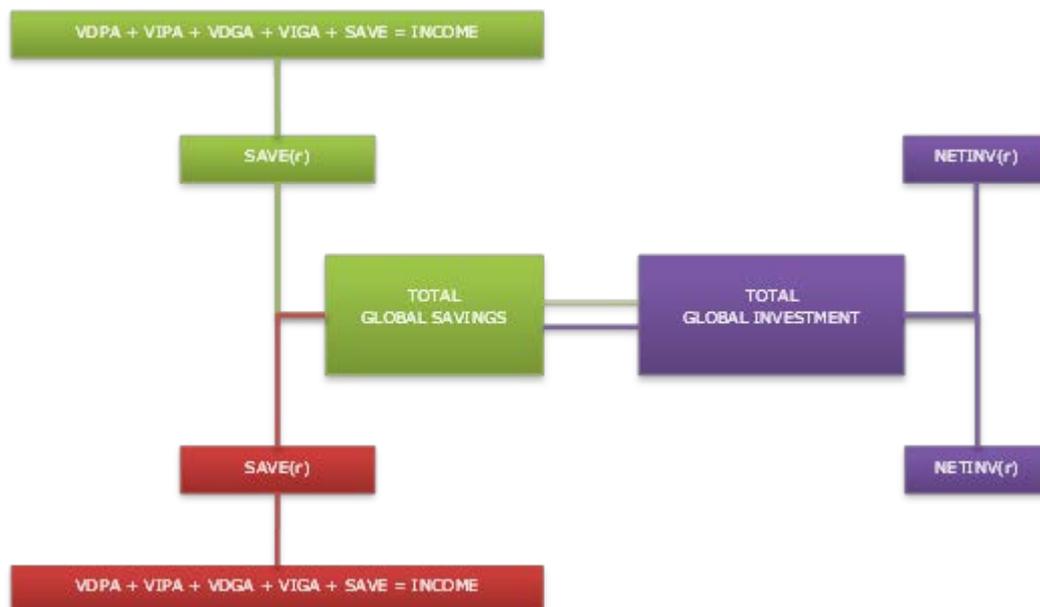
Figure 2.2: *Flow of savings to global bank*

Negative savings in a region can be interpreted as a transfer of income from other regions that is allocated by the global bank (see Figure 2.2). In the GTAP database, savings balance with net investment at the global level. This implies that the negative savings of countries are in fact deducted from the savings of all other countries. The total remaining amount is then invested by the global bank in each of the regions.

This approach to modelling savings and investment allows us to introduce transfers. These transfers make the balancing of savings over all regions explicit and thereby remove negative savings. They do not alter the total income of the regions. Countries with positive savings will now spend part of their income on transfers, which are deducted from their savings. Countries with negative savings receive transfers that offset their negative savings, thus keeping their total income balanced as well. Total investment is not affected as long as the global total of all transfers is zero.

2.5.4 Implementation in MAGNET – adjustment in the GTAP core

Since the presence of negative savings renders the standard GTAP core model inconsistent, adjustments to the model are made in the GTAP core and not limited to the modified GTAP.
The first step is to include the transfers when computing the savings in each region. The way in which savings are initialised is already different in the GTAP core. The SAVE header in the database is only there for informational purposes. To make sure the income equation holds, savings are computed as a residual.

```
Coefficient (all,r,REG)
   SAVE(r) # expenditure on NET savings in region r valued at agent's prices #;
Formula (all,r,REG)
     SAVE(r)=INCOME(r)- PRIVEXP(r) - GOVEXP(r) - TRANSFR(r);
!instead of reading with update in standard GTAP.
The procedure here guarantees consistency!
```

To this computation of savings we add a new coefficient TRANSFR(r), which holds the transfers paid or received (= negative transfers). This coefficient is available only when the module RemoveNegativeTransfers has been included in MAGNETagg. Therefore, the coefficient is initialised at

0 and only read if the header is available:

```
Coefficient (all,r,REG)
 TRANSFR(r) #  Transfers to offset negative savings in base data #;
  Formula (initial) (all,r,REG)
    TRANSFR(r) = 0;
  Read (IfHeaderExists) TRANSFR from file GTAPDATA header "TRNS";
  Update (all,r,REG)
    TRANSFR(r) = zeroupdate;
```

The removal of negative savings is an ad-hoc fix that does not consider how transfers are allocated; transfers are kept at their initial level with a zero-update variable. This approach keeps the (updated) values of the transfers in the database so they can be used to check the income calculation when analysing results.

The level of savings is also used in the computation of the Walras demand. Transfers sum to zero over all regions, but are not necessarily zero at the regional level. By adding the TRANSFR variable to savings, we effectively set the savings to their level before adjustments in MAGNETagg, and thereby ensure that the Walras equation holds:

```
Variable
  walras_dem # demand in the omitted market--global demand for savings #;

Equation WALRAS_DEM1    !WALRAS_D!
# Extra eq'n computes change in demand in the omitted market. #
    GLOBINV * walras_dem = sum(r,REG,
                      [SAVE(r) + TRANSFR(r)] * [psave(r) + qsave(r)]);
```

Therefore, for regions receiving a transfer, the sum of SAVE and TRANSFR is the original negative number contained in the GTAP database.

2.6 Implementing aggregated database adjustments through DSS

In order to adjust the aggregated database, go to the model tab in DSS. See the chapter on DSS in the 'Working with MAGNET' manual for guidance on using the DSS Model tab. To implement the removal of self-trade adjustments described above choose the following settings in **DSS Model tab**:

Choice	Selection to be made	Data adjustment made
Database folder	Any MAGNET database can be selected	
Files for standard choices	Any file with standard model choices can be selected	
Choose includes for model structure	Any includes can be selected	
Choose includes for MAGNETagg	Select RemoveSelfTrade	Implements the database adjustment described above to remove all self-trade from the aggregated database (= database created from aggregations defined in the last three questions of the DSS model tab)
	Select RemoveNegativeSavings	Implements the removal of negative savings from the aggregated database (= database created from aggregations defined in the last three questions of the DSS model tab)
Choose includes for MAGNET	Any includes can be selected	
Aggregate regions	Any aggregation can be made	
Aggregate commodities	Any aggregation can be made	
Aggregate endowments	Any aggregation can be made	

2.7 References

McDonald, S., Thierfelder, K. and S. Robinson (2007). 'Globe: A SAM Based Global CGE Model using GTAP Data', USNA Economics Department Working Paper No. 15.

Verikios G. and K. Hanslow (1999). 'Modelling the effects of implementing the Uruguay Round: A comparison using the GTAP model under alternative treatments of international capital mobility', Productivity Commission, Canberra, Australia. Paper presented to the Second Annual Conference on Global Economic Analysis, Denmark, 20-22 June 1999.

3   Creating a baseline with MAGNET

MAGNET is often used for scenario-based analyses whereby future changes from a predefined baseline are compared for various policy options. To facilitate the use of external data sources with project-specific aggregations and time horizons, these data are processed in various parts of the MAGNET system.

This chapter describes the general approach to preparing these data for use in scenarios as well as the data sources available in MAGNET.

3.1 Aim

The scenario data modules in MAGNET can be used to:
- Make external data compatible with any selected GTAP database
- Aggregate the scenario data to a user-define model aggregation and time horizon
- Prepare shock files for use with the MAGNET model.

3.2 Approach

In MAGNET, users make choices at various stages in the modelling process. As a result, the processing of external sources of projection data takes place in different parts of the system.

3.2.1   Making external data compatible with the selected GTAP database

Different versions of the GTAP database vary in terms of their reference year and the number of regions defined. The first step in using external data is therefore to make external data compatible with the sector and region definitions used in GTAP, including possible new sectors and regions defined by the user. This is done in the data adjustment step. It does not appear in DSS as a choice, since it is always done (in the Gtree code the relevant parts can be found under the DoThisAlways include statement). The result of this step is a set of mappings from external data sources to GTAP.

3.2.2   Aggregating the external data to the selected model aggregation and time periods

The second data processing step is to compute initial levels and percentage changes in the chosen model aggregation and for the selected time periods. These percentage changes can then be used as shocks when running the MAGNET model. These steps are performed in DSS in the Prepare Scenario tab (see the 'Working with MAGNET' manual for more details).

The computation of scenario data is performed in the 3_ScenarioSetUp step, and controlled by the definition of the number of periods and their ending years.

The scenario setup module has four main components (under \3_ScenarioSetUp\2_CreateMacro Scenarios\Code):
1) *Commons.gmp*: definitions of files and sets used by various components of the module.
2) *Periods.gmp*: define start and end years of each period based on input provided by the user, apply some consistency checks, and specify a period selector to match years in numbers to years as set elements.
3) *MacroShocks.gmp*: compute macro changes from a range of sources and combine them in a single coefficient to allow easy comparison across sources for the regional aggregation and periods used.

4) SectorShocks.gmp: compute changes in productivity for crop and livestock sectors for the regional and sectorial aggregations and periods used.

Data from different sources frequently extend across different periods. The periods defined for a specific model might extend beyond the years for which data are available. When computing the changes by period, there is a check on whether there are data available for all years. If this is not the case, the change in the variable will be set to zero. For example, if GDP data are available for 2011–30 and the user defines a period of 2011–31, the change in GDP will be set to zero since data for 2031 are missing.

The file PeriodData.har is automatically adjusted for the choices made by DSS, but it can also be adjusted by hand. To compute scenario data by hand:
1. Open the file 'PeriodData.har' located in ..\3_ScenarioSetUp\2_CreateMacroScenarios\ExtraData
2. Adjust the headers as described in Table 3.1
3. Save the file and run CreateMacroScenarios

Table 3.1

Defining periods for the computation of scenario data

Header	Description	Changes needed
PRDS	Number of periods (to be consistent with number of rows in header END)	Give the number of simulation periods; note that for each of these, an end year needs to be provided in the next header, thus this number needs to be equal to the number of rows in the header END.
END	End year of each period (adjust dimension to number of periods in PRDS)	Change the number of rows to the number of periods specified under the header PRDS and provide the last year for each period.
SNAT	Share of capital change used to compute change in naturel resources	Lacking data on the development of natural resources, we use a fraction of the change in capital to compute the change in the natural resource endowment; this fraction is specified here.

3.3 Available scenario data

For constructing baselines, we need projections of GDP, population and other key indicators. These data are obtained from various sources and are briefly described below. The manner in which they are converted into usable data for MAGNET is described in the documentation on macro scenarios.

3.3.1 ERS data

From the USDA-ERS website, projections of GDP and population for constructing macro scenarios were downloaded (http://www.ers.usda.gov/Data/Macroeconomics/#BaselineMacroTables).

Source: USDA-ERS, International Macro Economic Dataset
Types of data: Real GDP projections (2005 dollars)
                   Population projections (persons)
Scope: Data country level and at various levels of aggregation.
Years: 2000–30
Last update: 26 January 2012
URL: www.ers.usda.gov/Data/Macroeconomics/#BaselineMacroTables

These data are provided in an Excel spreadsheet (located in .\0_Database\3_ScenarioData\ERS\SourceData) and therefore need further adjustments for use in MAGNET. These adjustments are currently done in Excel spreadsheets. To update the data:
1. Download the most recent GDP and population projections from the ERS.
2. Copy the complete worksheet with GDP data to the excel file 'Real GDP and population data.xls' on worksheet ERS real GDP data.
3. Copy the updated GDP data from the worksheet GDP table to the har file ERS_GDP_pop.har, header EGDP.
4. Copy the complete worksheet with population data to the Excel file 'Real GDP and population data.xls' on worksheet ERS population data.
5. Copy the updated population data from the worksheet population table to the har file ERS_GDP_pop.har, header EPOP.

ERS provides data at the country level, combining estimated and projected data to generate a time series for 2000–30. Regional aggregates are filtered from the original data. Country names as used by ERS are mapped to ISO country codes. Note that the GDP and population datasets refer to the same regions but use different names. Mapping the regions to ISO codes resolves this discrepancy.

Also note that if the ERS data have new countries these need to be included in the mappings to GTAP regions to incorporate the new data (i.e. adjust the ERS related headers in the mappings.har files for each GTAP release (ECTR and MERS)). Table 3.2 summarises how the har and EXCEL files are linked to each other.

Table 3.2
ERS, link between data in har file and Excel files in source data

ERS_Data.har		Source data files
Header	*Description*	
EYER	Set ERS_YEAR Years in ERS projections	-
STRT	First year with ERS data	-
LAST	Last year with ERS data	-
EGDP	RS Real Projected Gross Domestic Product (GDP) in billions of 2005 $	ProjectedRealGDPValues.xls
EPOP	Projected population from ERS (persons)	ProjectedPopulationValues.xls

3.3.2 World Bank

A second source of macro data is the World Bank. We include two types of data in MAGNET: publicly available data from the World Development Indicators (WDI) and projections supplied as part of a joint project on scenarios (referred to as World Bank data). Again, the data are available in Excel spreadsheets and are manually transformed into a har file. The original data can be found in ..\0_Database\3_ScenarioData\WorldBank\SourceData. Table 3.3 defines the link between the headers in the WB_Data.har file and the Excel files as obtained from the World Bank.

Table 3.3
World Bank, link between data in har file and Excel files in source data

WB_data.har		Source data files
Header	Name	
WPYR	Set WB_PYEAR Years in World Bank projections	-
WWYR	Set WB_WYEAR Years with WDI data	-
MWYR	Map WDI years to years of projection data	-
WGYR	Set W_GYEAR Years with levels of projected GDP	-
STRT	Start year with World Bank data	-
LAST	Last year with World Bank data	-
WLBR	Labour force from WDI (persons)	Labour force 1960 – 2009.xls
WWGD	GDP from WDI (constant 2000 US $)	GDP data 1960 – 2009.xls
WGDP	GDP projections from World Bank (annual growth rates)	GDPScenJan2011.xls
TWNG	GDP of Taiwan in 2000 (2000 US $) which lacks in WDI	No data yet
CUMG	Parameter to establish cumulative growth rates (2001 - 2050)	-

Note that the WDI labour force data are not used for the World Bank projections; rather, they are an input for the OECD scenario calculations.

3.3.3 UN

We use population projections from the United Nations population data.

The UN data are a combination of estimated (observed) data through 2010 and projected data from 2011 onwards. We combine these to create a time series for 1950 until 2100 for each scenario. The UN does not have data on Taiwan, but there is a region in Eastern Asia labelled 'other non-specified areas' that appears to have the right order of magnitude to be Taiwan. We map this area to Taiwan for use in MAGNET.

In the cohort data, some regions drop below the 100,000-person threshold used by the UN to make projections and therefore they have no data. The totals for these regions are combined into aggregated regions. To ensure that totals for the cohort data add up to the population totals without mapping to a specific GTAP database region (since names vary between releases), we map the aggregates to a small country belonging to that GTAP aggregate. Choosing a small country reduces the risk of the country being a separate region in future GTAP databases (which then would have too large a population). Mappings listed in Table 3.4 are used in the procedures outlined. Table 3.5 shows how the har and EXCEL files are linked to each other.

Table 3.4
Mapping of UN aggregate regions to a single country

Aggregate region		Data assigned to country	
xnam	Rest of Northern America	BMU	Bermuda
xeaf	Rest of Eastern Africa	SYC	Seychelles
xwaf	Rest of Western Africa	ATG	Antigua and Barbuda
xcar	Rest of Caribbean	AIA	Anguilla
xner	Rest of Northern Europe	FRO	Faeroe Islands
xser	Rest of Southern Europe	AND	Andorra
xwer	Rest of Western Europe	LIE	Liechtenstein
xsam	Rest of South America	FLK	Falkland Islands (Malvinas)
xmic	Rest of Micronesia	KIR	Kiribati
Xpol	Rest of Polynesia	TUV	Tuvalu

Table 3.5
UN, link between data in har file and Excel files in source data

UN_data.har		Source data files
Header	Name	
UNPR	Set UN_PER Periods in UN population data	-
UNYR	Set UN_YEAR Years in UN population data	-
MUNY	Map UN years to UN periods	-
STRT	Start year with UN population data	-
LAST	Last year with UN population data	-
TOTL	UN total population projections (1000 persons)	Prepare UN1980_2100V2008.xls
P156	UN population projections, 15-64 cohort (1000 persons)	Prepare UN1980_2100V2008.xls
P65U	UN population projections, 65 and up cohort (1000 persons)	Prepare UN1980_2100V2008.xls
PL15	UN population projections, younger than 15 cohort (1000 persons)	Prepare UN1980_2100V2008.xls
UNPR	Set UN_PER Periods in UN population data	Prepare UN1980_2100V2008.xls

4   Modelling around a GTAP core

The standard GTAP model forms the core of the MAGNET model and, as a consequence, it influences the way the model is organised and how extensions to the model are coded. This chapter describes the reasons why GTAP was taken as the core of MAGNET and how this is reflected in the structure of the code.

4.1 Aim

The standard GTAP model forms the core of the MAGNET model for practical reasons:
– It provides a reference point to communicate contributions of MAGNET to a broad community of researchers involved in applied general equilibrium models.
– It provides an easy entry point for new MAGNET users who have attended the GTAP short course, by gradually switching on MAGNET modules users can discover various features of MAGNET.
– It provides a reference point for debugging model code (e.g. tests can be run with the GTAP core to establish whether errors are due to data issues or errors in model code).

4.2 Approach

Keeping the GTAP core intact has strong implications for the manner in which MAGNET developed. A guiding MAGNET coding principle is not to touch GTAP equations except when redefining set domains over which equations are defined. There are a limited number of other deviations from the 'do not touch GTAP' principle; most notably, the introduction of a distinction between production sectors and produced commodities throughout the model.

4.2.1   Modular setup of the model code

The MAGNET model code is set up in a modular fashion using Gtree. GTREE splits the model code into a large number of small files and brings those files together into one big tablo file that is required to run GEMACK. By using different combinations of files, the structure of the model can be adapted to the question at hand.

4.2.2   Use of sets to control which equations are active

MAGNET includes alternative behavioural equations. For example, regions can have the standard GTAP production structure or a fully flexible nested-CES production structure. By assigning regions to a specific set, the appropriate behavioural equations are activated.

4.2.3   Tracking any changes made to the GTAP core

In practice, a limited number of changes were needed to the GTAP core model in order to include extensions. To make clear the deviations from the 'do not touch GTAP' policy, they are placed in a dedicated file (MGTAP, for modified GTAP).

4.3 Organisation of the MAGNET model code

The MAGNET model is located in ..\4_MAGNET\CodeMainProgram. The folder contains only one small text file related to the model code, Magnet.gmp. This is a Gtree file that calls all of the separate files containing the actual model code contained in a large number of subdirectories. After compiling, there

is a corresponding Magnet.tab file that includes all activated modules, which can be read and used with any GEMPACK program.

Magnet.gmp

Files.gmp	Definition of logical file names for input and output files
Time.gmp	Definition of a time variable needed by DSS but used only in dynamic modules
Sets.gmp	Definition of standard GTAP sets
ModuleDefintions.gmp	Set definition determining which modules are active by assigning regions and sometimes sectors to specific sets
GTAP.gmp	The GTAP core model
MGTAP.gmp	Modifications of the standard GTAP model
ProdTree2.gm	MAGNET module with fully flexible nested CES production structure.
Land.gmp	MAGNET module with extensions for modelling land use
Production quota.gmp	MAGNET module allowing imposition of production quota
SummaryGDP.gmp	Different calculations of GDP to aid interpretation of model results
FinalThings.gmp	Writing of post-simulation coefficients

Legend:

Modules that are always included

Modules selected by user in DSS

MAGNET

4.3.1 Structure of the MAGNET model code

The figure above outlines the organisation of the MAGNET model code.

4.3.2 Activating a module

To activate a MAGNET module and thereby change the structure of the code, two steps are necessary. First, all of the necessary code needs to be added to the model (this is handled in the DSS Model tab). In terms of the figure above, this implies adding a blue box to the MAGNET code that is being compiled. DSS changes the characters !$I into !$include in the MAGNET.gmp file for the user selected modules and GTREE to includes them in the model file.

This first step does not change the behaviour of the model since modules are controlled by sets. If no regions are allocated to the sets associated with the MAGNET module, the new equations will use empty regions or world sets, and will therefore not affect model results.[2]

The second step is therefore to assign regions to the regional set associated with the newly added module. In terms of the figure above, this will affect the content of the sets defined in ModuleDefinitions.gmp. This step is handled in the DSS Model tab when selecting a standard choices file, and provides the initial setup of the model.

For any scenario, these choices (and thus the structure of the model) can be altered by adjusting the model parameters file in the DSS Scenario (GEMSE) tab, but this is a risky procedure because the changes will not be automatically documented. Although it is handy for doing comparisons of different model structures, if you are using a fixed model setup for a whole project, it is better to program the model parameters file in the Model Setup part by selecting choices through the Model tab of DSS, and when necessary, changing code in ModelStructure.gmp or MagnetAgg.gmp files to make the choices independent of an aggregation and reproducible for later use. Therefore, the same GEMPACK code can be used for different model structures by changing the contents of sets when defining the scenario in DSS.
Module descriptions in other sections of this manual provide the DSS settings required to activate the module.

4.3.3 Links with the rest of the MAGNET system

MAGNET model code is the final product of a lot of preparatory steps. When developing new modules, there are many links to earlier parts in MAGNET. Any additional data need to be prepared in the 1_DataAdjustment step. Choices for activating the new module and possibly defining the way it behaves are coded in 2_ModelDefinition\2_ModelStructure. Additional data are aggregated to the chosen model aggregation taking into account the model choices of the user (coded in part of 2_ModelDefinition\3_MAGNETagg).

It is very important that the user makes all choices at the most fundamental level. For example, the user can make changes in ModelSettings.prm, but this file will be overwritten when re-running the Model tab in DSS. It is better to prepare the Modelsettings.prm in the Model tab of DSS. That tab gives a modeller the opportunity to select a file with fundamental standard choices that is stored in 2_ModelDefinition\2_ModelStructure\ExtraData. You can also store aggregation-specific information in this file, but it is better if this information is derived from information stored in the MAGNET databases. For example, you can define in the file with standard choices which sectors are a part of the livestock sector, but it is also possible to store a mapping with a standard categorisation of sectors in the database that can be used to select which sectors are livestock sectors in the program files in modelstructure and magnetagg. Although in practice you will sometimes use the quick and easy solution, you must be aware that in general it pays to make procedures as general as possible.

---

2   GEMPACK allows empty sets, a feature which is used in MAGNET to have alternative equations (but defined over different subsets) governing the same variables co-existing in the model.

5   Modified GTAP

5.1 Aim

This module contains several small modifications to GTAP that make the model more robust and general. It must always be activated if the user wishes to include any of the MAGNET modules. It includes the following files:

1. MGTAP\ExtraSets.gmp
2. MGTAP\WorldFactorPrices.gmp
3. MGTAP\InputTechnologyShifter.gmp
4. MGTAP\WalrasConditions.gmp
5. MGTAP\Zeroconditions.gmp
6. MGTAP\JointProduction.gmp
7. MGTAP\DynamicsDefinitions.gmp
8. MGTAP\CONS_TASTESHIFTER.gmp
9. MGTAP\VIEW.gmp
10. MGTAP\Taxes.gmp
11. MGTAP\solutions\WriteVariables.gmp

The rest of this chapter describes the contents of each of the files. The final section of the chapter explains how to activate the MGTAP module.

5.2 Extra Sets

Additional sets are needed to modify GTAP. These sets are declared in ExtraSets.gmp, and can be found in the file 4_MAGNET\BaseData\Sets\Sets.har.

It should be noted that the file Sets.har is called GTAPSETS:

File GTAPSETS = .\BaseData**Sets\Sets.**har;

and it is created by the routine 2_ModelDefinition\3_MagnetAgg. It is a copy of the file 2_ModelDefinition\3_MagnetAgg results\sets.har. The 'copy' statement is included in the file 2_ModelDefinition\3_MagnetAgg\MagnetAgg.bat.

The extra sets are:

1. Mapping of commodities into sectors

The mapping has been created in the routine 2_ModelDefinition\1_GTAPAgg (the code is in the same directory in ..\..\Code\aggdat.gmp). MAGNET adjusts GTAP so that not only commodities are modelled, but so too are sectors in which one sector must produce at least one traded commodity. The TRAD_COMM set refers to the aggregated traded commodities and the TRAD_SECT set refers to the aggregated sectors producing traded commodities (the aggregation is as defined in DSS, tab Model, question on 'make aggregations for commodities'.

```
! <%GTREE 1  Sectors %>!
Mapping TRADC2TRADS from TRAD_COMM to TRAD_SECT;
Read (by_elements) TRADC2TRADS from file GTAPSETS header "MC2S";
```

2. Subsets of endowments:

The following subsets of endowments are defined:
- Set ENDWL_COMM: Land endowment; Land is considered as a sluggish endowment, hence the set ENDWL_COMM is a subset of ENDWS_COMM
- Set NLANDS_COMM: non-land sluggish endowments
- Set ENDWNC_COMM: non-capital endowments
- Set ENDWNL_COMM: non-land endowments, expressed both as subset of the all endowments and of non-capital endowments
- Set ENDWNLNC_COM: non-land and non-capital endowments
- Set AGRI_SECT: agricultural sectors
- Set NAGRI_SECT: non-agricultural sectors

5.3 World Factor Prices

Percentage change in the world factor price is defined as the weighted average of the percentage changes in the regional factor price indices:

```
Variable (orig_level=1.0)
  pfactwld # world price index of primary factors #;
Equation PFACTWLD1    !PRIMFACTPRWLD!
# computes % change in global price index of primary factors #
    VENDWWLD * pfactwld = sum(r,REG, VENDWREG(r) * pfactor(r));
```

with:

```
Variable
    pfactwld_1 # World price index of primary factors exogenous#;
Variable
    pfactwld_2 # World price index of primary factors exogenous#;

Equation PFACTWLD1a !PFACTWLD1 is already used in GTAP.gmp ;

# Computes % change in global price index of primary factors #
    pfactwld = pfactwld_1+pfactwld_2;
```

whereas pm is the market price and VOM is the value of output at market price for a commodity i in a region r.

The GTAP world price index of primary factors is split into two variables.

```
Coefficient (all,r,REG)
   VENDWREG(r) # value of primary factors, at mkt prices, by region #;
Formula (all,r,REG)    VENDWREG(r) = sum(i,ENDW_COMM, VOM(i,r));


Coefficient  VENDWWLD # value of primary factors, at mkt prices, worldwide #;
Formula   VENDWWLD = sum(r,REG, VENDWREG(r));
Variable (orig_level=1.0)(all,r,REG)
   pfactor(r) # market price index of primary factors, by region #;
Equation PFACTOR1     !PRIMFACTPR!
# computes % change in price index of primary factors, by region #
(all,r,REG)
   VENDWREG(r) * pfactor(r) = sum(i,ENDW_COMM, VOM(i,r) * pm(i,r));
```

The split enables us to define, if needed, an additional shock other than a shock to the numeraire (which is now pfactwrld_1; a shock to the numeraire could be used, for example, to set world inflation equal to 0) and use pfactwld_2 to shock with the world inflation rate. The latter can be relevant, for example, for the CAP budget if this is kept constant in nominal terms and therefore decreasing in real terms. Because we normally use the price index of world GDP as the numeraire in the model, this split is now out-dated.

5.4 Input Technology Shifter

Technical progress is a key determinant of economic growth and structural change. It is therefore essential to introduce assumptions about technical change when making projections with CGE models such as MAGNET. These assumptions can have major impacts on structural transformations, international trade patterns and price developments. In addition to the standard GTAP parameters to shock technical change (a-parameters), MAGNET also includes several pieces of code that explicitly model differences in technological change across sectors for the baseline projection. These are described below.

The aim of the code is to introduce a technology shifter that introduces differences in technological progress between sectors in the baseline projection. This will create a more dynamic baseline that is able to capture differences in technological progress between agriculture, manufacturing and services based on the empirical literature, and that introduces possibilities for various types of input-biased technological change.

5.4.1 Theory

Most CGE models assume that technological development is the same between sectors or industries, which is not in line with empirical evidence. Using detailed case studies, scholars in the field of innovation sciences have demonstrated the existence of 'technological trajectories' (Dosi, 1982) that may differ considerably between sectors, depending on the underlying knowledge base, opportunities for innovation, and demand factors. Another strand of literature has focused on the estimation of productivity growth at the detailed industry level using growth accounting techniques. For both advanced and developing countries, it has been commonly found that total factor productivity growth is higher in agriculture than in manufacturing (Jorgenson and Gollop, 1992; Bernard and Jones, 1996a, 1996b; Martin and Mitra, 2001). Recently, Jorgenson and Timmer (2011), using a new database with detailed information on sectoral output and productivity for a high number of sectors in OECD countries, highlighted the enormous heterogeneity in performance within the service sector. Kets and Lejour (2003) estimated sectoral total factor productivity for a number of countries used in the CGE model WorldScan. These data, and similar approaches, have been used by Hertel and colleagues (2005) and Strutt and Walmsley (2011).

5.4.2 Modelling technological change in MAGNET

Three pieces of code model sectoral technological change in MAGNET. Each is activated in a different part of the model.

1. Ascale.gmp (\2_ModelDefinition\2_ModelStructure\Code\modelstructure.gmp)

Ascale.gmp prepares the weights that will be used in the model to compute the technology shifter. At the moment, technological change can only be set for three aggregated sectors: agriculture, manufacturing and services – classifications that are stored in the file MAGNETCHOICES header 'SECT'. The weights for each sector are read from MAGNETCHOICINI, header 'ASSW', coefficient 'ASCSWGT' and are 2.00, 2.65 and 1.00 for agriculture, manufacturing and services, respectively, but they can be changed by the user. This means that technical change is fastest in manufacturing, closely followed by agriculture and finally services. The weights have been determined using expert knowledge. As MAGNET allows for the fully flexible aggregation of sectors, it is possible that a user-specific aggregation includes a combination of agriculture, manufacturing and services sectors (e.g. livestock and cattle). In such cases, the technology weight is a weighted average using sales of domestic product at market prices (D_TVOM) as weights.

Technological change can take various forms, such as Hicks-neutral technological change (measured by total factor productivity) that is identical for all value added production factors, or it can be non Hicks-neutral and have different weights for different production factors. It is also possible to have for intermediate input saving technological change. In MAGNET, factor augmenting technical change can be set for five input types: labour, capital, land, natural resources and intermediates. This classification is read from MAGNETCHOICES with header 'ASCI', and the weights are taken from MAGNETCHOICEINI, header 'ASIW', coefficient 'ASCIWGT'. Initial values are set to 1.00, 0.00, 0.00, 0.25 and 0.30 for the five production factors, respectively. This implies that technological progress is mainly labour augmenting and only slightly natural resource and intermediate augmenting. These values are based, once again, on expert knowledge. Capital is exempt, as the capital/output ratio has been shown to be roughly constant over long periods of time. Land productivity is assumed to follow exogenous yield projections. Before the current values can be used, they need to be mapped to the user-defined factor aggregation. ASCSWGT and SCIWGT are defined at the global level and are therefore the same for all regions.

2. Modified GTAP.gmp (\2_ModelDefinition\3_MagnetAgg\Code\magnetagg.gmp)

This part of the code calculates the technology shifter (ASCALE) using the sectoral weights for technological change and the parameters for factor augmenting technical change that are prepared in ascale.gmp. The sectoral weights equally apply to all the factor-specific technological change parameters. Labour, natural resources and intermediate augmenting technical change in agriculture is therefore twice as high than it is in services (capital and land are zero for both sectors). ASCALE is calculated for each demanded commodity (DEMD_COMM) by sector (PROD_SECT):

```
Formula (all,i, DEMD_COMM)(all,j,PROD_SECT)(all,r,REG)
  ASCALE(i,j,r)=
    sum{m,ASCASECTCAT,
      sum{k,ASCAINPCAT,ASCAI_CHOICE(i,k)*ASCIWGT(k)
        *ASCAS_CHOICE(j,m)*ASCSWGT(m)}};
```

Note that intermediate augmenting technological change within a sector (e.g. intermediate use of rice in the rice sector) is set to zero:

```
Formula (all,j,TRAD_SECT)(all,r,REG)
  ASCALE(j,j,r)= 0;
```

**3. MGTAP.gmp\InputTechnologyShifter.gmp
   (\4_MAGNET\CodeMainProgram\Magnet.gmp)**

A new equation is introduced in MGTAP that includes ASCALE as part of intermediate augmenting technical change (af)

(all,i,FIRM_COMM)(all,j,PROD_SECT)(all,r,MREG)
  af(i,j,r) = afcom(i) + afsec(j) + afreg(r) + afall(i,j,r)+afcomsec(i,j)
       + ASCALE(i,j,r)*aknreg(r)+DUM_I_LAND(i)*aland(j,r);

Together with ASCALE, two other variables are added to the equation. Aknreg is a scaling factor that is needed to calibrate the model to exogenous baseline projections of key drivers, such as GDP and population and capital growth. Aknreg is multiplied by ASCALE in order to impose sector-specific technological change. Most CGE models do not incorporate a technology shifter and generally calibrate the model using technical change in value added (ava) by region, which is similar to total factor productivity growth. Aland is introduced to measure technological advancement in land-using sectors, which is not captured by ASCALE (ASCIWGT is 0 for land). Information on aland may come from external sources; at the moment LEI uses the projections of Bruinsma (2003) as processed in the land allocation model IMAGE, the integrated assessment model of the Netherlands Environmental Assessment Agency (see baseline documentation).

The weights for calculating ASCALE are derived from intuition and experience with simulations. Available information can be included in the ASCALE parameter, and programmed in the MAGNETAgg and Modelstructure programs.

The module requires the variable aknreg to be exogenous and in the ModifiedGTAP closure. If aknreg is not shocked, nothing happens. In order to calibrate aknreg, the variable is swapped with qgdp, where qgdp is shocked based on projections from other sources. The DSS system then writes aknreg to the shock file, and this can be used by the standard baseline with technology defined as exogenous. Next to aknreg, which distributes shocks according to the ASCALE parameter, all types of other shocks can be included, for instance, shocks to aland, but also some other specific productivity shocks can be added. If the baseline is calibrated, the same shocks must be applied as in the real baseline, if it is desirable to target the GDP growth figures using external sources.

5.5 Walras Conditions

In GTAP, two equations define the international investment closure, namely the equation on the global rate of return and that on global investment.

In this section, we replace the GTAP international investment closure mechanism by introducing two definition equations and one equation determining the international investment closure.
This makes the system more lucid, while disentangling the definitions from the GTAP closures opens up the possibility to add alternative closures for international investment.
The definition equations are the following:

Equation RORG1_M   #Defines the global expected rate of return for the static model#
  (all,w,MWORLD)
     rorg(w)=sum{r,GINTCAP_MREG, [NETINV(r) / GLOBINV] * rore(r)};

Equation GLOBALCGDS1_M # Defines global net investment# (all,w,MWORLD)
  globalcgds(w)=sum{r, MREG, [REGINV(r) / GLOBINV] * qcgds(r) - [VDEP(r) / GLOBINV] * qk(r)};

The first one defines the percentage change in the global net rate of return (rorg) as the net investment weighted sum of the percentage changes in the regional net rates of return (rore). The

second equation defines the percentage change in global net investments (globalcgds) as the weighted sum of the percentage changes in regional gross investment and the weighted sum of the percentage changes in depreciation.[3]

The equation defining the closure choice is:

Equation RORE1_M
   # When RORDELTA=1 rorg is Walras shifter, when RORDELTA=0 globalcgds#
 (all,r,GINTCAP_REG) (all,w,MWorld)
 RORDELTA * (rore(r)-rorg(w)+walrasshift(w))
    +[1 - RORDELTA]*([[REGINV(r) / NETINV(r)] * (qcgds(r)+cgdslack(r))
       - [VDEP(r) / NETINV(r)] * qk(r)-globalcgds(w)+walrasshift(w)])=0;

The standard GTAP model has a static closure, where a choice is made that either domestic investment follows domestic savings (RORDELTA=0) or an expected rate of return is equilibrated (see explanation below) over countries (RORDELTA=1). If RORDELTA=0, then the equation RORE1_M reduces to:

[REGINV(r) / NETINV(r)] * (qcgds(r)+cgdslack(r))- [VDEP(r) / NETINV(r)] * qk(r)=globalcgds(w)

This implies that the percentage change in regional net investment (left-hand side) is equal for all regions. This equation defines an equation for globalcgds (which is defined with the equation GLOBALCGDS1_M). The RORE1_M equation thus becomes redundant. For this reason, the variable walrasshift has been added to the model. It becomes zero, but adds an endogenous variable to allow for two equations doing the same thing without causing a closure problem.

If RORDELTA=1, then:

rore(r)=rorg(w)

This implies that the regional expected rate of return equals the global expected rate of return. This equation implies the defined equation for the global rate of net return already specified with the equation RORG1_M and again the walrasshift is added to prevent this redundancy.

5.6 Zero Conditions

The Zeroconditions module concerns the modified GTAP part of MAGNET which is governed by the set MREG, a subset of the region REG. All equations in this section have counterparts in the Standard GTAP part of magnet (region index GREG):

---

[3] Alternatively one could define the percentage in regional net investment (netqcgds(r)):
 netqcgds(r) = [REGINV(r) / NETINV(r)] * (qcgds(r)+cgdslack(r))- [VDEP(r) / NETINV(r)] * qk(r))
  and to define the global one as the weighted local net investments:

   globalcgds(w)=sum{r, MREG, [NETINV(r) / GLOBINV] * netcgds(r)};
 Because regional net investment may sometimes be zero, this would generate a calculation problem.To avoid the computational problem those two equations are integrated in one in standard GTAP.

Modified GTAP equation	Standard GTAP equation
QOES1_GLNDALL_M	QOES1_GLNDALL
PMES1_M	PMES1
QGM1_M	QGM1
QFM1_MREG	QFM1
QXS1_M	QXS1
QTMFSD1_M	QTMFSD1

All equations in this section of the model have the same meaning and interpretation as the associated Standard GTAP equations.

The objective of these equations is to solve the modified GTAP version of the model. In the case that some elements of the SAM database of MAGNET are zero, the solution procedure of standard GTAP can create the following errors or misleading results associated with these elements:
– The calculated growth rate is not equal to zero. It has no meaning because the initial value of the SAM element is zero.
– The calculated growth rate is lower than -100. The program will report in the log file '% change less than -100 for Header ....'. This suggests that the solution is wrong, but it is not because the associated SAM element has starting value 0.
– The model does not solve and the program stops with the message 'LHS structurally singular'.

To avoid these problems, we have modified the original standard GTAP equations by adding an explicit solution if the data are zero.

The approach used to avoid these problems is based on the obvious observation that, independently of the growth rates of MAGNET variables, updates of elements of a SAM equal to zero lead to elements equal to zero as well. Therefore, the equations are modified as follows.

First, the original (standard GTAP) part of the equations is used only when the associated SAM element on the left-hand side variable of the equation is not equal to zero. An example of such a term is if{VIGA(i,r)>0,qg(i,r) + ESUBD(i) * [pg(i,r) - pgm(i,r)]} in equation QGM1_M below. Alternatively, the 'if condition' is formulated for a coefficient associated with a SAM element connected with the left-hand side variable of the equation. An example is a coefficient VTMUSESHR(m,i,r,s) in equation QOES1_GLNDALL_M below.

Second, in the case that the 'if condition' outlined above is not satisfied, the term $0*time$ is used to determine the value of the left-hand side variable. It is obviously equal to zero, which is consistent with the value of the associated SAM element. The time variable is used because GEMPACK does not accept a term without a variable if there are other terms with a variable on the same side of an equation.

Equation QGM1_M
government consumption demand for aggregate imports (HT 43)
(all,i,TRAD_COMM)(all,r,GARM_MREG)
   qgm(i,r) = 0*time
         +if{VIGA(i,r)>0,qg(i,r) + ESUBD(i) * [pg(i,r) - pgm(i,r)]};
Equation QTMFSD1_M   *!QTRANS_MFSD!*
bilateral demand for transport services
(all,m,MARG_COMM)(all,i,TRAD_COMM)(all,r,MREG)(all,s,REG)
   qtmfsd(m,i,r,s) = 0*time
     + if{VTMUSESHR(m,i,r,s)>0, qxs(i,r,s) - atmfsd(m,i,r,s)};

5.7 Joint Production

GTAP does not make a distinction between commodities and sectors. It is implicitly assumed that each sector produces a single product. This approach prevents the modelling of by-products such as

distillers' grains from the distillation process or molasses from sugar production – an important consideration when modelling the bio-based economy. To address this, MAGNET includes a module called jointproduction.gmp that makes it possible for sectors to produce multiple commodities. The aim of the module is to model the joint production of one or more commodities by a single sector. A CET function distributes the production of the sector to the different commodities.

5.7.1 Modelling joint production in MAGNET

With respect to naming, the GTAP names are placed first and an s is added for sector variables even though qo concerns production and ps concerns sales.

In order to make joint production possible, it is necessary to model the relationship between commodities and sectors in terms of quantities and prices. Sectoral output price change (pss) is equal to the weighted average of the commodity price change (ps) using the value of output at agent prices as a share (REVCOMSHR). The structure of this equation is the same as for many other equations in standard GTAP, for example the market clearing condition for non-margin commodities. The capital goods sector (CGDS) always produces one commodity and therefore pss equals ps.

Equation PSS1_M
    # Composite sector output price based on commodity supply prices#
  (all,i,TRAD_SECT)(all,r,MREG)
 pss(i,r) = sum{k,TRAD_COMM:TRADC2TRADS(k)=i,REVCOMSHR(k,r)*(ps(k,r))};
Equation PSS1_CGDS_M
    # Composite sector output price based on commodity supply prices#
  (all,i,CGDS_COMM)(all,r,MREG)
 pss(i,r) = ps(i,r);

Demand for commodities (qo) is determined by total production of sector output (qos) and the substitution elasticity between the co-products (ETQS) times their relative price. The structure of this equation is the same as the standard demand equations for value added and endowments in GTAP. In the standard MAGNET settings, ETQS is read as zero and therefore the growth in production of all co-products (qo) is the same as the growth in sectoral output (qos). In other words, the proportion in which co-products are produced is fixed. Note that for the model to solve with this assumption, a flexible form of demand needs to be introduced. If both the demand and supply of the or one of the co-products are fixed but not the same, a solution is not feasible. When the value of output is zero, the equation determines the price of the commodity explicitly; in other cases, the equation describes a relationship between relative prices and relative development of production of the different commodities. If ETQS is zero, which is standard, then the output is produced in fixed proportions.

Equation PS1_TRAD_M *!QO is determined at demand side!*
eq'n distributes sector production over commodities#
(all,j,TRAD_COMM) (all,r,MREG)
   if(VOM(j,r)>0,qo(j,r) -
          [sum{i,TRAD_SECT:TRADC2TRADS(j) eq i,qos(i,r)*! - qsslack(i,r) !*
          + ETQS(i,r) * [pss(i,r) - ps(j,r)]}])
     +if(VOM(j,r)<=0,sum{i,TRAD_SECT:TRADC2TRADS(j) eq i,
        pss(i,r) - ps(j,r) + qo(j,r) - qos(i,r)})=0;
Equation PS1_CGDS_M *!QO is determined at demand side!*
eq'n distributes sector production over commodities#
(all,j,CGDS_COMM) (all,r,MREG)
     qo(j,r) = qos(j,r);

The demand for value added (qva), intermediates and endowments (qf) is determined by the standard demand function (only the qva equation is presented here). Since the model includes both commodities and sectors, the equations need to be defined using sector prices (pss) instead of commodity prices. The multiplication by zero is added for technical reasons because it ensures that a

zero is calculated when EVFA is smaller or equal to zero, which is needed for GEMPACK to function properly.

Equation qva1_GPROD_MREG *!VADEMAND!*
sector demands for primary factor composite
(all,j,PROD_SECT)(all,r,GPROD_MREG)
    qva(j,r)
    = 0*time+if(sum{e,ENDW_COMM,EVFA(e,j,r)}>0,-ava(j,r) + qos(j,r) - ao(j,r)
        - ESUBT(j) * [pva(j,r) - ava(j,r) - pss(j,r) - ao(j,r)]);

Finally, the zero profit function needs to be restated so that it defines sector prices (pss) instead of ps.

Equation pss1_GPROD_MREG *!ZEROPROFITS!*
industry zero pure profits condition (HT 6)
(all,j,PROD_SECT)(all,r,GPROD_MREG)
    pss(j,r) + ao(j,r)
        = sum(i,ENDW_COMM, STC(i,j,r) * [pf(i,j,r) - af(i,j,r) - ava(j,r)])
        + sum(i,TRAD_COMM, STC(i,j,r) * [pf(i,j,r) - af(i,j,r)])
        + profitslack(j,r);

Nothing needs to change in the closure. If the database contains commodities, the system works.

5.8 Dynamics Definitions

The base data file holds the year of the GTAP database from which the modelling period begins. By updating this header, the updated data files contain the year to which the data refer using the length of the period computed by DSS (time):

```
Coefficient YEAR;
  Read YEAR from file GTAPDATA header "YEAR";
  Update (change) YEAR=time;
```

In the Dixon investment module, a specific variable is used to make sure that the equations satisfy the base data. This exogenous variable shifts from zero to 1, thereby eliminating parts of an equation that are only needed to initially satisfy the data (in models developed at Monash University, Australia, this variable is appears as del_unity):

```
Variable  (change) !del_unity!
  zero2one # Shifts from zero to one $$#;
```

Since this variable may be of use elsewhere in the code, it is defined as part of modified GTAP. This procedure also avoids the problem of having to define a specific closure file for the Dixon Investment module. Changing this variable from zero to 1 is done as part of the modified GTAP closure with the following statement:

```
Shock zero2one=1;
```

If the variable is not used in any of the extensions, it will cause a warning when checking the code. To prevent this happening, a variable and equation are added using the zero2one variable:

```
Variable
    stayzero # variable to avoid warning on zero2one not being used #;
Equation STAYZERO1
  # assuring that zeroupdate variable is indeed zero #
  stayzero = zero2one - zero2one;
```


5.9 Consumption Taste Shifter

In some applications (e.g. when running long-run projections), it can be useful to allow a change in consumption preferences. We limit this possibility to a change in the preferences of private

households, since government consumption is to some extent an artificial construct. The aim of the PrivateConsumption.gmp module is to allow a change in the composition of private demand while respecting the budget constraint. In other words, to get a proper taste shifter, we need to ensure that we do not change the total expenditures of the household but only its composition. This is achieved by the following code:

```
! Define shifting variables!
Variable (all,i,TRAD_COMM)(all,r,MREG)
  ap(i,r) # taste change in favor of comm i in region r #;
Variable (all,r,MREG)
  ap_ave(r) # average taste change in region r #;
Variable (all,i,TRAD_COMM)(all,r,MREG)
  ffap(i,r) # slack variable for taste change in favor of comm i in r #;

Equation QP1_GCON_M        !PRIVDMNDS!
# private consumption demands for composite commodities (HT 46) #
(all,i,TRAD_COMM)(all,r,GCON_MREG)
    qp(i,r) - pop(r)
        = sum(k,TRAD_COMM, EP(i,k,r) * pp(k,r)) + EY(i,r) * [yp(r) - pop(r)]
          + ap(i,r) - ap_ave(r);
! Note: for regions with a PPP-corrected consumption function the shifters
are added to the QP1_PCON equation!

Equation AP_AVE1
  # compute average taste change in region r#
  (all,r,MREG)
  sum{i,TRAD_COMM,VPA(i,r)} * ap_ave(r)= sum[i,TRAD_COMM, VPA(i,r) * ap(i,r)];

Equation AP_1
  # determine consumption preference shift from changes in production #
  (all,i,TRAD_COMM)(all,r,MREG)
  ap(i,r) = - afcom(i) + ffap(i,r);
```

The variable ap(i,r) is the actual taste shifter. In the MGTAP closure file, it is defined as exogenous and thus can be shocked to increase or decrease the preference for a particular commodity i in region r. As an example, assume we increase the preference for meat in all regions by a positive shock to ap("meat",r). All else being equal, this would increase the demand for meat, qp("meat",r) and cause a violation of the budget constraint. Thus if the demand for meat increases, the demand for other commodities needs to decline.

This is handled by the ap_ave(r) variable. Note that it does not have a commodity index. It thus shifts demand for all commodities by the same amount. The amount it needs to shift to maintain the private household's budget is computed in the AF_AVE1 equation. This equation ensures that total private expenditure does not change directly due to the shifter. Of course, when the preference shift is implemented, it will trigger a general equilibrium response to the change in demand pattern, which is likely to change household income. To return to our example, the increased preference for meat causes a lower demand for all commodities through the ap_ave(r) term in the demand equation. For meat this will temper the increase due to the taste shifter, for all other commodities it will decrease demand.

The default setting for the module is to have ap(i,r) exogenous so it can be shocked as desired. In some applications, for example historical projections, the preference shifter can be used to absorb changes in production induced by technological change (captured by afcom(i)). In this case, ap(i,r) can be made endogenous by swapping it with the slack variable ffap(i,r) using the following statement in the shock file (if needed, swapping only specific commodities and/or regions):

```
swap ap(TRAD_COMM,MREG) = ffap(TRAD_COMM,MREG);
```

With this swap effective, the generic technical change (afcom does not have a regional dimension) will determine the taste in consumer preferences.

Finally, note that the taste shifter is available only for regions that are part of MREG. This includes regions that have a PPP-corrected consumption function; the taste variables have been added to the relevant variables in the PPP-corrected consumption module.

5.10   View

Write statements to the GTAPVIEW file are defined in the View.gmp.

```
write (set) FIRM_COMM to file GTAPVIEW header "FCOM";
```

To remind the reader, the set FIRM_COMM includes the traded commodities, the investment commodity (CGDS), the endowments, and the sub-products as used in the CES production tree if it is switched on.

5.11   Taxes

Several modules are linked to the rest of the MAGNET model through taxes, like the CAP and biofuels modules. To avoid changing all income and tax equations in the model, we modify existing taxes to account for contributions from various models. The taxes.gmp module links all sorts of module-determined taxes to already existing tax rates.

Tax rates are normally exogenous, but for regions in MREG, taxes are defined as endogenous in the MGTAP closure file if they need to be computed from other taxes. These other taxes are defined as exogenous in the MGTAP closure, so the code works if the additional modules are not included. Including a module and its closure then activates the link to the rest of the model by making taxes endogenously defined in the module.

Note that this approach implies that some standard GTAP taxes, like to(i,r) on output, cannot be shocked in MREG regions because they are endogenous. Instead, one of the exogenous components needs to be shocked. This will be further explained when discussing each of the taxes below.

5.11.1 Taxes linking to other modules

Since several modules could be linked to the same standard GTAP tax, we start the module by defining the taxes that link to other modules:

```
! Taxes related to biofuel directive!
Variable (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
  tbdir_i(i,j,r) #biofuel directive: tax on interm. demand for i by j in r#;
Variable (all,i,TRAD_COMM)(all,r,MREG)
  tbdir_f(i,r) #biofuel directive: tax on final demand for i in r#;

! Taxes related to production quota!
Variable (all,j,NSAV_COMM)(all,r,MREG)
  to_quota(j,r) # Change in output tax equivalent of the production quota rent#;
```

There are currently two taxes linked to the biofuel directive and one to the production quota module. Note that to have a single equation that combines all related taxes, these two taxes are defined over MREG and are not limited to the regions with a biofuel directive (a subset of MREG). The MGTAP closure defines these taxes as exogenous for all MREG. When including the closure for the biofuel directive, for example, only the taxes for biofuel directive regions are made endogenous (since only these have matching equations in the biofuel directive module) thereby activating the link:

```
Endogenous
   tbdir_i(BLEND_COMM,PROD_SECT,BDIR_REG)
   tbdir_i(BIOFUELS,BLEND_SECT,BDIR_REG)
   tbdir_f(BLEND_COMM,BDIR_REG)
```

The remainder of the taxes module then combines taxes, sorted by type of tax.

5.11.2 Taxes on intermediates: tfd and tfm

To separate (normally exogenous) taxes present in the base data from endogenous taxes from various modules, we first define taxes from the base data:

```
! Taxes equivalent to tfd and tfm in GTAP core model!
Variable (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
   tfd_b(i,j,r) # from basedata: tax on domestic i purchased by j in r#;
Variable (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
   tfm_b(i,j,r) # from basedata: tax on imported i purchased by j in r #;
```

These are equivalent to the exogenous tfd and tfm in the GREG regions. Therefore, if you want to shock tfd from GREG, you need to shock tfd_b in MREG.

Then we compute the endogenous intermediate taxes:

```
! Define total tax on domestic and imported intermediates!
Equation TFD1_MREG (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
   tfd(i,j,r) = tfd_b(i,j,r) + tbdir_i(i,j,r);
Equation TFM1_MREG (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
   tfm(i,j,r) = tfm_b(i,j,r) + tbdir_i(i,j,r);
```

These taxes then carry all changes to the income and tax equations in the remainder of the model. The impact of the different modules on the total change in intermediate taxes can be decomposed using the equations above.

5.11.3 Taxes on household demand: tpd and tpm

A similar setup is used for taxes on private household demand:

```
! Taxes equivalent to tpd and tpm in GTAP core model!
Variable (all,i,TRAD_COMM)(all,r,MREG)  tpm_b(i,r)
   # from basedata: comm., source-spec. tax on private cons. of imports#;
Variable (all,i,TRAD_COMM)(all,r,MREG)   tpd_b(i,r)
   # from basedata: comm., source-spec. tax on private cons. of domestic#;

! Define total tax on domestic and imported private demand!
Equation TPD1_MREG (all,i,TRAD_COMM)(all,r,MREG)
   tpd(i,r) = tpd_b(i,r) + tbdir_f(i,r);
Equation TPM1_MREG (all,i,TRAD_COMM)(all,r,MREG)
   tpm(i,r) = tpm_b(i,r) + tbdir_f(i,r);
```

Again, shocking the base tax rates can be done through tpm_b and tpd_b, while tpd and tpm carry the combined effect of changes in base tax rates and of biofuel directive taxes over the rest of the model.

5.11.4 Taxes on government demand: tgd and tgm

An identical setup is used for taxes on government demand:

```
! Taxes equivalent to tpd and tpm in GTAP core model!
Variable (all,i,TRAD_COMM)(all,r,MREG)   tgm_b(i,r)
   # from basedata: comm., source-spec. tax on gov't cons. of imports#;
Variable (all,i,TRAD_COMM)(all,r,MREG)   tgd_b(i,r)
   # from basedata: comm., source-spec. tax on gov't cons. of domestic#;
```

```
! Define total tax on domestic and imported government demand!
Equation TGD1_MREG (all,i,TRAD_COMM)(all,r,MREG)
  tgd(i,r) = tgd_b(i,r) + tbdir_f(i,r);
Equation TGM1_MREG (all,i,TRAD_COMM)(all,r,MREG)
  tgm(i,r) = tgm_b(i,r) + tbdir_f(i,r);
```

5.11.5 Taxes on production: to

Taxes originating from the production quota do not feed into the intermediate or consumption taxes, but affect the output tax to. Again, the setup separates the exogenous tax rate from the base data from the endogenous tax rate from the quota module:

```
! Taxes equivalent to in GTAP core model!
Variable (all,i,NSAV_COMM)(all,r,MREG)
  to_b(i,r) # from basedata: output (or income) tax in region r #;

Equation TO1
 # Production tax changes with the endogenous quota tax #
(all,i,NSAV_COMM)(all,r,MREG)
 to(i,r) = to_b(i,r) + to_quota(i,r);
 ! For regions and sectors with no production quota, 'to_quota(i,r)' is fixed!
```

5.12   Write Variables

The GEMSE Analyst requires an input file in har format. The standard GEMPACK solution file, however, has a different format. There is a conversion program for this, but on some computers it does not work properly. To avoid the need for conversion, we explicitly write all variables to a solution file. The advantage of this approach is that the headers used for each variable can be specified, easing the use of variables in other programs like the downscaling program.

In principle, each module has its own write file. The variables defined in MGTAP are written in the WriteVariables.gmp file. Which has the following structure:

```
postsim (begin);
write
 pfactwld_1 to file Solfile header "pfw1" longname
 "pfactwld_1: World price index of primary factors exogenous";
 pfactwld_2 to file Solfile header "pfw2" longname
 "pfactwld_2: World price index of primary factors exogenous";
 aknreg to file Solfile header "AKNR" longname
 "aknreg: endowment enhancing technc change in region r for baseline";

 ............

 tgd_b to file Solfile header "tgdb" longname
 "tgd_b: from basedata: comm., source-spec. tax on govt cons. of dom ..";
 to_b to file Solfile header "tob" longname
 "to_b: from basedata: output (or income) tax in region r";
 postsim (end);
```

You can only write variables in a post-sim procedure. For each variable that is introduced in MGTAP, postsim defines the header and the description. You may omit the description, in which case the description in the definition of the variable is used.

5.13   Activating MGTAP

5.13.1 Settings in DSS

The following need to be selected in order to activate the module. To repeat, this module should always be activated if any of the MAGNET modules are used, in other words, if the user is not running the standard GTAP model within the MAGNET system.

DSS tab	DSS question	Actions	Comments
Database	-	-	-
Model	Choose includes for MAGNET	Include MGTAP/MGTAP	Includes the code of the module described in sections of this chapter
Prepare Scenario	Closure file	Add to the list the file 4_MAGNET\CommandFiles\Closures\ModifiedGTAPModuleClosure.cmf	Includes the closure needed for the module
	Edit Shock file	The following commands should be given: Formula (all,i,PROD_SECT) (all,r,REG) aland(i,r)=IMC_aland(i,r,@period@); Write aland to file @filename@ header "ALAN"; WRITE AKNREG to file @filename@ header "AKNR"; WRITE PFACTWLD to file @filename@ header "PFAC";	With these commands aknreg (exogenous variable), aland (land productivity tech change, for more refer to the user manual on the DSS scenario design) and pfactwld to the shock files used for simulation scenarios. If you create a scenario file this text is automatically included.
Scenario (Gemse)	Closure file	In the list of closure files 4_MAGNET\CommandFiles\Closures\ModifiedGTAPModuleClosure.cmf must be included.	Includes the closure needed for the module

5.13.2 Adjustments to headers in ModelSettings.prm file

The header MODG defines whether the standard GTAP or the modified GTAP is used. To use the standard GTAP, this header should have the value 0, whereas to use the module MGTAP (and as a consequence any of the MAGNET modules), this header needs to have the value 1.

5.13.3 Closure

The following are modified:
1. Splitting the GTAP world price index of primary factors implies that pfactwld_1 is swapped with the GTAP pfactwld whereas the pfactwld_2 is exogenous.
2. Technology and technical change shifters defined in MGTAP are declared as exogenous.
3. Demand for endowment commodities is made endogenous when a module is switched on that explains this particular endowment.
4. For regions in MREG, taxes are defined as endogenous in the MGTAP closure file if they need to be computed from other taxes.

The relevant GEMPACK code is included in the file ModifiedGTAPModuleClosure.cmf.

5.13.4 Changes to MAGNET

Phase	Directory	Subfile & Description
Model definition	*2_ModelDefinition\2_ModelStructure\ Code*	*Ascale.gmp* Prepares the weights that will be used later on in the model to compute the technology shifter
	2_ModelDefinition\3_MagnetAgg\Cod e	*Modified GTAP.gmp* This part of the code calculates the technology shifter (ASCALE) using the sectoral weights for technological change and the parameters for factor augmenting technical change that are prepared in ascale.gmp.
MAGNET code	*4_MAGNET\CodeMainProgram\MGTA P*	*MGTAP_activate.gmp* Defines the settings for activating the modified GTAP module *MGTAP.gmp* Contains the include statements for the following files (they are described in Sections of this chapter): *ExtraSets.gmp* *WorldFactorPrices.gmp* *InputTechnologyShifter.gmp* *WalrasConditions.gmp* *Zeroconditions.gmp* *JointProduction.gmp* *DynamicsDefinitions.gmp* *CONS_TASTESHIFTER.gmp* *VIEW.gmp* *Taxes.gmp* *Solutions\WriteVariables.gmp*
MAGNET command files	*\4_MAGNET\CommandFiles\Closures*	*ModifiedGTAPModuleClosure.cmf* Command file with the needed closure.

5.14   References

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6   A fully flexible CES production structure

A major extension of MAGNET is the introduction of a fully flexible CES production structure that can vary among sectors. This allows the modelling of production to be tailored to a given research question without requiring a change in model code. The code is located in ProdTree2.gmp in the model code (\4_MAGNET\CodeMainProgram\ProdTree2\).

6.1 Aim

The production structure module:
– Allows different production structures among sectors.
– Allows full freedom in defining each production structure, in terms of both the number of nests and the ordering of nests in terms of the inputs entering nests.
– Facilitates computation of the implied substitution elasticities resulting from the structure of the production tree, substitution elasticities in each nest and cost share.

6.2 Approach for the production structure

The MAGNET production structure uses a nested CES production structure that is commonly used in general equilibrium models. However, in contrast to other models, users can define each production structure through a limited number of parameters. This greatly facilitates possibilities for tailoring the production structure to the research question being addressed and for comparing the impacts of various production structures on model outcomes.

6.2.1   Assign sectors to a production structure

Apart from activating the module by assigning regions a flexible production structure, each sector in the model database needs to be assigned to one (and only one) production structure.

6.2.2   Define each production structure

For each production structure that has been assigned to one or more sectors, the structure needs to be specified. This amounts to assigning all commodities present in the database to one (and only one) CES nest and defining the ordering of the nests. Not all production structures or nests need to be used. All sectors assigned to the same production structure have the same CES nesting of inputs. By assigning sectors to different production structures, the nesting of CES inputs can vary.

6.2.3   Check the elasticities for each nest

Since the user has full freedom in designing the production structure, care should be taken that substitution elasticities for each nest are applicable.

6.3 Computing implied elasticities

The production tree module of MAGNET allows users to define any nested-CES structure of production. This allows modellers to better capture the production characteristics relevant to a specific case. A drawback of a multi-layered nested CES is that the implied elasticities are no longer obvious.

Reasonable elasticities in each sub-nest can give rise to improbable implied elasticities between inputs. Therefore, these implied elasticities are computed as part of the production tree module.

6.3.1 Theoretical background to implied elasticity calculation

To compute the implied elasticities in a nested CES structure we can use the following relationships for the substitution elasticities (σ) between inputs n and m defined by Keller (1979:121):

$$\sigma_{nm} = \sigma_{n,K} C_{n,K}^{-1} - \sum_{l=K+1}^{L} \sigma_{n,K}(C_{n,l-1}^{-1} - C_{n,l}^{-1}) \qquad n \neq m$$
$$\sigma_{nn} = \sum_{l=1}^{L} \sigma_{n,l}(C_{n,l-1}^{-1} - C_{n,l}^{-1})$$

where K is the lowest common level (i.e. the lowest level where two inputs 'meet'); $C_{n,l}$ is the cost share of component $q_{n,l}$ in total costs; $\sigma_{n,K}$ is the substitution elasticity at level K; and $\sigma_{n,l}$ is the substitution elasticity at all levels above K.

Cost shares are an important component of the calculation. Since these vary by sector and region, the same structure with the same elasticities can result in very different implied elasticities across sectors and regions. To illustrate this, take the following example. For Brazil and the USA, the GTAP V8 2007 database gives the following cost shares for the production of wheat:

	Brazil	USA	EU27	ROW
Land	0.10	0.14	0.08	0.13
UnSkLab	0.14	0.18	0.32	0.25
SkLab	0.00	0.01	0.02	0.00
Capital	0.36	0.17	0.10	0.10
NatRes	0.00	0.00	0.00	0.00
Intermediates	0.40	0.49	0.47	0.51
Total	*1*	*1*	*1*	*1*

Now assume the following simple production structure which is assumed to be identical for all four regions in this model:
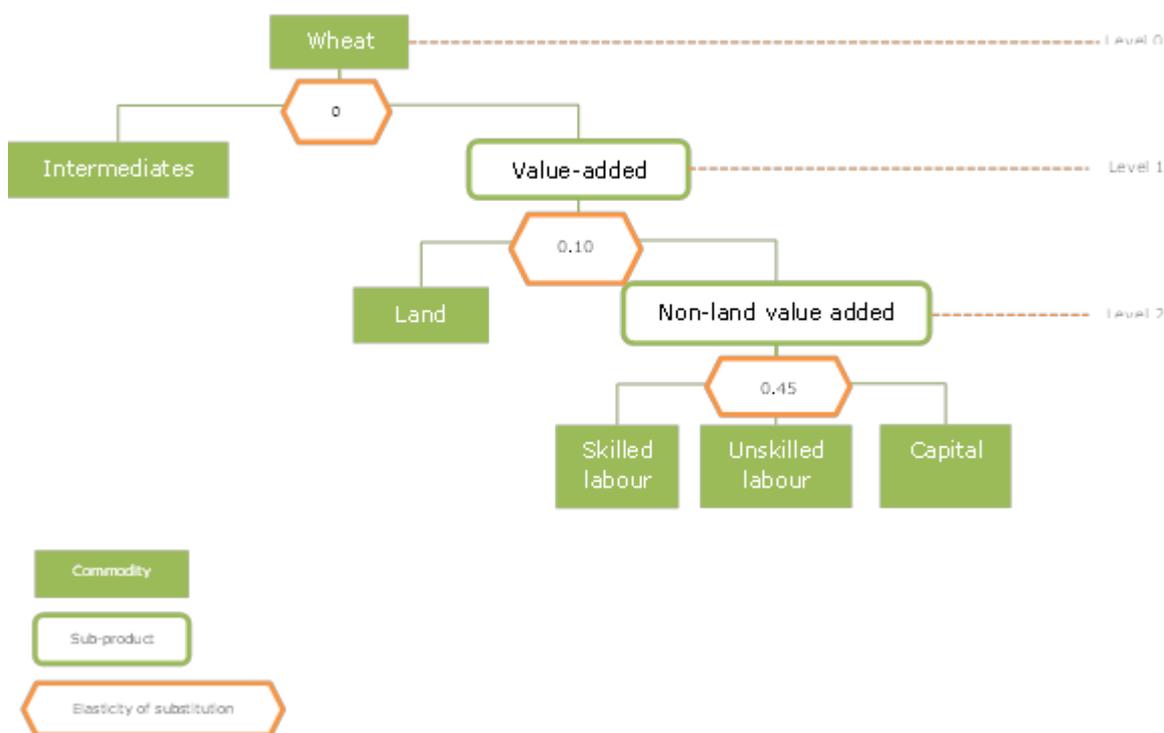
If we then apply Keller's formula, we end up with the following substitution elasticities.

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Intermediates meet all other inputs at the top level, thus K=0. This simplifies the equation to:

$$\sigma_{intermediates, I} = \sigma_{top} * C^{-1}_{top} = 0 * 1 = 0$$

Land meets the other factors of production (fp) in the value added (va) nest:

$$\sigma_{land, fp} = \sigma_{va} * C^{-1}_{va} - \sigma_{top} * (C^{-1}_{va} - C^{-1}_{top}) = \sigma_{va} * C^{-1}_{va} - \sigma_{top} * (C^{-1}_{va} - 1)$$

The results of this equation vary by country.

Finally, the non-land factors of production meet in the non-land value added nest (nl):

$$\sigma_{ij} = \sigma_{nl} * C^{-1}_{nl} - \sigma_{va} * (C^{-1}_{nl} - C^{-1}_{va}) - \sigma_{top} * (C^{-1}_{va} - C^{-1}_{top}) \text{ for all } i \text{ ne } j$$

Again, the results vary by country.

Computing the elasticities for the example for each of the regions above, we get:

		Brazil	USA	EU27	ROW
Intermediates	Production factors	0	0	0	0
Land	Non-land production factors	0.17	0.20	0.19	0.20
Non-land production factors	Non-land production factors	1.62	1.23	1.01	1.10

Due to variations in cost shares, the implied elasticities vary by region despite an identical production structure and elasticities of substitution. Since cost shares are updated with each run of the model, the implied elasticities will change as well. This calls for a re-computation of the elasticities after each model run.

6.3.2 Computing implied elasticities in MAGNET

The module implied_elas.gmp was built to calculate the implied elasticities for each sector defined in ProdTree2.gmp. The main challenge in developing the code was to account for the flexibility users have in defining their own production structure. Not knowing beforehand what the structure will be, the module uses the supplied CES nesting structure (header CESN in ModelSetting.prm file) to determine the level of the nests, which products belong to which nests and in which of the nests each product meets other products.

For the example given above, the relevant parts of the input CES structure (CESN) should be as follows:

	top_comm	vaen	nlvaen
Intermediates	1	0	0
Land	0	1	0
Unskilled Labour	0	0	1
Skilled Labour	0	0	1
Capital	0	0	1
vaen	1	0	0
nlvaen	0	1	0

To compute the elasticities, it is important to determine how the nests and sub-products are connected (we need to establish where products 'meet'). This is done in the 'define sets' and 'define mappings' part of the code.

In the example above, the structure is very simple. There are 3 nests: top commodity (top_comm), value added nest (vaen) and non-value added nest (nlvaen). Therefore, the module distinguishes 3 sets for the nests: top=top_comm, lev1=vaen and lev2=nlvaen. The module currently allows for 3 nest levels (this can be easily extended if needed). In this example, lev3 is left empty. In the example, there is only one nest at each level, but the code can handle multiple nests at the same level

(e.g. if intermediate inputs enter not at the top level but through a separate intermediate input nest, there will be two nests at the first level).

The input sets (comprising both actual commodities and sub-products) belonging to each nest are: ptop=intermediates and vaen, plev1=land and nlvaen, plev2=unskilled labour, skilled labour and capital.

Cost shares are calculated as follows:

```
Formula (all,i,DEMD_COMM)(all,j,PROD_SECT)(all,r,REG)
   CS_S4(i,j,r) = VFA(i,j,r)/VOA(j,r);
```

Where CS_S4 is the cost share in sector 4 (each production tree is denoted by a sector indication S1 through S4), VFA(i,j,r) represents the costs of each input (encompassing both commodities and sub-products) in total costs of production, and VOA(j,r) is total costs of production.

Combining the cost shares by input (commodities and sub-products), with the sets defining the point at which each input enters the production tree, the inverted cost shares of each nest can be determined (ICS_S4). In the equation below, the inverted cost share for the nlvaen nest (lev 2) is calculated. The inverted cost share is equal to the sum of the total cost shares divided by the cost shares of the sub-products belonging to the nest (plev2) plus the cost shares of products of nests of all lower levels (plev3).

```
Formula (all,i,LEV2_S4)(all,j,PROD_SECT)(all,r,REG)
   ICS_S4(i,j,r)=SUM{k,DEMD_COMM,CS_S4(k,j,r)}
                /(SUM{k,pLEV2_S4,CS_S4(k,j,r)}
                  +SUM{k,pLEV3_S4,CS_S4(k,j,r)});
```

The implied elasticity of the nest can then be calculated following the equation of Keller. For the case of the nlvaen nest at level 2 in sector 4, this amounts to:

```
Formula (all,i,LEV2_S4)(all,j,PROD_SECT)(all,r,REG)
   ELAS_S4(i,j,r) = EL_PROD(i,j,r)*ICS_S4(i,j,r)
                    - sum{l,LEV1_S4:LEV22LEV1S4(i)=l,
                        EL_PROD(l,j,r)*[ICS_S4(i,j,r)-ICS_S4(l,j,r)]
                      - sum{m,top_S4:LEV12topS4(l)=m,
                          EL_PROD(m,j,r)*[ICS_S4(l,j,r)-1]}};
```

Here, a mapping of nests to one another (e.g. LEV22LEB1S4) is used to establish which nests need to be included to link this specific nest to the top of the production tree.

Knowing the implied elasticities for each of the nests, we must then attribute these to the inputs meeting in those nests. For this, we need to determine in which nest inputs meet. The procedure works from the bottom up, defining mappings from inputs to nests to establish where inputs enter the production tree and the level at which they meet other inputs (these mappings have a p prefix).

The example below illustrates the case of an input of level 2 meeting another input in the nest of level 2: in the example above, this could be capital and skilled labour, or capital and unskilled labour. The implied elasticity is then equal to the elasticity of nest 2:

```
Formula
 (all,i,pLEV2_S4)(all,j,pLEV2_S4: j ne i and pLEV22LEV2S4(i)=pLEV22LEV2S4(j))
 (all,k,PROD_SECT)(all,r,REG)
 IM_ELAS_S4(i,j,k,r) =  sum{l,LEV2_S4:pLEV22LEV2S4(i)=l,ELAS_S4(l,k,r)} ;
```

where the set pLEV2_S4 contains the inputs entering at level 2 in sector 4 and pLEV22LEV2S4 is a mapping establishing a relationship between the input entering in level 2 and level 2 in sector 4.

The equations quickly become rather complicated, since the code allows multiple nests at each level. The mappings thus need to search through each branch to establish all possible places at which inputs could meet. As an illustration, the formula combines inputs from a level 3 nest with inputs from another level 3 nest that meet each other at the top (i.e. are located in two completely separated branches of the tree):

```
!implied elasticity plev3 to plev3 if connected through nest TOP!
Formula
 (all,i,pLEV3_S4)(all,j,pLEV3_S4:pLEV32LEV3S4(i) ne pLEV32LEV3S4(j)
       and LEV32LEV2S4(pLEV32LEV3S4(i)) ne LEV32LEV2S4(pLEV32LEV3S4(j))
       and LEV22LEV1S4(LEV32LEV2S4(pLEV32LEV3S4(i)))
             ne LEV22LEV1S4(LEV32LEV2S4(pLEV32LEV3S4(j))))
 (all,k,PROD_SECT)(all,r,REG)
 IM_ELAS_S4(i,j,k,r) =sum{l,TOP_S4:
             LEV12TOPS4(LEV22LEV1S4(LEV32LEV2S4(pLEV32LEV3S4(i))))=l,
                       ELAS_S4(l,k,r)};
```

6.4 Activating the flexible production structure

6.4.1 DSS settings to activate the module

DSS tab	DSS question	Actions	Comments
Database	-	-	-
Model	Includes for MAGNET	Select ProdTree2	Adds code to model
	Model parameters file	Adjust headers in ModelSettings.prm as described in table below	Assigns regions and defines structure
Scenario (Gemse)	Model parameters file	Reuse (& adjust, if desired) file from Prepare scenario tab or modify the file with default settings in the same way if Prepare Scenario tab is not used	Assigns regions and defines structure
Downscale	-	-	-

The implied elasticities are always calculated for the flexible production structure. The results are written to the View file under header 'IEST'. Note that the own elasticities of substitution are not computed, this is indicated by the -99 value in the matrix.

Also note that the current code for implied elasticities allows for 3 levels of nests in addition to the top level: top_comm, lev1, lev2, lev3. This suffices for the production structures currently used in the production version. If more levels are needed the code will have to be adjusted. The module currently does allow more than one nest per level.

6.4.2 Adjustments to headers in ModelSettings.prm file

Be aware that normally only the modelsettings.prm file is changed when experimenting with different production structures. If you would like to change the settings for the production structure, you must either change the sets guiding the creation of a production structure in the file for default settings in the Default.prm file, or write a program for the creation of the production structure and place it in cesprodtree.gmp in 2_ModelDefinition\2_ModelStructure\Code\CESNESTS.

If you want to change the production structure by hand, the following instructions are relevant.

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode, which allows the addition of modules
PREG	For all regions with a flexible structure, set the value in the GTAP_PROD column to 0 and in the CES_PROD to 1	Parameter assigns regions to either a GTAP or a flexible CES production structure. Check that each region in your model has a production structure assigned (each row should sum to 1).
CESA	Allocate all sectors in your model to one of the four production structures[a)]	The names used for the four sectors refer to the default structure used to initialise the production structures. These default structures can be modified by the next step. Carefully check that all sectors have been assigned to 1 (and only 1) nest, otherwise an error will result.
CESN	Use the upper-right toggle box to select the production structure that you are using and define its structure by adjusting the matrix as needed. Repeat for all production structures that have been assigned sectors with the CESA header. Production structures that are not used do not need to be adjusted.	The rows contain all available inputs (n sectors + m endowments from your model aggregation + 13 predefined sub-products each representing a single CES nest). The 13 columns indicate in which nest each input enters. Thus a 1 in the (land,top_comm) cell places land in the top of the production structure. A 1 in (SkLab,vaen) places skilled labour in the vaen nest. Putting a 1 in (vaen,top_comm) then places this nest at the top of the production structure. Check very carefully that all commodities and endowments enter 1 (and only 1) nest, and that this nest is linked (possibly through other nests) to the top_comm nest, otherwise the production structure will not make sense, resulting in an error. Not all sub-products need to be used, that is, you can leave nests empty.
ELPR	Check and if necessary adjust the elasticities for the nests that you are using in your model. Note the toggle boxes in the upper right hand corner that allow e.g. different elasticities by region.	The flexibility in defining the production structure can easily lead to the use of meaningless default elasticities, which can cause errors (commonly infeasible solutions). Carefully check that the elasticities associated with the nests you are using make sense given the inputs that you have assigned to these nests.

[a)] Currently 4 production structures are pre-coded. Since these follow a generic pattern by copying the code additional structures can easily be generated if needed. See for instructions in the MAGNET model code (Sector1.gmp).

Below we give an example of how to program the creation of a production tree in cesprodtree.gmp in 2_ModelDefinition\2_ModelStructure\Code\CESNESTS.

In our example we define a production tree for ethanol as shown below:
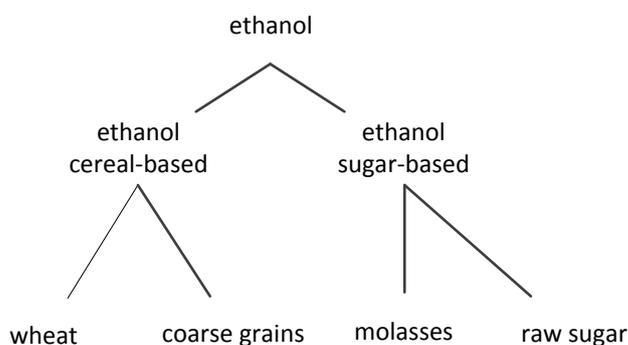
In this production tree, we imply that ethanol can be produced from four feedstocks: wheat, coarse grains, raw sugar and molasses, whereas wheat and coarse grains can be considered substitutes for cereal-based ethanol, and raw sugar and molasses substitutes for sugar-based ethanol. Furthermore, the cereal-based ethanol can substitute for sugar-based ethanol.

To program this tree, the following steps should be followed:
1. Define two sets, one for the feedstock of the cereal-based ethanol and one for the feedstock of the sugar-based ethanol. The naming of the elements should be in accordance with the naming of the elements of the set TRAD_COMM:

!define two sets one with ethanol feedstock from grains and the other ethanol feedstock from sugar and molasses!

```
set eth_grain(wht, grain);
set eth_sugar (sug, mola);
subset eth_grain is subset of TRAD_COMM;
subset eth_sugar is subset of TRAD_COMM;
```

1. Modify an existing nest. In our example we modify the 'othernest'. Ethanol from grains and ethanol from sugar and molasses will now no longer enter the top commodity:

```
Formula (all,i,eth_grain) CESNESTSTRUC(i,"top_comm","othernest")=0;
Formula (all,i,eth_sugar) CESNESTSTRUC(i,"top_comm","othernest")=0;
```

Instead, they will be placed in the second level, whereas the feedstock should be in the third level. In this example we assign wheat and grains (feedstock of the cereal-based ethanol) to the header "hpfeed" and raw sugar and molasses to the header "hefeed". Those two headers are assigned to the header "totfeed" and the latter is considered in the top commodity:

```
Formula (all,i,eth_grain) CESNESTSTRUC(i,"hpfeed","othernest")=1;
Formula (all,i,eth_sugar) CESNESTSTRUC(i,"hefeed","othernest")=1;
Formula CESNESTSTRUC("totfeed","top_comm","othernest")=1;
Formula CESNESTSTRUC("hefeed","totfeed","othernest")=1;
Formula CESNESTSTRUC("hpfeed","totfeed","othernest")=1;
```

6.5 An example of activating the flexible production structure

The full flexibility offered by the flexible production structure makes it crucial to ensure that a production structure is appropriate for a given model. Experience has shown that drawing the production tree with the desired inputs and elasticity values greatly facilitates changes made to the modelsettings.prm file. And, of course, it also eases communication with others on the production structure implemented in the model.

In our simple example, we have created the following database:
– 3 regions: ZAF (South Africa), EU27 (European Union) and ROW (Rest of the World)
– 5 endowments: land, UnSkLab, SkLab, capital, Natres
– 3 sectors: food (primary and processed agriculture), mnfc (manufacturing), serv (services)

6.5.1 Checking that the model is in modified GTAP mode

We first check the MODG header to ensure that the modules can be added to the standard GTAP core:

MODG	ModifiedGTAP
1	1

6.5.2   Define which regions have a flexible production structure

We adjust the PREG header in the following way:

PRODREG	1 GTAP_PROD	2 CES_PROD	Total
1 ZAF	0	1	1
2 EU27	1	0	1
3 ROW	1	0	1
Total	3	0	3

This allocates ZAF (South Africa) to regions with a flexible nested CES production structure. EU27 and ROW maintain the standard GTAP production structure.

6.5.3   Allocate sectors to production structures

We adjust the CESA header in the following way:

CESSECTALLOC	1 petronest	2 feednest	3 chemnest	4 othernest	Total
1 food	0	1	0	0	1
2 mnfc	0	0	0	1	1
3 serv	0	0	0	1	1
4 CGDS	0	0	0	1	1
Total	0	0	0	4	4

This allocates the food sector to a production structure that is different from that for the other four sectors (note that CGDS is added to the user-defined sectors). This allocation applies to all regions that have a nested CES production structure. Given our previous choices, this change affects only ZAF. The EU27 and ROW maintain the standard GTAP production structure.

6.5.4   Define production structures

In the previous step, we selected two production structures for our model: feednest and othernest. We now need to specify the structure for each of these.

Using the toggle boxes, we select the feednest structure, which yields the following default structure:

CESNESTSTRUC	1 top_comm	2 vaen	3 nlvaen	4 ken	5 eny	6 nely	7 solen	8 nsolen	9 fuel	10 feedland	11 totfeed	12 hefeed	13 hpfeed	Total
1 land	0	0(1)	0	0	0	0	0	0	0	1 (0)	0	0	0	1
2 UnSkLab	0	0	1	0	0	0	0	0	0	0	0	0	0	1
3 SkLab	0	0	1	0	0	0	0	0	0	0	0	0	0	1
4 capital	0	0	1	0	0	0	0	0	0	0	0	0	0	1
5 NatRes	0	0	1	0	0	0	0	0	0	0	0	0	0	1
6 food	1	0	0	0	0	0	0	0	0	0	0	0	0	1
7 mnfc	1	0	0	0	0	0	0	0	0	0	0	0	0	1
8 serv	1	0	0	0	0	0	0	0	0	0	0	0	0	1
9 vaen	1	0	0	0	0	0	0	0	0	0	0	0	0	1
10 nlvaen	0	1	0	0	0	0	0	0	0	0	0	0	0	0
11 ken	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12 eny	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 nely	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 solen	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 nsolen	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 feedland	0	1 (0)	0	0	0	0	0	0	0	0	0	0	0	1
18 totfeed	0	0	0	0	0	0	0	0	0	1 (0)	0	0	0	1
19 hefeed	0	0	0	0	0	0	0	0	0	0	1 (0)	0	0	1
20 hpfeed	0	0	0	0	0	0	0	0	0	0	1 (0)	0	0	1
Total	4	2	4	0	0	0	0	0	0	2	2	0	0	14

All rows sum to 1, so all inputs have been allocated. The columns sum to 0 for several of the sub-products (each representing a nest), indicating that not all are being used. In fact, only the nests highlighted in green are used. Using the matrix above, we can deduce the implied production structure.

Looking down the first column (1 top_comm), we find 4 inputs entering this nest. When working with nested CES functions, it is very helpful to create a visual presentation to summarise the structure. The first column translates into the top row of Figure 6.1, with 3 commodities (food, manufacturing and services) and a sub-product (vaen) entering in the top nest. The second column in the table is translated into the second row with two sub-products (nlvaen and feedland) entering the vaen nest. Working our way through the table we can construct the visual representation of the production structure implied by the matrix above.

The figure shows that the default settings of the feednest structure do not match the sectors in our example: the totfeed nest with its sub-products is completely empty. Although this does not cause an error in the model, it does create unnecessary complications in the structure.

We therefore adjust the structure as depicted in Figure 6.2, removing the unused nests while maintaining a different substitution elasticity between land and the other endowments. To implement this new structure in MAGNET, the matrix determining the production structure of the feednest needs to be adjusted. The green values in the matrix above indicate the new values needed to create the production structure of Figure 6.2. We remove the unnecessary nests by setting their values to 0 and moving land from the feedland to the vaen nest.

The production structure for the manufacturing and services sectors (othernest) can be checked and adjusted in a similar fashion.
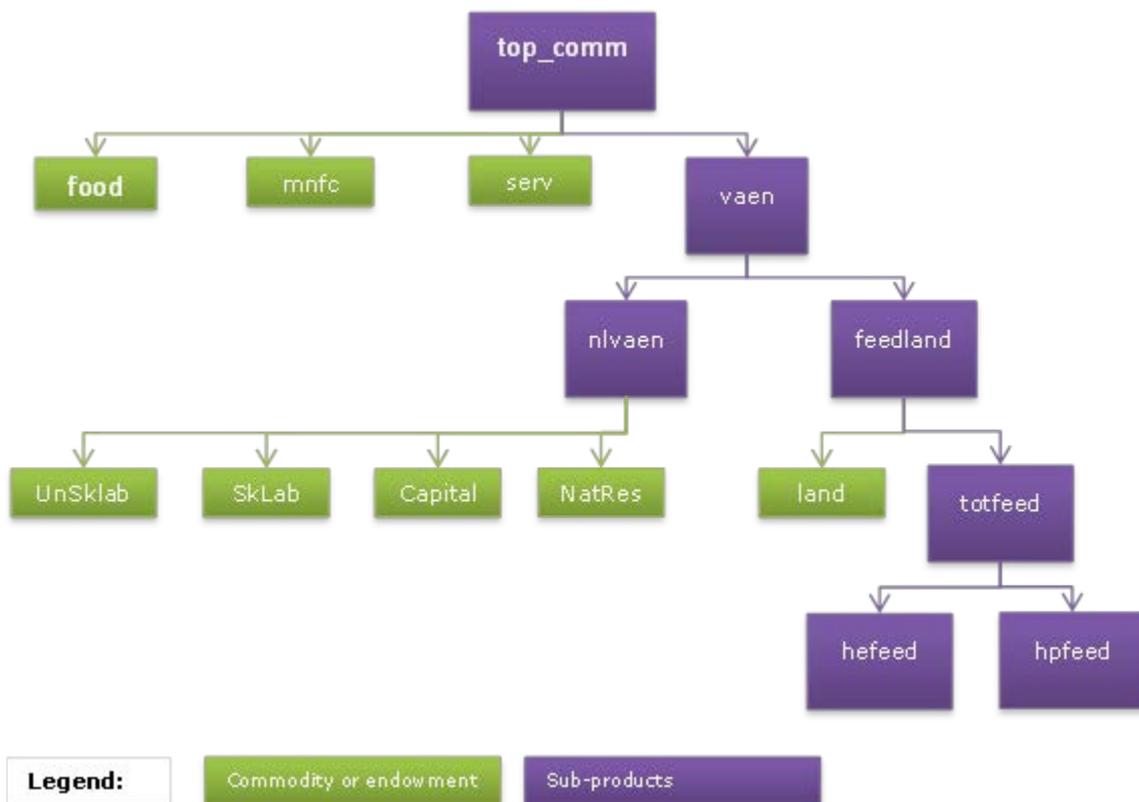
Figure 6.1   *Default feednest structure applied to the example database*
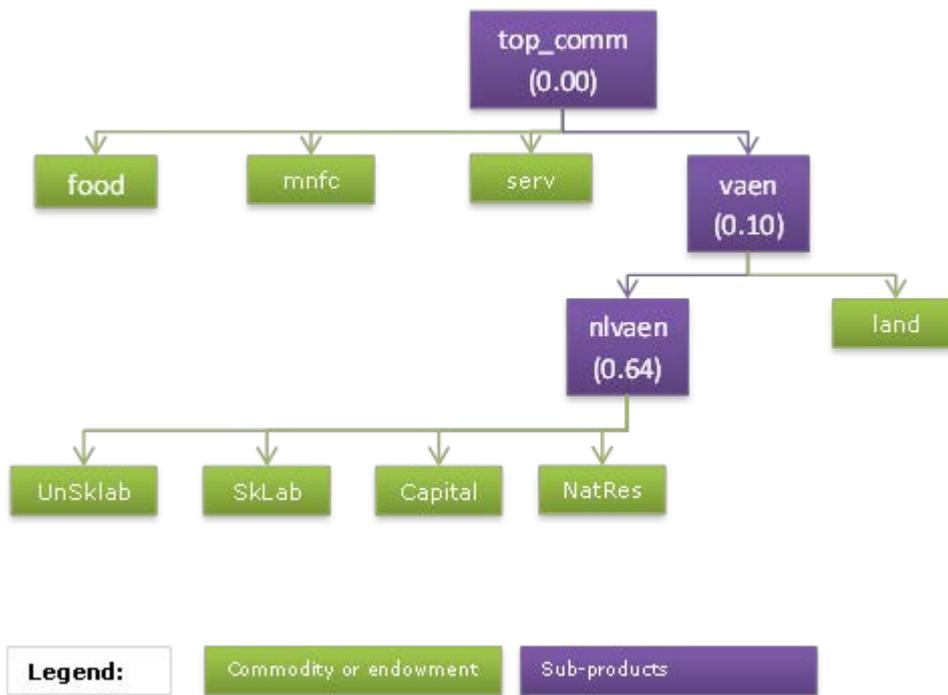
Figure 6.2   *Adjusted feednest structure applied to the example database*

6.5.5   Checking the elasticities

Having defined the production structures, the last step is to see whether the default substitution elasticities from MAGNET are suitable for this model. These elasticities can be found in the ELPR header (use the toggle boxes to select a single region):

EL_PROD	1 food	2 mnfc	3 serv	4 CGDS	Total
1 top_comm	0.00	0.00	0.00	0.00	0.00
2 vaen	0.10	0.10	0.10	0.10	0.40
3 nlvaen	0.64	1.05	1.36	1.00	4.05
4 ken	0.50	0.50	0.50	0.50	2.00
5 eny	0.00	0.00	0.00	0.00	0.00
6 nely	0.00	0.00	0.00	0.00	0.00
7 solen	0.00	0.00	0.00	0.00	0.00
8 nsolen	0.00	0.00	0.00	0.00	0.00
9 fuel	0.00	0.00	0.00	0.00	0.00
10 feedland	0.10	0.10	0.10	0.10	0.40
11 totfeed	2.00	2.00	2.00	2.00	8.00
12 hefeed	5.00	5.00	5.00	5.00	20.00
13 hpfeed	5.00	5.00	5.00	5.00	20.00
Total	13.34	13.75	14.06	13.70	54.85

Focussing on food, to which the feednest designed above is applied, there are three sub-products/nests used: top_comm, vaen and nlvaen (marked in green). As the other nests are not used, the elasticities are not relevant. To complete the picture, the relevant elasticities are added to Figure 6.2. If an elasticity is not appropriate to a sector in a specific country, it can be changed in this header. Note that only the elasticities for regions with nested CES functions can be changed here. The EU27 and ROW regions maintain the standard GTAP values whatever values are included for those regions.

Note also that due to variations in cost shares, implied elasticities may vary across regions. It is therefore worth checking the implied elasticities in the view file (header 'IEST').

6.6 References

Keller, W.J. (1979) Tax Incidence: a general equilibrium approach, PhD thesis, Erasmus University, Rotterdam.

7 Endogenous land supply

Understanding how land use changes over time and with different policies is not only a concern for agricultural analyses; it also features prominently in discussions on climate change. Most CGE models[4] do not account for possible changes in the total amount of agricultural land. In contrast, the land supply module in MAGNET uses a land supply curve to describe a relationship between average real agricultural land rent and the area of land in a country that is used for agriculture.

7.1 Aim

In the standard GTAP model, land is a primary production factor and the quantity of land is expressed as the value added of land in constant prices. The total regional supply of land in constant prices (qo("land",r)) is an exogenous variable in the model. The land supply module makes this variable endogenous and determines land supply by a land supply curve, that is, a relationship is defined between the real agricultural land rent and the agricultural land area in km^2. In order to do this, land area in km^2 is added to the database.

7.2 Theory

A question in the modelling of the long-run supply of land in agricultural and forestry activities is how (and whether) new land can be used for agricultural and forestry production. One way to handle this question is to construct a land supply schedule in which increasing land rent causes additional land to be used for cultivating crops, an approach explained in Eickhout and colleagues (2009).
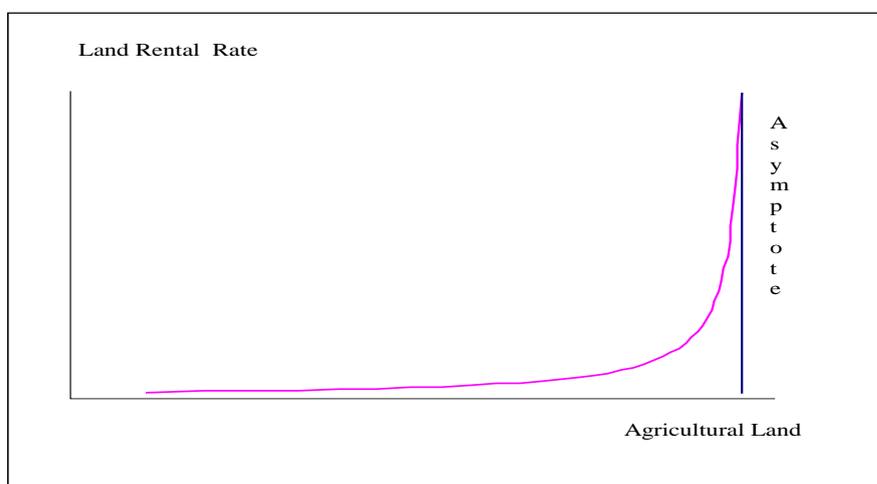
Figure 7.1 *Land supply curve determining land conversion and land rental rate*

In detail, the total agricultural land supply is modelled using a land supply curve that specifies the relation between land supply and a land rental rate (see Figure 7.1). The general idea underlying the curve specification is that the most productive land is taken into production first. The potential for bringing additional land into agriculture production is limited to the maximum potentially available land. That maximum is defined on the basis of regional data on land use (arable land, forestry,

---

[4] For an overview of how land use is handled in global scale CGE models see e.g. Hertel et al. (2009).

pasture areas, fallow land, etc.) and is arranged in order of diminishing productivity. Eickhout and colleagues (2009) assume that land rents and yields are related in that increasing yields result in lower land rents, and vice versa, which gives a land supply curve in which the total amount of land used in production is an increasing function of land rent.

If there is a large gap between the potentially available agricultural land and the land used in the agricultural sector, an increase in demand for agricultural land will lead to land being converted to agricultural land and a modest increase in rental rates to compensate for the cost to put this land into production (see left-hand part of Figure 7.1). Such a situation is illustrated by points situated on the left-hand, flat part of the land supply curve. However, once nearly all agricultural land is in use, an increase in demand for agricultural land will mainly lead to large increases in land rental rates (land becomes scarce; see right-hand part of Figure 7.1). In this case, land conversion is difficult to achieve and therefore the elasticity of land supply with respect to land rental rates is low.

Additional land is brought into production until the point where the benefit of the last (additional) hectare of land (hence marginal benefit), measured by its marginal value, equals the cost of making an extra hectare of land suitable for cultivation.

7.3   Modelling land supply in MAGNET

In MAGNET, the land supply curve shown in Figure 7.1 is defined using the following function:

$$L = A - B/(P^C) \tag{1}$$

where L is land supply, P is the real land rental rate, A is the maximum agricultural land area and called the land asymptote, and B and C are positive parameters. The rental rate elasticity E is given by the equation:

$$E = C\ (A/L-1) \tag{2}$$

Note that the elasticity E in equation (2) depends on land supply L, which is endogenous in the model (equation (1)) and therefore it is not constant in the simulation experiments.

In MAGNET, a linearised version of equation (1) is implemented:

$$p\_L = (A/L)\ p\_A + E\ p\_P \tag{3}$$

where p_X denotes percentage change of variable X.
The associated MAGNET equation is:

Equation `LANDSUPPLY1_LS` *# Land supply function #* (**all**,r,`ENDLAND_REG`)
   `p_landsupply(r)` = `ASYMPTOTE(r)/LANDSUPPLY(r)*p_asymptote(r)`
                   + `LANDELAST(r)*p_lprice(r);` (4)

where r is the region index, ENDLAND_REG is the set of regions endogenous land supply specification and:

LANDSUPPLY (LDEM);	- agricultural land supply (L), calculated as the sum of agricultural land use
p_landsupply	- percentage change of LANDSUPPLY (p_L);
ASYMPTOTE	- the land asymptote, namely the maximum area of land that can be used for agriculture (A);
p_asymptote	- percentage change of ASYMPTOTE (p_A);
LANDELAST	- real rental rate elasticity E;
p_lprice	- percentage change of real land rental rate (P).

The price elasticity of land supply LANDELAST is calculated using the following formula:

Formula (all,r,ENDLAND_REG)
```
LANDELAST(r) = LANDPOW(r)*(ASYMPTOTE(r)/LANDSUPPLY(r)-1);            (5)
```

Note that in equation (5), the asymptote is defined as a variable that is set exogenous in the closure. This allows shocks to the asymptote. However, shocks to the asymptote may generate results that are not very plausible if land use decreases as a consequence of the change in asymptote (Dixon et al., 2012), a situation that can happen when a shock to the asymptote is large.

In addition to the land supply equation, MAGNET specifies a land demand equation. To model land demand changes, we introduce the following equation:

$$L = \Sigma_{i=1,\dots,n}\ LD_i \tag{6}$$

where LD_i is the land demand of sector 'i'. This equation defines the market equilibrium condition in the model: land supply in km^2 equals land demand in km^2. It implicitly determines the real land rental rate (implicitly since lprice is not part of the equation), since it needs to adjust to make the land market equilibrium condition hold.

The linearised version of equation (6) is:

$$L\ p\_L = \Sigma_{i=1,\dots,n}\ LD_i\ p\_LD_i \tag{7}$$

and it is implemented in MAGNET as follows:

Equation LPRICEL1_LS # Land market equilibrium condition # (all,r,ENDLAND_REG)
```
   if{LANDSUPPLY(r)>0,LANDSUPPLY(r)*p_landsupply(r)}+
     if{LANDSUPPLY(r)=0,qo("Land",r)} =sum(j,PROD_SECT,LDEM(j,r)*p_ldem(j,r));(8)
```

where r is region index, j is sector index, PROD_SECT is a set of MAGNET sectors and:
LDEM   - land demand;
p_ldem   - percentage change of LDEM;
qo("land")   - supply of land in constant prices.

In MAGNET, the real land rental rate (lprice) influences both land supply (equation (5)) and sectoral land demand. As the result, this is the equilibrating variable associated with the land market equilibrium. The regional supply of land in constant prices (qo("land",r)) is an endogenous variable in the model. The land demand equation (7) is only active in MAGNET if there is land available in the database, that is, if LANDSUPPLY – which is the sum of all agricultural land use – is positive. This condition is introduced by the if-condition in (8). Otherwise, qo("land",r) has to be exogenised via the equality qo("land",r) = 0 to which equation (8) reduces in case when LANDSUPPLY(r)=0.

Implementation of the land supply curve in MAGNET influences the land use and land price development. This in turn affects land rent and prices of agricultural products.

7.4   Land supply function parameterisation

To apply the land supply function, one needs to define parameters B and C and the asymptote A (the potentially available agricultural land). In applications of LEITAP, the precursor of MAGNET, information to determine asymptote A was taken from IMAGE data (Eickhout et al., 2009). The default IMAGE asymptote is defined as the total available land available excluding non-productive land (mainly ice and desert in regions like Canada and the Middle East), urban areas and protected areas. This asymptote, corrected for differences in land use in the IMAGE database and the land data used in MAGNET, is stored in the database and is used as the default (header ASSY in basedata_b.har).

A user who wants to use a different asymptote can choose from the six that are available (the calculation of which can be found in the AddAndmodifyData program):

1. *Baseline*: cropland + pasture land + savannah & grassland + shrub land + forest land
2. *exPA (Excluding protected areas)*: baseline − 0.25 * forest land
3. *NoForest (No land use of forests)*: baseline − forest
4. *NoForNoWood (Neither land use of forest nor of woodland)*: baseline − forest land − shrub land (if FAO data are used this is equal to the NoForest asymptote)
5. *IMbase:* land supply * IMAGE asymptote/IMAGE land demand (initial default asymptote)[5]
6. *IMbasefrs:* (land supply + forestry)*IMAGE asymptote/IMAGE land demand.

Once an asymptote is selected, it becomes the default for all remaining periods. The default asymptote is the asymptote used in the current application and is available in database file BaseData_b.har in header ASSY. In standard applications, MAGNET considers the '*IMBase*' asymptote as the current default asymptote. Other asymptotes may be used in policy applications involving agricultural land use limitations due to different policies (Tabeau et all., 2011, Overmars et al., 2012).

If the asymptote, rental rate elasticity E, real land rental rate P and the corresponding land supply (L) are known for the initial data set, the parameters B and C can be determined by solving a system of equations (1) − (2). In Eickhout and colleagues (2009), these parameters were calibrated for 45 world regions using land supply elasticities for real land rental rates provided by Cixous (2006) for EU countries or derived from biophysical data from the IMAGE[6] modelling framework (Tabeau et al., 2006, Eickhout et al., 2009).

Alternatively, if the real rental rate elasticity of the land supply function is known, parameter B can be calculated directly from (1) and elasticity E from (2). In general, in current applications, we choose the version of the land supply function with parameter C = 1. This allows us to use the second method of land supply function calibration to easily parameterise the land supply function for any chosen regional aggregation of MAGNET.

The C parameter is specified in the land data in \0_Database\2_OtherData_Land\LandData.har under the header 'LPOW'. The default value is 1 in each region, which introduces an inelastic response in the land supply to changes in the land price. Other positive values can be used by changing the value in the LPOW header in 4_MAGNET\BaseData\Par\Parameters.prm. This parameter is active only for regions that have an endogenous land supply curve.

The land supply approach allows users to determine the maximum amount of available agricultural land by taking into consideration biophysical constraints related to land availability and, for example, exclude protected areas, national parks, etc. from the land supply schedule.

7.5   Model choice and Magnetagg

In the file with standard model choices, the desired general land supply approach can be selected under the header LSUP. In the Modelstructure code, this choice is generalised for all regions. If you want to select a specific approach for only a limited number of regions, you can do so either when you are running the scenario or by adding code in Modelstructure that determines which set of regions will use the GTAP code and which will use the endogenous land supply code:

---

[5] Note that land demand does not have to equal area harvested. The ratio between harvested area and crop area is a measure which used to indicate the intensity of a cropping system. The ratio is higher than 1 in cases in which more crops per year are grown on the same ha or, for example, two crops of rice grown in one period (which is quite normal in tropical countries). The ratio is lower in cases where part of the crop area has been left fallow or in cases in which crops can only be harvested once in two or three years.

[6] Integrated Model to Assess the Global Environment; Alcamo et al., 1998.

```
Set Landsuptypes # Landsuptypes #
    read elements from file MAGNETCHOICINI header "LSUT";


Coefficient (all,l,Landsuptypes) LandSupChc(l)
   # Land mechanism supply choice #;
Read LandSupChc from file MAGNETCHOICINI header "LSUP";
coefficient (all,r,REG) (all,i,Landsuptypes) LandSupCh(r,i);
Formula (all,r,REG) (all,l,Landsuptypes)  LandSupCh(r,l)=LandSupChc(l) ;
```

The current asymptote is defined in \2_ModelDefinition\3_MagnetAgg\Code, land .gmp:

```
Set AVASS # Available asymptotes (due to different conversion assumptions) #
  read elements from file MAGNETSETS header "AVAS";
Transfer "AVAS" from file MAGNETSETS to file SETS;
Transfer "AVA1" from file MCHOICE to file SETS;
! Choice made on current asympote!
Set CURASS # Currently selected asymptote from available asymptotes #
  (IMBase);
  subset CURASS is subset of AVASS;
```

As the code above shows, the IMBase asymptote is selected because it was the standard asymptote LEI used in most of its projects.
The code on the MAGNET aggregation (\2_ModelDefinition\3_MagnetAgg\Code) defines how land demand and supply should be aggregated to the regional aggregation of each application of the model.

Regarding land demand, we first check whether there is indeed a positive land rent:

```
! <%GTREE  4.4  Check on land rents  %>!
Coefficient (all,i,DPROD_SECT) (all,r,DREG)
  D_LDEM(i,r)# Land demand (km2)#;
Read D_LDEM from file MAGNETDATA header "LDEM";
Formula  (all,i,DPROD_SECT) (all,r,DREG)
  D_LDEM(i,r)=0+if{D_EVFA("land",i,r)>0,D_LDEM(i,r)};

! <%GTREE  4.3  land use  %>!
Formula (all,j,PROD_SECT)(all,m,REG)
  LDEM(j,m) = sum(k,DPROD_SECT:DPRODS2PRODS(k) = j,
           sum(r,DREG:DREG2REG(r) = m, D_LDEM(k,r)));
```

Regarding land supply, MAGNET includes an assertion that checks whether the total land used worldwide is greater than a certain share of total available land. The share is defined in \0_Database\2_OtherData_Land\LandData.har under the header 'LOWB'. The default value is 0.08 and the model will stop running if the share of total land initially in use is less than 8%. Failing this assertion is an indication that something is fundamentally wrong with the land data and they should be checked before proceeding. In the past, we used land demand in km^2, while the asymptotes were defined in ha. The model does not complain because everything is calculated in percentage changes, but the interpretation of results is more difficult.

```
Formula (all,r,REG)
  LANDSUPPLY(r) = sum{j,PROD_SECT,LDEM(j,r)};
  Assertion   # Land supply should exceed minimum share of asymptote #
        sum(r,REG,LANDSUPPLY(r)) > LOWBOUND* sum(r,REG,ASYMPTOTE(r));
```

7.6 Additional data

The endogenous land supply module requires additional data beyond the parameter values described above. To implement the land supply function in MAGNET, we need the agricultural land area per sector in each region. The data that may be used come from the following three sources:

1. GTAP satellite data on land use (SAGE)
2. FAOSTAT
3. IMAGE.

The default is to compute the initial land demand based on GTAP land use data. These data can be replaced by FAOSTAT data by including the replace_landandproduction module when creating the DSS database. This replaces the harvested areas from GTAP by those computed from FAOSTAT data.

How these data are processed is discussed in detail in the manual on the MAGNET database.

7.7 Activating the endogenous land supply module

7.7.1 DSS settings to the module

DSS tab	DSS question	Actions	Comments
Database	Choose includes	Select replace_landandproduction	Optional include. If using GTAP 2001 (=the default setting) is not appropriate (e.g. because you use a 2007 database), including this module will update the land use data with FAOSTAT data from the year of the selected database
Model	Includes for MAGNET	Select Land	Adds code to model
Scenario (Gemse)	Model parameters file	If you want to change model parameters by hand instead of programming it, adjust headers in ModelSettings.prm as described in the table below	Assigns regions to having endogenous land supply and defines relevant asymptote
	Closure file	Add LandModuleClosure.cmf	Closure needed as soon as the Land module is included in the code (even if it is not activated)

7.7.2 Adjustments to headers in ModelSettings.prm file

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode, which allows to add modules
LSUT	-	Set defining the land supply types
LNDS	For all regions with endogenous land supply set the value in the GTAP column to 0 and in the Endogenous column to 1	Parameter assigns regions to either fixed land supply as in GTAP or introduces endogenous land supply. Check that each region in your model has a land supply mechanism assigned (each row should sum to 1).
AVAS	-	Set defining the available asymptotes
ASMC	Define the current asymptote	Different asymptotes are available to reflect different assumptions on which land can be brought into agriculture. Here you can choose the appropriate one.

This setting allocates the regions to the sets that control which land supply function is implemented in the MAGNET model. An aide memoire for the land supply function sets in the model is shown below:

```
|------------------------------------------------|
|                   REG                 |        |
|------------------------------------------------|
|   GLAND_REG   |   ENDLAND_REG   |              |
|------------------------------------------------|
```

Key:
REG   all regions
GLAND_REG   regions with no land supply function GTAP (specification)
ENDLAND_REG   regions with endogenous land supply

7.7.3 Closure

The endogenous land supply module requires an exogenous asymptote in the model closure. To do this, users need to add the file LandModuleClosure.cmf file to the closure (DSS tab 'Scenario Gemse', question on closure).

7.8 Changes to MAGNET

Phase	Directory	Subfile & Description
ModelDefinition	*2_ModelDefinition\2_ModelStructure\Code*	*\Land\Land.gmp* Land supply model and asymptote choice, land allocation
	2_ModelDefinition\3_MagnetAgg\Code	*\Land\Land.gmp* Asymptotes and land prices calculation, model calibration
MAGNET code	*4_MAGNET\CodeMainProgram\Land*	*Land.gmp* Endogenous land supply module code

7.9 Testing the module

The asymptote can changed by:
- Shocking the asymptote in the standard way by using, for example, a command:

    shock p_ asymptote(r) = uniform -10;

- Or reading in a new asymptote from the parameter file from header ASSP. The preferred asymptote should be selected in the model choice file through the coefficient ASYMP_CHOICE (header) ASMC. The chosen asymptote has to be marked by 1. (The file can be found in \4_MAGNET\BaseData\ModPar).

The first method can produce implausible results if an asymptote shock is very large. The second method implicitly changes the land supply elasticity in the benchmark equilibrium situation (see equation (2)) and, when it is working correctly, only if a new asymptote is larger than the total land demanded in equilibrium.

7.10   References

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8   Allocation of land over sectors

Moving land from one use to another involves adjustment costs. To capture these costs, land is treated as a sluggish input in the GTAP model. We have developed a nesting structure for the CET function to allow for differences in ease of land use change between different land use types. In addition, it is possible to model perfect competition in the land market.

8.1 Aim

The land allocation module offers two options:
− CET allocation treating land as sluggish with more nests than in the standard GTAP model
− Treating land as a perfectly mobile endowment.

8.2 Approach to allocating sluggish land

To improve the modelling of land use decisions, we introduced more detail into the structures of land use allocation in MAGNET. This extension is based on a more detailed modelling of land use allocation in:
• Policy Evaluation Model (PEM) of the OECD (see Huang et al., 2004 and OECD, 2006)
• MIRAGE model of IFPRI (Bouët et al., 2010).

In standard GTAP, land is modelled as a sluggish factor with allocation across sectors governed by a single-level CET function (see Figure 8.1)[7] where the elasticity of substitution equals -1 in the GTAP database. The two additional land allocation schemes mentioned above assume that the various types of land use are imperfectly substitutable, but the substitutability is equal among all land-use types. Therefore, the new land use allocation structures are an extension of GTAP because they take into account the degree of substitutability across different types of land.

The PEM land allocation structure distinguishes different types of land in a nested 3-level CET structure. The model covers several types of land use more or less suited to various crops (i.e. cereal grains, oilseeds, sugar cane/sugar beet and other agricultural uses). The lower nest assumes a constant elasticity of transformation between land (L) used for 'vegetables, fruit and nuts' (horticulture), 'other crops' (e.g. rice, plant-based fibres; OCR) and the group of 'field crops and pastures' (FCP), which are elements of all agricultural land. The transformation is governed by the elasticity of transformation σ1. The FCP group is itself a CET aggregate of 'cattle' and 'raw milk' (both 'pasture'), 'sugar crops' (sugarcane and beet), and the group of 'cereal, oilseed and protein crops' (COP). In these categories the elasticity of transformation is σ2. Finally, the transformation of land within the upper nest, the COP group, is modelled with an elasticity σ3. In this manner, the degree of substitutability of different types of land can be varied between the nests. Doing so captures, to some extent, certain agronomic features. In general, it is assumed that σ3> σ2 >σ1; which means that it is easier to change the allocation of land within the COP group, while it is more difficult to move land out of COP production into, say, vegetables.

---

[7]   Note that this is a general specification which applies to all sluggish factors. The CET elasticity of substitution depends on the type of endowment. The second sluggish factor in GTAP is natural resources with a default elasticity of substitution -0001.

The MIRAGE land allocation system is based on the same idea as the PEM land allocation tree, but the allocation structure in that model is more extensive than the PEM. In the PEM case, only one crop group can be split at each CET level, while in MIRAGE more than one group can be disaggregated.
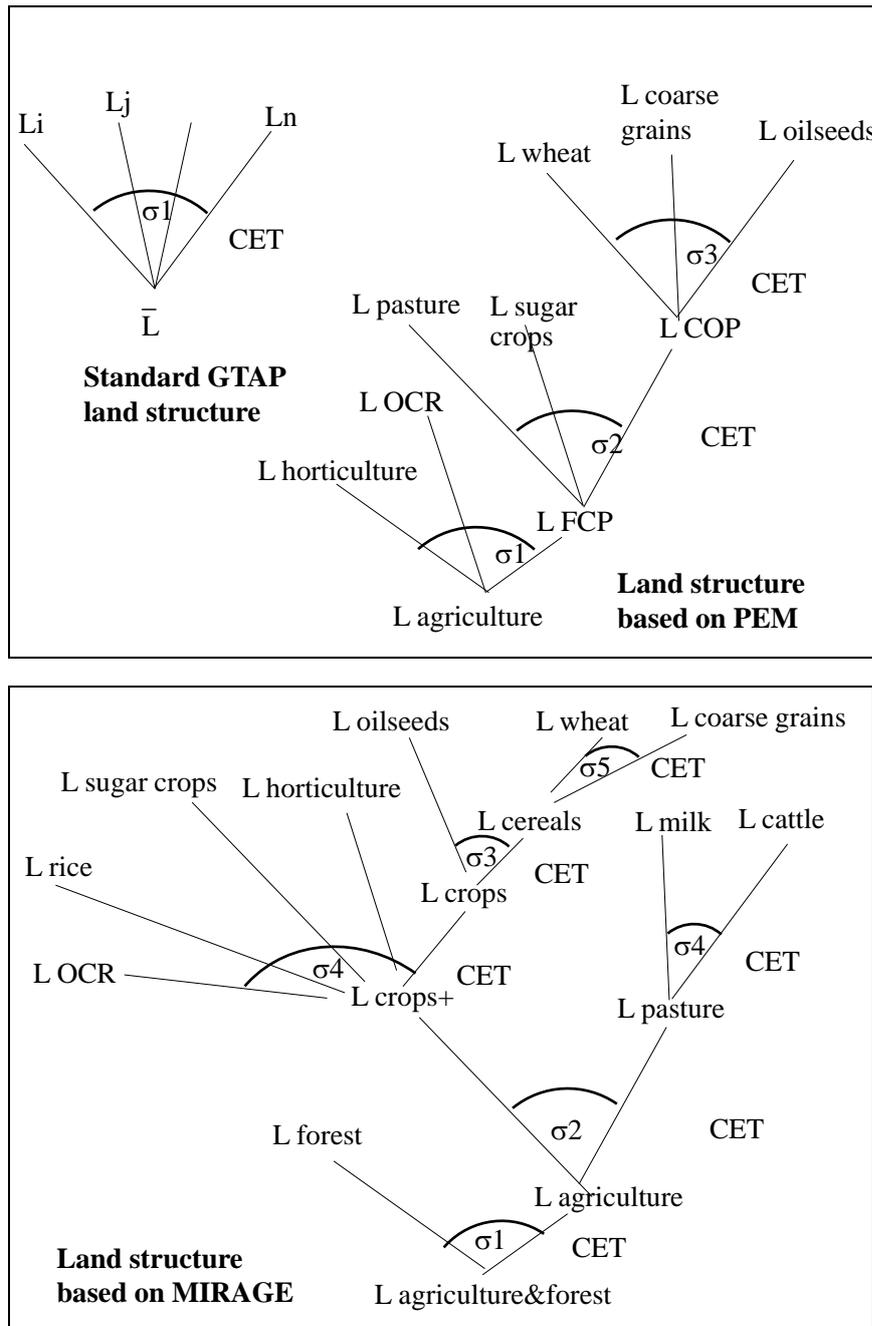
Figure 8.1   *Land allocation tree in standard GTAP and MAGNET: PEM and MIRAGE like specification*

As the code of the CET land allocation tree is similar for all nests, we present only one nest example:

Equation QCETLAND1_CETSUB1 *# demands for endowment commodities (HT 34) #*
(**all**,i,CETINP1) (**all**,r,CETLAND_REG)
    qcetland(i,r) = 0*time-CETendwslack(i,r)+**if**(CS_CETLND_S1(i,r)>0,
        sum{k,CETSUB1,qcetland(k,r)} - **sum**{k,CETSUB1,EL_CETLAND(k,r)}
        *[pcetland(i,r)- **sum**{k,CETSUB1,pcetland(k,r)}]);   (1)

where k ∈ CETSUB1 is type 1 of land (level 1, i.e. bottom level of land allocation tree; in the case of PEM, k is agriculture), i k CETINP1 is land subtypes included in type 1 of land use (in the case of PEM, horticulture, OCR and FCP) and r h CETLAND_REG is the region using the CET land allocation structure and:

qcetland   - land use by different land types and subtypes

pcetland   - land price for different land types and subtypes

EL_CETLAND   - (<0) elasticity of substitution of the CET function

endwslack   - normally exogenous slack variable, which could be endogenised and swapped with an associated land price if the user wishes to employ a partial equilibrium closure

CS_CETLND_S1 - value share of land subtypes in the total value of associated and type (e.g. value share of horticultural in total value of agricultural land)

time   - absolute change in time measured in years.

According to equation (1):

a)   if land type 'k' ($qcetland(k,r)$) increases *ceteris paribus* by 1%, then the associated land subtype 'i' ($qcetland(i,r)$) increases as well by 1%, and;

b)   if the price difference between land type 'k' and associated land subtype 'i' ($pcetland(i,r)-sum\{k,CETSUB1,pcetland(k,r)\}$) increases *ceteris paribus* by 1%, then the associated land subtype 'i' decreases by EL_CETLAND %.

So, in the case of the bottom level of PEM, if (a) agricultural land increases *ceteris paribus* by 1%, the horticultural land increases by 1% too, and if; (b) horticultural land becomes *ceteris paribus* 1% more expensive than agricultural land, horticultural land decreases by EL_CETLAND %.

The if-condition ($CS\_CETLND\_S1(i,r)>0$) in the equation (1), together with the 0*time component, produces land growth equal to zero if agricultural land does not exist in the particular sector 'i' in the particular region 'k' (e.g. rice in Sweden).

Table 8.1

PEM land allocation structure specification CETN header in ModelChoices.har or ModelSettings.prm

CETNESTSTRUC	1 L_AGRI	2 L_ANIMALS	3 L_CROPSPLUS	4 L_CROPS	5 L_CEREALS	6 L_FCP	7 L_COP	8 L_FORESTRY	Total
1 pdr	1	0	0	0	0	0	0	0	1
2 wht	0	0	0	0	0	0	1	0	1
3 grain	0	0	0	0	0	0	1	0	1
4 oils	0	0	0	0	0	0	1	0	1
5 sug	0	0	0	0	0	1	0	0	1
6 hort	1	0	0	0	0	0	0	0	1
7 crops	1	0	0	0	0	0	0	0	1
8 cattle	0	0	0	0	0	1	0	0	1
9 milk	0	0	0	0	0	1	0	0	1
10 L_ANIMALS	1	0	0	0	0	0	0	0	1
11 L_CROPSPLUS	1	0	0	0	0	0	0	0	1
12 L_CROPS	1	0	0	0	0	0	0	0	1
13 L_CEREALS	1	0	0	0	0	0	0	0	1
14 L_FCP	1	0	0	0	0	0	0	0	1
15 L_COP	0	0	0	0	0	1	0	0	1
16 L_FORESTRY	1	0	0	0	0	0	0	0	1
Total	9	0	0	0	0	4	3	0	16

CET land allocation structure is coded in the CETLAND.gmp model code 4_MAGNET\CodeMainProgram\cetLand.

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8.3 Modelling land as perfectly mobile

In some applications, it can be worthwhile to treat land as a perfectly mobile endowment. This is implemented by adding an equation equalising land prices for all sectors, and is coded in the PerfectLandMarket.gmp model code 4_MAGNET\CodeMainProgram\Land.

8.4 Additional data

The land allocation module needs CET function elasticities. The transformation parameters in PEM (OECD, 2006) or the MIRAGE (Bouët et al., 2010) CET structure can be calibrated to land supply elasticities used in the PEM model (OECD, 2001 and OECD, 2003). The calibration method is described in OECD, 2006. The elasticities obtained there vary depending on country/region and are as follows: $\sigma 1$ = -0.05 or -0.1, -0.21 <= $\sigma 2$ <= -0.11, -0.59<= $\sigma 3$ <= -0.2 and -0.35 <= $\sigma 4$ <= -0.15.

Hertel and colleagues (2009), propose $\sigma 1$ = -0.25 (between agriculture and forestry), $\sigma 2$ = -0.5 and $\sigma 4$ = -1 for static scenarios, whereas Golub and colleagues (2009) propose $\sigma 1$ = -1.5 (between agriculture and forestry) and $\sigma 2$ = -3 for long-run scenarios[8,9].

In MAGNET applications, we usually run simulations over 10-year periods. We therefore tend to use CET elasticities close to those proposed by Hertel and colleagues (2009), namely $\sigma 1$ = -0.2, $\sigma 2$ = -0.4, $\sigma 3$ = -0.8 and $\sigma 4$ = -0.6.

8.5 Activating the flexible land allocation module

8.5.1 DSS settings to activate the module

DSS tab	DSS question	Actions	Comments
Database	Choose includes	Include Land\add_landrent_to_forestry if you want to include land in the forestry sector.	Only necessary if you want to model forest land.
Model	Choose file with standard choices	Adjust headers in StandardChoiceINI.har as described in the table below.	Chooses land nested structure, defines land types, sets elasticities
	Choose includes for model structure	Select either newcetland or pem_cetland.	pem_cetland uses the PEM structure, newcetland uses MIRAGE structure
	Includes for MAGNET	Select land	
	Make aggregation for commodities.	Define land using commodities with different names then predefined land types names used in StandardChoiceINI.har	Violation of this rule will result in an error when the model is run
Prepare Scenario	Closure file	Add landmoduleclosure2.cmf to the list of closures	Defines a slack coefficient as exogenous
Scenario (Gemse)	Model parameters file	Adjust headers in ModelSettings.prm as described in the table below. If you want to store the procedure and make it independent of aggregation, do this in the Modelchoice program or in the file with standard choices. Reuse (& adjust, if desired) file from Model tab or modify the file with default settings in the same way if Model tab is not used	Assigns regions and defines structure. Sets elasticities.
	Closure file	Add landmoduleclosure2.cmf to the list of closures	Defines a slack coefficient as exogenous

---

[8] In Hertel et al. (2009), and Golub et al. (2009), σ1 and σ4 are based on econometric estimates.
[9] Golub et al. (2009) runs a simulation experiment for 28 years.

8.5.2 Adjustments to headers in StandardChoiceINI.HAR file

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode, which allows the addition of modules
LALC	Choose land allocation NESTCET or PerfComp land allocation structure. Set 1 for NESTCET or PerfComp; set 0 for remaining.	Only one element should be set at 1; the others should be 0.
LSUB	This header contains 'Set CETLAND_SUB Subtypes of land use'. Review contents of this header and add additional land types you may need. It is possible to add a maximum of 2 land types.	Predefined land types are AGRI, ANIMALS, CROPSPLUS, CROPS, CEREALS, FCP, COP. They are hard coded, so do not change them unless you are changing the code too. **Warning**: the predefined land type names must be different from the names of MAGNET commodities that you will define later on, otherwise the model will not work.
ELND	If you changed the LSUB header (definition of Set CETLAND_SUB Subtypes of land use), i.e. add additional land types, then change the dimension of ELND accordingly and add additional value of CET elasticity.	The flexibility in defining the allocation structure can easily lead to the use of meaningless default elasticities, which can cause errors (commonly infeasible solutions). Thus carefully check that the elasticities associated with the nests you are using make sense given the inputs that you have assigned to these nests. For example, do not assume perfect competition on the land market if you include forest land, and do not run very long–run scenarios.

8.5.3 Adjustments to the headers in ModelChoices.har or ModelSettings.prm files

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode, which allows the addition of modules
RNLC	For all regions with a multilevel nested CES, set the value for GTAP to 0 (default is 1), place a 1 with NESTCET. For regions with a perfect land market, set GTAP to 0 and place a 1 in PerfComp	Parameter assigns regions to GTAP, multilevel nested CES or perfect land markets. Check that each region in your model has a land allocation mechanism assigned (each column should sum to 1).
CETN	Design a CET allocation structure by placing 1's in the proper places.	The matrix works the same as for designing the nested CES production structure. See Chapter 6 for a detailed example of how the matrix can be translated into a nested production tree. Carefully check that all sectors have been assigned to 1 (and only 1) nest, otherwise a closure error will occur. Also, unlike in case of nested CES production structure, all aggregated land types should be assigned to 1 (and only 1) nest even when they are not used in the land allocation structure. In the latter case, the aggregated sector should be assigned to the top level, whereas none of the original MAGNET sectors should be assigned to the aggregated header. For example if the aggregate L_ANIMALS is not used, it should be assigned to the top commodity (L_AGRI) but none of the original MAGNET sectors will be assigned to it (sum of columns should be zero) (see the example for PEM land allocation structure above)
ELND	Check and if necessary adjust the elasticities for the nests that you are using in your model.	The flexibility in defining the allocation structure easily leads to the use of meaningless default elasticities, which can cause errors (commonly infeasible solutions). Thus carefully check that the elasticities associated with the nests you are using make sense given the inputs that you have assigned to these nests.

8.6 References

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9 Consumption function corrected for real GDP changes

9.1 Background

When conducting long-term projections, incomes may change considerably and, as a consequence, so too may income elasticities. To capture such changes a module has been developed in which income elasticities are calibrated using ppp-corrected GDP per capita. In GTAP, private (household) consumption behaviour is modelled via a constant difference of elasticity (CDE) function, which is a relatively flexible, non-homothetic function allowing for non-constant marginal budget shares. It is calibrated by GTAP using data on income and price elasticities of demand. Since the use of the CDE function in practice results in constant income elasticities over time – leading to unrealistically high levels of consumption of food items in fast growing economies – MAGNET allows income elasticities to be adjusted over time using real (PPP-corrected) GDP per capita. This approach can be implemented by activating the consumption module.

9.2 Aim

The consumption module is intended to improve long-term projections of consumption by households, including dietary patterns, by adjusting income elasticities as GDP per capita changes over time.

9.3 Approach

This module uses the CDE function from the standard GTAP model, but calibrates the price and income elasticities in each step of the Euler optimisation routine, based on a functional relationship between real (PPP-corrected) GDP per capita and income elasticities, and on exogenously given price elasticities that are normally taken from the GTAP database. The same procedure can also be used to calibrate exogenously given income elasticities. In calculating the income elasticities, commodities are divided into groups that determine the order of calculation. Currently, the commodities categorised in the service sector are scaled in order to guarantee that the sum of the income elasticities equals 1. Because in every step in the Euler optimisation procedure the standard CDE consumption function is used, the approach preserves the welfare calculations as present in the GTAP model.

9.4 Module equations

The essence of the module is the calibration of income elasticities and price elasticities, where the price elasticities are set exogenously and the income elasticities are calculated by a formula that explains them from real GDP per capita.

9.4.1 Determination of the income elasticities

The basic idea is that the income elasticity is determined by an externally defined income elasticity function in which the target income elasticity EYt depends on real GDP per capita, RGDPPERCAPB:

```
Formula (all,i,NSER_COMM)(all,r,PCON_REG)
 EYt(i,r) = exp(EYPAR("a" ,i)
        + (EYPAR("b" ,i)
        + 0.5 * EYPAR("d",i)) * LOGE(RGDPPERCAPB(r))
        + EYPAR("c",i) * (LOGE(RGDPPERCAPB(r)))^2)
        + EYPAR("d", i)
        - EYPAR("d", i) * 1500/RGDPPERCAPB(r)
        +EYSHIFTER(i,r);
```

This relationship was derived from an analysis of the income elasticities in the GTAP database and PPP corrected real GDP per capita data from the Groningen Growth and Development Center (GGDC) as well as from theoretical arguments. The estimated parameters EYPAR are saved in the header EYPR in the model parameter file, while the PPP corrected real GDP and population figures used to calculate RGDPPERCAPB are stored in the ConsumptionData.har file in \0_Database\2_OtherData\Consumption. The data are for 2007 and aggregated to the regional aggregation of the GTAP database in 2007. In the file AddAndmodifyData, these data are mapped to the MAGNET aggregation, and placed in the base data file.

The plausibility of the obtained elasticises was verified in by means of simulation experiments and an EYSHIFTER shifter was used to adjust values of the elasticities based on this verification.
The service commodities' elasticities are scaled in order to get a sum of elasticities equal to 1. This choice was made because service commodities are a large part of the economy and because the focus of most of our analyses is on the agricultural sectors:

```
Formula (all,i,SERVICE_COMM)(all,r,PCON_REG)
      EYtsv(i,r) = 0 + if{sum{k,SERVICE_COMM,CONSHR(k,r)} > 0,
        (1-sum{k,NSER_COMM,CONSHR(k,r)* EYt(k,r)})
                /sum{k,SERVICE_COMM,CONSHR(k,r)}};
Formula (all,i,SERVICE_COMM)(all,r,PCON_REG)
      EYt(i,r) = EYtsv(i,r);
```

9.4.2   Calibration of the CDE consumption function parameters

The initial price elasticities are either equal to the price elasticities provided by GTAP or target price elasticities specified by the modeller in the ModelChoices file. The price elasticities used in the model are stored in the model parameters file as EPt.
During the data initialisation procedure, the CDE consumption function parameters INCPAR and SUBPAR are calibrated using the initial price elasticities and stored in the base data file as INCPARPPP and SUBPARPPP with headers INCP and SUBP (the standard CDE function uses the INCP and SUBP in the parameter file). During simulations, the parameters INCPARPPP and SUBPARPPP are continuously updated in an iterative process.

9.4.2.1   Calibrating the SUBPAR parameter

Because the calibration of the SUBPAR parameter does not depend on the INCPAR parameter, this parameter is calibrated first. Price elasticities are calculated in the standard way (which therefore does not need to be documented here), and then one iteration is made to adjust the parameters so that they are consistent with these elasticities. The iteration starts with a calculation of the alphas (=1-SUBPAR) for the service sectors (where alpha is temporarily called ALPHAt1, ALPHAt0 or ALPHAt2, i.e. the temporary alphas):

Formula (all,i,SERVICE_COMM)(all,r,PCON_REG)
  ALPHAt1(i,r) = 0 + if{CONSHR(i,r)>0,(EPt(i,r)/CONSHR(i,r) + EYt(i,r)
            + sum{n,TRAD_COMM:n<> i,CONSHR(n,r)*ALPHAt0(n,r)})
            /(2.0 + CONSHR(i,r) - 1/CONSHR(i,r))};
Formula (all,i,SERVICE_COMM)(all,r,PCON_REG)
  ALPHAt2(i,r) = if(ALPHAt1(i,r)<UBND, ALPHAt1(i,r))
          + if(ALPHAt1(i,r)>=UBND,UBND);
Formula (all,i,SERVICE_COMM)(all,r,PCON_REG)
  ALPHAt0(i,r) = if(ALPHAt2(i,r)>LBND, ALPHAt2(i,r))
          + if(ALPHAt2(i,r)<=LBND,LBND);

This procedure is repeated for the industry and agriculture sectors. The cycle is then repeated, but in a different order. Here, some minimum and maximum values are forced (LBND and UBND) in order to prevent implausible results. The Subpar parameter is updated after this exercise by doing a change update to the newly calculated SUBPARPPP (begin 1-alpha).
Update (change) (all,i,TRAD_COMM) (all,r,PCON_REG)
   SUBPARPPP(i,r) = (1-ALPHAt0(i,r)) - SUBPARPPP(i,r);

9.4.2.2   Calibrating the INCPAR parameter

The INCPAR parameter of the CDE function can then be calibrated. This is done in a number of steps, where the formula for the income elasticity is rewritten in an efficient way, and solved from the income elasticities and alpha instead of incpar and alpha. The resulting formula is:

Formula (all, i, IND_COMM) (all,r,PCON_REG)
  INCPARt2(i,r) = [{EYt(i,r) - ALPHATERM(i,r)}*INCPARTERM(r)
          - sum{n,TRAD_COMM: n<>i,CONSHR(n,r)*INCPARt1(n,r)*ALPHA(n,r)}]
          /[1.0 - ALPHA(i,r)*(1-CONSHR(i,r))];
Where ALPHATERM is a shorthand for:
Formula (all, i, TRAD_COMM) (all,r,PCON_REG)
        ALPHATERM(i,r) = [ALPHA(i,r) - sum{n,TRAD_COMM, CONSHR(n,r) * ALPHA(n,r)}];

The calibration of INCPAR is done for agricultural, industrial and services commodities, and the procedure is repeated a number of times to guarantee convergence. The resulting INCPAR is then used to update INCPARPPP:

Update (change)(all, i, TRAD_COMM) (all,r,PCON_REG)
   INCPARPPP(i,r) = INCPARt1(i,r) - INCPARPPP(i,r);

Because some formulas and equations in the GTAP consumption and regional household module are influenced by the new INCPAR and SUBPAR, these formulas and equations need to be recalculated. Finally, the resulting coefficients are written to the view file, as are the target income and price elasticities, and some of the coefficients derived from them that can be used to aggregate the income and price elasticities over regions (ETPCONS, EPCONS, EYCONS) in the GEMSE_Analist by dividing the sum of these coefficients by total consumption value. These include the calibrated coefficients (the target income elasticity EYT, and the new substitution and expansion parameters of the CDE function, SUBP and INCP respectively) and the resulting new household consumption demands (CONS).

9.5 Data requirements

The module requires parameters on the function that determine income elasticities. These parameters were estimated by first estimating the implicit income elasticities as a function of PPP-corrected real GDP per capita, and then adjusting some parameters to get lower values inspired by the parameters used in the FAO @2030 model. Both the function and the parameters used in the module can be easily replaced by better ones, if they are available.

9.6 User specifications to activate and use the consumption module

9.6.1 DSS settings to activate the module

DSS tab	DSS question	Actions	Comments
Database	-	-	-
Model	Includes for MAGNET	Select consumption\consumption	Adds the model code
Scenario (Gemse)	Model parameters file	Normally, you do not adjust anything here. In the case of fast fixes to test some specific issues, you may change parameters. In that case, adjust headers in ModelSettings.prm as described in the table below. If you change the parameters by hand, it is best to give it a new name in order to prevent DSS overwriting the file when re-running the model tab of DSS.	Assigns an alternative consumption structure to regions and determines the structure of the calibration procedure. Change parameters

9.6.2 Adjustments to headers in ModelSettings.prm file

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode, which allows the addition of modules
COCH	Put a 1 for each region in the type of consumption function you like to use, and a 0 in the other cells	Parameter assigns regions to GTAP- or PPP-corrected CDE equations. Check that each region in your model has a consumption function assigned (each row should sum to 1)
COEP	0	Normally, the function calibration keeps the standard GTAP price elasticities. If you want to determine price elasticities yourself, set COEP to 1 and fill in the header CEP3.
CEP3	If you want to be different, import the price elasticity parameter EPt from the GTAPview file, rename it CEP3 and adjust the price elasticities.	Target price elasticities. This is depending on the aggregation, so delete this header if you have COEP at 0.
SHEY	0	If you want to shift the target income elasticities compared with the standard formula, set SHEY on 1. In that case, you need to include header EYSH in the file, as it shows by how much the income elasticity function must be shifted down.
EYSH	You have to create this aggregation specific header with dimensions TRAD_COMM and REG, and default value zero. If you type in a number, the income elasticity changes by this amount compared with the standard formula. See the formula for EYt(i,r).	Shifter to adjust average income elasticity function.
CCAT	Categorise the commodities in your model as food, industrial or services.	Depending on the type of commodity the income elasticities will vary in size, which affects the calibration of income elasticities (e.g. food commodities are necessity goods with income elasticities below 1, industrial goods and services are generally luxurious goods with income elasticities above 1.
CPEY	0	This aggregation-specific parameter provides a lower bound to the income elasticities calculated by the income elasticity function.

9.7 Module illustration

The figure below illustrates how income elasticities may change over time for a selection of products consumed by households in Egypt in a baseline run from 2007 up to 2020. A first observation is that income elasticities for other food, beverage and tobacco products (which include fast-food products), manufacturing and services are initially relatively high (close to 1) as they are considered luxury items. Those for cattle and meat products and vegetables, fruits and nuts are below 1, and that for processed rice is close to zero, since they are virtually necessity goods. All commodities are assumed to be normal goods in that we expect consumption to go up as incomes rise, but the consumption of luxury goods will increase more than proportionally, while necessity goods increase less than

proportionally. A second observation is that, over time, as incomes rise, we expect that the share of the budget households spend on food will decline, and so the income elasticities for food items are adjusted downwards depending on the development of GDP over time. This is in line with observed dietary patterns.

Example of income elasticities over time in MAGNET for Egypt
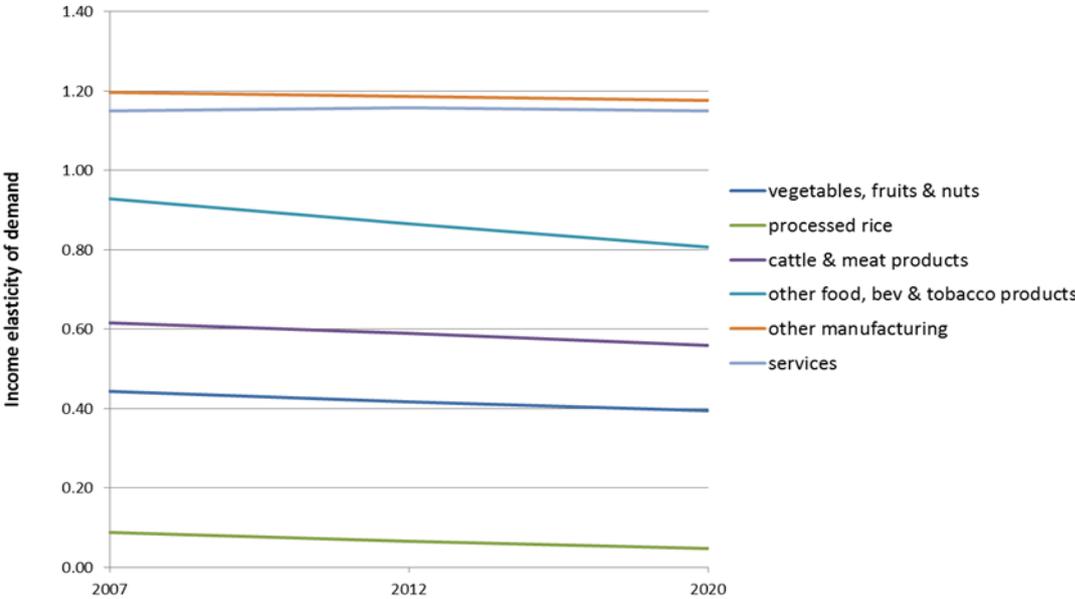
Source: A baseline simulation with MAGNET done in the past

9.8 Validation

The module requires the parameters for the function that determines income elasticities. These parameters were estimated by first estimating the implicit income elasticities as a function of PPP-corrected real GDP per capita, and then adjusting some parameters to get lower values inspired by the parameters used in the FAO @2030 model. All of these parameters and functional forms are very much ad hoc, and should be improved. Nevertheless, compared with the standard GTAP elasticities, and the standard static CDE function, the results of simulations are much more plausible.

10 Mobile endowments & segmented factor markets

Divergence in developments between agricultural and non-agricultural wages and capital returns can play an important role in long-term projections. To this end, a module for segmenting the market for mobile factors in the agricultural and non-agricultural sectors has been developed. There is a static variant that may be used for medium-term policy experiments, and a dynamic variant that shows the difference between long-term and short-term policy effects on farm income and employment.

10.1 Aim

The purpose of the segmented mobile factor market module is to introduce separate agricultural and non-agricultural markets for labour and capital. The introduction of the dynamic version of the segmented mobile factor market improves insights into medium- and long-term dynamics in simulations, and makes it possible to show the effects of time on reforms of agricultural income and employment.

The module complements MAGNET results by including different factor prices and quantities for agricultural and non-agricultural labour and capital.

10.2 Theory

Factor mobility refers to the speed at which factors move between sectors in response to changes in relative returns. Keeney and Hertel (2005) motivated the introduction of segmented factor markets by four observations: the role of off-farm factor mobility in farm incomes, co-movements in farm and non-farm wages, off-farm migration and persistent rural–urban wage differentials (Keeney and Hertel, 2005, pp. 6-7). MAGNET includes a variant with the CET function that Keeney and Hertel used, and a variant in which an econometrically estimated dynamic mobility equation of capital and labour between agricultural and non-agricultural markets is modelled. Capturing these features better represents agricultural factor markets in the model and improves long-term projections by accounting for off-farm labour migration.

10.3 Modelling segmented factor markets in MAGNET

Three types of factor markets for mobile factors are implemented in MAGNET: unsegmented, segmented with mobility between the two sectors governed by a CET function, and segmented with a dynamic migration function. The unsegmented variant follows standard GTAP. The segmented market with CET function variant follows GTAP-AGR, and the dynamic segmented market is a new variant in which factors migrate between sectors in response to changes in relative returns.

The separation of agricultural and non-agricultural markets leads to separate market clearing conditions and different factor prices in the two markets. The segmented factor markets module links to the rest of the model through endowment prices (pf) and the factor market clearing condition. The endowment price is defined as the market price for the factor endowment plus any taxes on factor use. As there are two markets for factors in the segmented market (agriculture and non-agriculture), the endowment price is defined as the agriculture market price plus taxes in the agricultural market, and as the non-agriculture market price plus taxes for the non-agricultural market. The market price

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for each factor (pm) is therefore a weighted average of the agricultural market price (pmagr) and the non-agricultural market price (pmnagr).

The standard GTAP factor market clearing condition is replaced by two market clearing conditions in the segmented factor market module: one for agriculture and one for non-agriculture. The market supply of each factor is therefore equal to the demand for each factor across all industries *within* each market. The total supply of each factor is the sum of the supply of each factor in the agricultural and non-agricultural factor markets. A sector is automatically allocated to the agricultural sector if more than 10% of the domestic sales of its product are in the agricultural sector.

Although there are two distinct markets for mobile factors in the segmented factor markets module, labour and capital can still move between the two markets. Indeed, extra labour or capital needed in the non-agricultural sector must be pulled from the agricultural sector and vice versa. The movement of factors between agricultural and non-agricultural markets is determined by either changes in relative prices and an elasticity of transformation (CET function), or by changes in relative prices and a speed of adjustment parameter (dynamic factor markets).

In the absence of available data on the underlying barriers to factor mobility, Keeney and Hertel (2005) introduced a CET function in GTAP-AGR to 'transform' farm labour into non-farm labour and farm capital into non-farm capital. This option in MAGNET follows the setup in GTAP-AGR as documented in Keeney and Hertel (2005). The transformation of factors between the two markets is governed by the elasticity of transformation. The transformation elasticity is set at -1 for all factors and regions in the first instance.

The dynamic factor market specification offers an alternative way to determine the movement of factors from agriculture to non-agriculture. The module includes an agricultural employment equation,

$$\text{qoagr(i,r)} = \text{DYNAGNAG(i,r)} * \left(\frac{\text{PAENDWM}_{i,r}}{\text{PNAENDWM}_{i,r}} - 1 \right) * 100 * \text{time}$$

in which the percentage change in the quantity of labour or capital (i) used in agriculture (qoagr) in each region (r) is determined by the relative wage of the two sectors, the time period and a speed of adjustment parameter (DYNAGNAG). The initial difference between the agricultural and non-agricultural wage levels is taken as indicative of the reservation wage in agriculture. In the first instance, the wage in each market is set to 1. A value of 0.07 is used for the speed of adjustment between the two markets and is based on econometric estimation. A full description of the estimation of the agricultural employment equation and the econometric estimation can be found in Tabeau and Woltjer (2010).

It should be noted that if wages or returns in agriculture and non-agriculture markets are different in the initial situation, the difference reflects an initial disequilibrium for the model and causes the model to be non-homogeneous. The dynamic mobile factor market option should therefore not be active during a homogeneity test of the model.

10.4   Additional data

No additional data are used in this module beyond the parameter values described above.

10.5   Activating the segmented factor markets module

10.5.1 DSS settings to activate the module

DSS tab	DSS question	Actions	Comments
Model	Includes for MAGNET	Select Mobileendowments	Adds the model code for the factor markets module
Scenario (Gemse)	Model parameters file	Adjust headers in modelsettings.prm as described in table below	Activates the type of factor market operational in each region

10.5.2 Adjustments to headers in ModelSettings.prm file

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode, which allows the addition of modules
RMFM	For all regions with a CET specification, put a 1 in the CET column and a 0 in the GTAP and dynamic columns. For a dynamic specification, put a 1 in the dynamic column and a 0 in all other columns.	The REG_MFM_CH choice parameter assigns regions to GTAP, CET or Dynamic specifications of the factor markets. Check that each region in your model has one type of factor market selected to avoid closure errors (each row should sum to 1)

The REG_MFM_CH parameter allocates the regions into the sets that control which factor markets are implemented in the MAGNET model. An aide memoire to the factor market sets in the model is shown below:

```
|---------------------------------------------------|
|                     REG                           |
|---------------------------------------------------|
|   GMOEND_REG    |            NGMOEND_REG           |
|---------------------------------------------------|
                  |  CETMOEND_REG    |   DYNMOEND_REG   |
                  |-----------------------------------|
```

Key:
REG   all regions
GMOEND_REG   regions with GTAP mobile non-segmented factor markets
NGMOEND_REG   regions with non-GTAP segmented mobile factor markets
CETMOEND_REG   regions with a CET segmented mobile factor market formulation
DYNMOEND_REG   regions with a dynamic segmented mobile factor market formulation

The shocks that can be implemented using this module include the speeding-up or slowing-down of the migration of mobile factors between the agricultural and non-agricultural markets.

10.6 Changes to MAGNET

Phase	Directory	Subfile & Description
ModelDefinition	*2_ModelDefinition\2_ModelStructure\Code*	*\FACTORMARKETS\MobileFactorMarkets.gmp* Parameters for activating and configuring the segmented factor markets module.
	2_ModelDefinition\3_MagnetAgg\Code	*\FACTORMARKETS\SegmentedFactorMarkets.gmp* Set CET elasticities at -1, the speed of adjustment parameter at 0.07 and initialise agricultural and non-agricultural prices at 1.
MAGNET code	*4_MAGNET\CodeMainProgram\MobileEndowments*	*MobileEndowments.gmp* Provides the link to the mobile endowment code. *AgriNonAgriFactorMarkets.gmp* Defines agricultural and non-agricultural prices, quantities and market clearing conditions common to both the CET and dynamic variants. *CETFactorMarkets.gmp* Implementing movement between markets based on a CET function. *DynamicFactMarkets.gmp* Implementing movement between markets based on a dynamic migration function.

10.7 Testing the module

The module has been tested with a reference policy scenario including EU direct payments decoupling, EU milk quota abolition and the EU agricultural offer in the WTO negotiations. The results of the tests can be found in Tabeau and Woltjer (2010).

10.8 References

Keeney, R. & Hertel, T.W. (2005). GTAP-AGR: A Framework for Assessing the Implications of Multilateral Changes in Agricultural Policies. GTAP Technical Papers 1869, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University. https://www.gtap.agecon.purdue.edu/resources/download/2310.pdf

Tabeau, A. and Woltjer, G. (2010). Modelling the agricultural employment development within the CGE framework: the consequences for policy responses. Paper prepared for the Thirteenth Annual Conference on Global Economic Analysis, Bangkok, Thailand, June 9-11, 2010. https://www.gtap.agecon.purdue.edu/resources/download/4729.pdf

11 Production quota

Production quotas are an important part of agricultural policies. For example, they are one of the policy instruments employed in the EU Common Agricultural Policy. The production quota module allows the introduction of this policy instrument in MAGNET.

11.1 Aim

The production quota module allows the imposition of an upper bound on the production of selected sectors in selected regions. This can be used, for example, to model European agricultural policies via the imposition of limits on milk and sugar production.

The main challenge when modelling quotas is ensuring that the quotas are endogenously switched off when they are not binding. This can be achieved through a complementarity condition, where either the quota is binding (i.e. production equals the upper bound imposed by the quota and a positive quota rent exists) or production is below the quota and quota rents are zero.

11.2 How to model production quota in GEMPACK

In contrast to, for example, GAMS, the linearisation used by GEMPACK complicates the implementation of complementarities. Fortunately, a two-pass method for accurately solving models containing complementarity conditions has been devised (see Harrison et al., 2004). In summary, a model with complementarities is solved in two steps. The first determines which quotas are binding, while the second determines the final solution. This two-step procedure increases the time needed to solve a model, and solutions need to be checked carefully. The use of complementarities should therefore be limited.

Step 1: The approximate simulation
A single Euler computation of limited accuracy is used to discover which constraints will finally bind. The basic Euler procedure is modified with: (1) Newton corrections after each Euler step so as to force the solution path back onto the appropriate branch of the complementarity condition, and (2) variable step length to minimise overshooting. The two modifications ensure that the solution path in the first, approximate run, 'hugs' complementarity equations very closely and so enables an accurate prediction of the final state.

Step 2: The accurate simulation
Using the results from step 1 to predict which constraints will finally bind, the complementarity condition is replaced by either the statement that production equals the upper bound (i.e. the ratio of production to the quota level – the quota ratio – equals 1) or the statement that quota rents are zero (i.e. the power of the tax equivalent of the quota rent equals 1).
GEMPACK checks that the post-simulation variable values are consistent with the final complementarity states that were predicted by the approximate simulation and were used to set closure and shocks for the second, accurate simulation. If not, an error message is given. If you use automatic accuracy, the process is repeated automatically using more, smaller steps in the first, approximate simulation.

The complementarity condition in GEMPACK is formulated as follows (using our example of production quota):

```
==========================================================================
COMPLEMENTARITY (Variable = TOR_QUOTA, Lower_Bound = 1)
TOR_QUOTA1 (all,j,PQUOTA_COMM)(all,r,PQUOTA_REG)    1-QO_RATIO(j,r);
==========================================================================
```

So, either TOR_QUOTA (the complementarity variable) equals 1 and 1-Q0_RATIO (the quota expression) exceeds 0 (quota not binding), or TOR_QUOTA exceeds 1 and 1-Q0_RATIO equals 0 (quota binding). Note that the quota-related variables are levels variables and are redefined in ratios. This is to ensure that they have values of the same order of magnitude (around 1) and avoids potential scaling problems.[10]

You need to make sure that the quota variables are linked to the remainder of the model. This means specifying how the quota ratio relates to production and the quota, as well as where the tax equivalent of the quota rent feeds in. We have done this via the output tax, which becomes endogenous in cases in which quotas are modelled, but this can also be accomplished via price linkage equations (see GEMPACK documentation, GPD-3, Chapter 16, 16.8.8). Normally, you also need to specify who receives the revenues (quota rents) arising from the quota tariff. In GTAP, however, it automatically accrues to the regional household, in which case it is the regional household of the region imposing the quota. For concrete, practical examples of how to model complementarities, see GEMPACK documentation, GPD-3, Chapter 16.

11.2.1 Command file statements for complementarity simulations

See 16.6 of GPD-3, Chapter 16. Options include:
- Specify the number of Euler steps in the approximate run (optional if default is not satisfactorily).
- Omit the approximate run if (if you think the shocks will not cause any state changes) to save time. Default is YES. Check results carefully!
- Do not redo a step if state changes occur during approximate run (can slow down accurate run, but is more accurate). Default is YES.
- Step length when redoing step. Default is 0.005.
- *Rreat state or bound errors as warnings only (normally such errors are fatal, unless using automatic accuracy, in which case the subinterval is redone automatically). Default is FATAL.
- Omit the accurate run, for example if your model is large and takes a long time to solve and you are happy with the results of the approximate run. Default is YES. Note restrictions on when this can be applied (notably: if you carry out only the approximate run you must switch off automatic accuracy and Euler must be used as the solution method. Gragg may also be used in the accurate run).

11.3   Modelling production quotas in MAGNET

11.3.1 Defining regions and commodities with a quota

When activating the biofuel module (Quota_activate.gmp), we identify the regions and commodities with a production quota:

```
! Read the quota choice parameter!
Coefficient (parameter) (all,j,TRAD_COMM) (all,r,REG)
  REG_PQOT_CH(j,r) # Quota - activate maximum production by sector & region #;
  read REG_PQOT_CH from file MODPARM1 header "RPQO";
  Formula(initial) (all,j,TRAD_COMM) (all,r,REG)
  REG_PQOT_CH(j,r)= 0+IF[REG_PQOT_CH(j,r)>0,1];
! Recode choice parameter to 0 and 1 for typo safety (is used in equations as
  a dummy)!
```

---

[10] For alternative ways of expressing complementarities see GEMPACK documentation, GPD-3, Chapter 16, 16.3.7.

```
! Determine which regions have at least one production quota !
Set PQUOTA_REG # regions with at least one maximum production quota #
  =(all,r,MREG: sum[j,TRAD_COMM, REG_PQOT_CH(j,r)]>0);
! Quota regions are part of MREG since they require an adjusted equation for
  output taxes, too!


! Determine which sectors have at least one production quota !
Set PQUOTA_COMM # comm. with a maximum production in at least one country #
 = (all,j,TRAD_COMM: sum[r,REG,REG_PQOT_CH(j,r)]>0);
```

The regions with a quota are a subset of MREG and not REG, since the inclusion of a production quota requires a change in the output tax (see below). Note that the set of commodities with a production quota is defined over all regions. If countries impose quotas on different commodities, each country with at least one quota (thus part of PQUOTA_REG) will have equations for all commodities on which a quota is imposed in at least one country. To avoid activating a quota for region–commodity combinations with no quota, we use the choice parameter as a dummy (see below).

11.3.2 Modelling production quota

To begin with, initial levels of the power of the tax equivalent on production quota are read in via parameters defined over all traded commodities and regions. This allows a modeller to switch the production quota module on and off without having to recreate the database.

```
! <%GTREE 1 Parameters %>!
Coefficient(parameter) (all,j,TRAD_COMM)(all,r,REG)
  ITO_QUOTA(j,r) # Initial power of tax equivalent of rent on prod quota #;
    Read ITO_QUOTA from file GTAPDATA header "IPQR";
```

Furthermore, the initial level of the production quota is read.

```
! <%GTREE 3 Coefficients %>!
Coefficient (all,j,TRAD_COMM)(all,r,REG)
  IQO_QUOTA(j,r) # Initial level of production quota #;
    Read IQO_QUOTA from file GTAPDATA header "IPQO";
```

In multi-periods, the initial production quota level for all traded commodities should grow with the percentage change p_iqo_quota. We update the initial quota level so as to have a starting point for implementing production quotas that are in line with the current production level. Since parameters are not allowed in an update statement, we use a linear variable to control how the initial quota is updated.

```
! <%GTREE 3 Variables %>!
Variable (all,j,TRAD_COMM)(all,r,REG)
  p_iqo_quota(j,r) # Change in initial production quota level #;
Update (all,j,TRAD_COMM)(all,r,REG)
    IQO_QUOTA(j,r) = p_iqo_quota(j,r);
```

The formula below initialises the power of a tax equivalent of rent on production quota. In detail, in the presence of a quota, the ratio of the market price including the rent to the supplier price with no rent is greater than 1 if the quota is binding. Otherwise, there is no rent and the ratio becomes equal to 1, and thus TOR_QUOTA has a lower bound of 1.

```
Variable(levels) (all,j,PQUOTA_COMM)(all,r,PQUOTA_REG)
  TOR_QUOTA(j,r) # Power of tax equivalent of rent on production quota #;
    Formula(initial) (all,j,PQUOTA_COMM)(all,r,PQUOTA_REG)
      TOR_QUOTA(j,r) = 1 + REG_PQOT_CH(j,r)* {ITO_QUOTA(j,r)-1};
```

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The initial level of production quota is set equal to VOM. This does not affect the results, because we ensure that quotas are never binding for sectors without a production quota. Note that due to the updating of IQO_QUOTA, this variable has to be defined over TRAD_COMM and REG

Variable(levels) (all,j,TRAD_COMM)(all,r,REG)
  QO_QUOTA(j,r) # Output quota level #;
    Formula(initial) (all,j,TRAD_COMM)(all,r,REG)
    QO_QUOTA(j,r) = (1-REG_PQOT_CH(j,r))* VOM(j,r)
              + REG_PQOT_CH(j,r)* IQO_QUOTA(j,r);

The ratio of the production quota for non-quota commodities in quota regions is set to 0.001, ensuring that production quota is not binding.

Variable(levels) (all,j,PQUOTA_COMM)(all,r,PQUOTA_REG)
  QO_RATIO(j,r) # Ratio of production to quota (maximum 1 if binding) #;
    Formula(initial) (all,j,PQUOTA_COMM)(all,r,PQUOTA_REG)
    QO_RATIO(j,r) = (1-REG_PQOT_CH(j,r))* 0.001
                + REG_PQOT_CH(j,r)* VOM(j,r)/QO_QUOTA(j,r);

Changes in production quota ratio are related to their components, for example changes in production and in the level of quotas. In the absence of a quota, the change in the ratio equals 0, which switches off the complementarity condition for commodities without quota (QO_RATIO is fixe to 0.001 at which it is initialised).

! <%GTREE 4.1 Linking production volume, quota and ratio %>!
Equation QO_RATIO1
  # Change in production quota ratio #
  (all,j,PQUOTA_COMM)(all,r,PQUOTA_REG)
  p_qo_ratio(j,r) = REG_PQOT_CH(j,r)*[qo(j,r) - p_qo_quota(j,r)];

The complementarity condition implies that either the quota is binding and there is a rent (QO_RATIO =1 and TOR_QUOTA >1) or the quota is non-binding (QO_RATIO <1 and TOR_QUOTA =1).

Complementarity (Variable = TOR_QUOTA, Lower_Bound = 1)
    TOR_QUOTA1
    # Complementarity determining quota rent if quota is binding #
    (all,j,PQUOTA_COMM)(all,r,PQUOTA_REG)
    1-QO_RATIO(j,r);

TOR_QUOTA is defined as PM/PS while output tax TO is defined as PS/PM. We therefore need to introduce this additional variable and we need to specify how the two quota tax variables relate in the equation block. To do this we need a negative sign in the following equation. The tax equivalent of the quota rent feeds into the output tax module in the modified GTAP part to link the quota module to the core model. The dummy ensures that for products with no quota, the change in tax is fixed to 0.

Equation TO_QUOTA1
  # Change in output tax equivalent of the production quota rent #
  (all,j,PQUOTA_COMM)(all,r,PQUOTA_REG)
  to_quota(j,r) = - REG_PQOT_CH(j,r)* p_tor_quota(j,r);

Last but not least, the initial quota quantity is updated to the VOM value, since this is the value at which the production level is initialised. This ensures that the quota is always based on the current production level. Note that because of the initialisation in value terms, the quota level may vary between simulations if the market price pm(j,r) changes.

! <%GTREE 4.3 Updating initial quota levels for all regions %>!
Equation IQO_QUOTA1
  # Controlling the update of initial quota levels derived from production #
 (all,j,TRAD_COMM)(all,r,REG)
 p_iqo_quota(j,r) = (1-REG_PQOT_CH(j,r))*qo(j,r)
           + REG_PQOT_CH(j,r)*p_qo_quota(j,r) + pm(j,r);

The schema below illustrates how the production quota module is linked to the core MAGNET model.

MAGNET to(TRAD_COMM, REG)	to_pquota(j,r) only for pquota_comm and pquota_reg; else to(j,r) remains exogenous	Production quota PQUOTA_REG *E* REG PQUOTA_COMM *E* TRAD_COMM
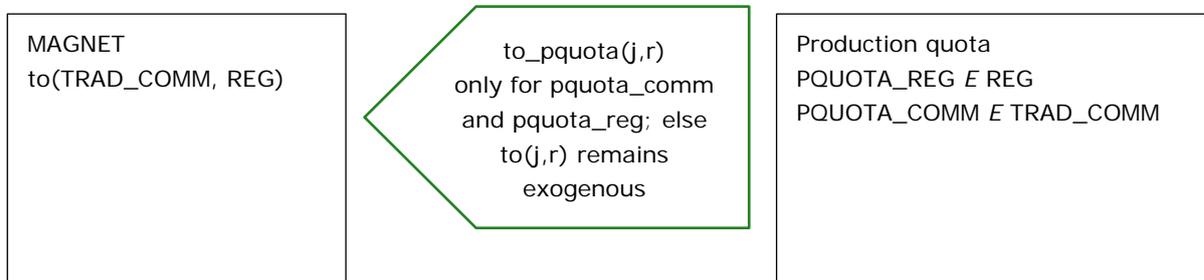
11.4   Additional Data

Currently no addition data are used for the quota module. The quota levels are initialised in MAGNETagg on the value of production (VOM), since this is the value at which the level of production (qo) is initialised. The initial power of the tax equivalent of the rent on quota is set to 1, that is, quotas are initially non-binding.

These data procedures are in line with the approach previously used in LEITAP, except that in LEITAP quota rent data were implemented. If quota levels should be set in quantity terms based on external data, this requires a modification of the quota module to define quota restrictions in actual quantities similar to the way land use is modelled in hectare terms for endogenous land supply.

11.5   Activating the production quota module

11.5.1 DSS settings to activate the module

DSS tab	DSS question	Actions	Comments
Database	-	-	-
Model	Includes for MAGNET	Select production quota	Adds the model code for the production quota module
Prepare Scenario	Closure file	Add ProductionQuotaClosure.cmf to the closure list	Fixes production for commodities with quota
Scenario (Gemse)	Closure file	Add ProductionQuotaClosure.cmf to the closure list	Fixes production for commodities with quota
	Model parameters file	Adjust headers in ModelSettings.prm as described in table below	Assigns quota to commodities in specific regions

Adjustments to headers in ModelSettings.prm file

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode, which allows the addition of modules
RPQO	A matrix of commodities and regions; putting a 1 in a cell imposes a quota on that commodity in that region (see example below)	A 0 in this matrix implies that there is no production quota for that commodity in that region, a 1 implies the imposition of a quota.

The following settings impose a quota on sugar and milk in Europe. There is no quota on these products or on any other commodity in other regions.

REG_PQOT_CH	1 OCEANIA	2 NAM	3 MSAM	4 Europe	5 Africa	6 ASIA	Total
1 pdr	0	0	0	0	0	0	0
2 wht	0	0	0	0	0	0	0
3 grain	0	0	0	0	0	0	0
4 sug	0	0	0	1	0	0	0
5 oils	0	0	0	0	0	0	0
6 hort	0	0	0	0	0	0	0
7 crops	0	0	0	0	0	0	0
8 milk	0	0	0	1	0	0	0
9 oap	0	0	0	0	0	0	0
10 cattle	0	0	0	0	0	0	0
11 frs	0	0	0	0	0	0	0
12 vol	0	0	0	0	0	0	0
13 ofd	0	0	0	0	0	0	0
14 agro	0	0	0	0	0	0	0
15 c_oil	0	0	0	0	0	0	0
16 petro	0	0	0	0	0	0	0
17 othind	0	0	0	0	0	0	0
18 ser	0	0	0	0	0	0	0
19 gas	0	0	0	0	0	0	0
20 coa	0	0	0	0	0	0	0
21 ely	0	0	0	0	0	0	0
22 chem	0	0	0	0	0	0	0
23 dairy	0	0	0	0	0	0	0
24 sugar	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0

- Analysis of results
- The log file (which can be found in the MAGNET\Scenarios directory of the accompanying scenario) reports the results of the approximate and accurate simulation. Specifically, you can find:
- The numbers in pre- and post-sim states 1 and 2 (state 1: quota not binding; state 2: quota binding).
- Whether there are state changes (and if so, when they occur).
- Any error messages will be included there, for example if post-sim states are not the same as those found after the approximate run, or post-sim values of complementarity variables are outside specified bounds (search for '%%' to find error messages).

Search for 'complementarity' throughout the file to see how each of the stages went and whether and, if so, when state changes occurred.

In AnalyseGE you can open the accompanying solution file (ending with .sl4; can be found in MAGNET\Solutions directory of accompanying scenario). Again, search for the word complementarity, right click and select 'show state and variable values' . The resulting table shows:
- Pre- and post-sim states for region and sector combinations with quota; state-pre, state-post.
- Pre- and post-sim values of the complementarity variable (TOR_QUOTA): var-pre, var-post.
- Pre- and post-sim values of the complementarity expression (1-QO_RATIO): exp-pre, exp-post.
- (Pre- and post-sim values of the lower bound of the complementarity variable are also given, lb-pre and lb-post, in our case equal to 1. In theory the lower bound could also be a variable, in which case its value may change).

You can also directly open the solution file (with extension .sl4) in <u>ViewSol</u>. It will contain extra variables that are introduced to model the complementarity condition for the production quota:

- $TORQUOTA1@D: dummy variable in complementarity, used during the approximate run to switch on the equation during the approximate run and switch off the equation during the accurate run (it contains a value of 0 for region and sector combinations with quota).
- cTORQUOTA1@E: change in the complementarity expression (if positive, then quota has become less binding, if negative more binding).

These are of no concern to users (see 16.7 of GPD-3, Chapter 16 and Harrison et al., 2004, section 3.3. for an explanation of how GEMPACK treats complementarities during a simulation and which variables are introduced along the way. These variables are included in the log file.). The only concern for users is that all components of the complementarity variable (TOR_QUOTA) are endogenous. Other relevant results to check:

- p_iqo_quota: change in initial production quota level
- P_QO_QUOTA: change in production quota level
- P_QO_RATIO: change in production quota ratio
- P_TOR_QUOTA: change in power of tax equivalent of production quota rent
- to: change in output tax
- to_quota: change in output tax equivalent of production quota rent
- qo: change in production.

NB: TOR_QUOTA and to_quota (and to) are defined in opposite ways, the former as pm/ps, the latter (and to) as ps/pm, so the reported changes may differ!

11.6   Changes to MAGNET

Phase	Directory\File	Subfile
Model structure	*ModelDefinition\ModelStructure*	
	Modelstructure.gmp	Quota.gmp
		Specification of choice parameter, REGPQOT_CH (see below)
Data	*ModelDefinition\MagnetAgg*	
	Magnetagg.gmp	Quota.gmp
		Initialisation quota at value of output at market prices from GTAP database, with power of tax equivalent of rent set equal to 1.
Model code	*MAGNET\CodeMainProgram*: MAGNET.GMP	
	ModuleDefinition.gmp	QuotaActivate.gmp
		New choice parameter, REGPQOT_CH, defined over traded commodities and regions which:
		activates the quota module (indirectly via sets)
		used to limit domain of quota-related equations to region *and* sector combinations with production quota in place
		New sets based on the choice parameter:
		PQUOTA_REG: regions with at least a production quota in one sector
		PQUOTA_COMM: traded commodities with at least a production quota in one region
	MGTAP.gmp	Outputtax.gmp
		Output tax (to) now has an equation linking it to the (endogenous) output tax derived from the quota module (to_quota):
		to is made endogenous for sectors and regions with quota (elements of PQUOTA_REG and PQUOTA_COMM)
		otherwise, for regions (and sectors) without production quota, to is exogenous as before
		to is defined as ps/pm (and so is to_quota)
	Quota.gmp	Quota_history.gmp
		development of module based on LEITAP2 code used in the OECD project (LEITAP2BPBIOTECHAcon.tab)
		only included production quota with rents captured in a tax on output
		Quota_maxprod.gmp
		Specification of the production quota:
		initial quota tax and level are read in over traded commodities and regions so as to allow switching on and off without having to re-create database
		choice parameter is used as a dummy to further restrict the equations only to those region and sector combinations with quota
		in multi-period runs, initial quota level is updated to current value, since initialisation is based on value of production (with price = 1)
		complementarity statement governs the modelling of quota:
		formulated over variables in levels, with variables defined as ratios so as to avoid scaling problems
		QO_RATIO: ratio of production level to quota level (upper bound: 1)
		TOR_QUOTA: power of tax equivalent of rent (lower bound: 1). Introduced and separately linked to to_quota via a – sign since it is defined as pm/ps
		either the quota is binding and there is a rent (QO_RATIO =1 and TOR_QUOTA >1) or the quota is non-binding (QO_RATIO <1 and TOR_QUOTA =1)
Closure	MAGNET\CommandFiles\ Closures	ProductionQuotaClosure.cmf
		Endogenous: to(PQUOTA_COMM,PQUOTA_REG)
		Exogenous: QO_QUOTA(TRAD_COMM,REG)

11.7   References

Harrison, W. Jill, Mark Horridge, K.R. Pearson and Glyn Wittwer (2004), 'A Practical Method for Explicitly Modeling Quotas and Other Complementarities', *Computational Economics 23*: 325-341.

GPD-3, Chapter 16 *Simulations for Models with Complementarities*, GEMPACK documentation.

12   EU Common Agricultural Policy

The EU Common Agricultural Policy has implications for global markets and forms an important component of many analyses done with MAGNET. To capture the effects of the CAP in more detail, a dedicated module has been developed. The code is included in newcap.gmp.

This dedicated module alone is not sufficient to analyse the EU's CAP. For a more complete CAP analysis, it is necessary to include other modules (e.g. the production quota module, the land allocation and land supply module, the mobile endowments module, the production tree module) as the impact of CAP measures are dependent on production trees, production quotas, land markets and imperfect factor (labour, capital) markets. The land and non-homogenous factor markets are crucial for measuring CAP effects because agricultural-specific factor prices absorb a part of the impact of changing or reducing the CAP budget. To give an example, in the case of reducing CAP payments (budget cuts), factor prices (market prices) would adjust downwards, which in turn would result in more limited effects on production and employment. This is because farmers tend to accept a lower income and adjust their production instead of leaving farming altogether.

Implementing a module like CAP in a model is not a substitute for thinking and empirical research. The current CAP module implements only the main mechanisms that were used in the Modulation and Scenar2020 studies by LEI – with the additional proviso that data on the distribution of funds over different CAP measures and information on CAP measures on productivity were limited. For sound analyses with the CAP module, relevant information on the distribution of CAP funds and information from empirical studies on the effects of the CAP measures on productivity and behaviour of firms should be considered.

12.1   Aim

The purpose of the module is to allow the simulation of changes to the CAP budget. The changes can be in both absolute and relative terms (i.e. absolute level of the subsidies and % change) and they can refer to the overall CAP budget or to the distribution of the overall CAP budget among Pillar I and Pillar II measures.
In detail, the objective of the module is to allow simulating changes in:
– The distribution of Pillar I and Pillar II payments by keeping the overall CAP budget unchanged (e.g. modulation)
– The overall level of the CAP budget both in real and in nominal terms
– The way the CAP budget is distributed over the production factors
– The technology effects of Pillar II measures
– The rate of decoupling.

Please note that production quotas are handled in a separate module and hence are not discussed in this chapter.

12.2   Background

In order to be able to assess the reliability of the model's results effectively, it is necessary to elaborate on the way in which first and second pillar measures are treated. CAP payments, and more generally domestic support payments, are considered factor-based payments and in a CGE model they are normally expressed per production factor and per commodity. Market models are hence more suitable tools for the analyses of the first pillar of the CAP, but less so for the analyses of the effects of the very specific measures within the second pillar with very specific regional effects.

Modelling the reductions of direct payments within the first pillar is worthy of attention as the impacts of decoupling and of reducing decoupled payments are not yet empirically known. Pillar II measures are difficult to analyse mainly because of the range of different measures that have different objectives and can be implemented in many different ways in individual Member States or regions. In addition, any attempt at modelling second pillar measures such as physical and human capital investments, needs to include *dynamic* effects. The current implementation is still based on the Scenar2020 (Nowicki et al., 2009a) and Modulation studies (Nowicki et al., 2009b). For detailed policy analyses, first and second pillar budget data and parameter values should be reviewed and possibly updated.

1. First pillar payments

Modelling decoupled Single Farm Payments (SFP) in market models is challenging, as the impact of decoupling per agricultural commodity is not yet empirically known. The way that direct payments have been dealt with in MAGNET is based on the general logic of intervention for direct payments as explained in Nowicki and colleagues (2009a and 2009b).

According to the provisions of EC Regulation 1782/2003, decoupled payments (namely the SFP) are by definition not linked to a particular agricultural sector and hence should not influence a farmer's decision on what and how much to produce. There is, however, a weak direct production link still in place via restrictions on which land is eligible to receive payments. Land entitled for payments must be kept in 'good agricultural and environmental condition'; that is to say, land cannot be abandoned or its use changed into non-agricultural land. Furthermore, there may be an indirect effect via income: theoretically, a lump sum payment has no influence on production decisions, if farmers operate in a perfect market with no risk and uncertainty. These are rather strong assumptions, however. In the literature, one comes across the following five lines of arguments, which suggest that decoupled direct payments affect production decisions:

- Because decoupled direct payments are a rather fixed and reliable type of income support, farmers may opt for more risky production decisions (hence not cost minimising), with higher levels of input use and output. This would be a reason for a positive production effect of direct decoupled income support (Sckokai, 2005, Roche and McQuinn, 2004).
- Farmers might be liquidity constrained. Because of differences in interest rates for debts and savings, receiving the SFP can stimulate investment (Vercammen, 2003; Sckokai, 2005; Bezlepkina et al., 2005; Hennessy and Thorne, 2005).
- Decoupled direct payments lead to an increase in income and wealth (either directly or via asset prices). The income and wealth effect may reduce the labour time farm households spend in agricultural production (Ooms and Hall, 2005; Ahituv and Kimhi, 2006; Kimhi and Rapaport, 2004).
- Decoupled direct payments may influence the structure of agricultural production by keeping more farms in business than would be the case in the absence of support (a freezing effect), as well as by increasing the number of small and medium-sized farmers who give up farming and sell their land quota (including the rights on direct income support) to larger and more efficient farms. Large farms often generate more production per hectare. Literature suggests that the structural effects of direct income support are ambiguous, can be region specific and are hence an item for further research (see e.g. Brady et al., 2009; Schunk, 2001).
- Decoupled payments can easily leak away to other parts of the economy, for example by being capitalised in agricultural land rent of land owners (Burfisher and Hopkins, 2003). As is usual with agricultural policy measures, the rent element leaks away during the ownership change of farms or farm assets.

Given these considerations, in MAGNET decoupled direct payments are modelled as factor payments. It is assumed that all production factors or only land in all agricultural sectors that are eligible for the SFP, receive the same payment rate. Therefore, payments have no effect on the choice between eligible crops within agriculture and no effect on the choice of which production factor to use in production. However, in this economy-wide model, payments favour agricultural sectors over manufacturing and service sectors, which is in line with the purpose of these measures. Due to the payments, farm income increases and more production factors stay within the agricultural sector and thus, for example, land abandonment decreases. There is no convincing evidence concerning the

degree to which the SFP are linked to production factors other than land, and therefore in the Modulation study all payments were attributed to land.

Box 1 summarises how Pillar I payments are modelled in MAGNET.

Box 1 Treatment–Implementation of Direct Payments (Pillar I) in MAGNET

- Direct payments are implemented as primary factor payments in the various agricultural sectors.
- Coupled direct payments are directly coupled to sectors. No convincing evidence exists about the division of payments among factors. Different distribution mechanisms are possible within MAGNET.
- Decoupled payments are implemented as:
  - Option 1: an equal payment rate to all factors in all eligible sectors. Accordingly, payments do not provide an incentive to switch between eligible sectors and between production factors used within the eligible sectors.

Option 2: an equal payment rate to land in all eligible sectors. Accordingly, this option favours land over other production factors and does not provide an incentive to switch land between eligible sectors (method used in Modulation study – Nowicki et al., 2009b).

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2.   Second pillar payments
Following the elaboration of the economic mechanisms underlying the intervention logic for the rural development measures as developed within the Modulation study (Nowicki, et al, 2009b, Chapter 1, Section 1.3), MAGNET is adjusted so as to allow for the formulation of shocks in regard to Pillar II measures. It should be noted that we do not model each of the 46 rural development measures separately, but group them according to fundamental similarities in underlying economic mechanisms. Below we explain our approach.

2.1   Human capital investments
Investments in human capital, according to the intervention logics for these measures (see Textbox 2), are likely to lead to an overall increase in productivity: higher levels of knowledge may lead to better use of machinery and better treatment of cattle, better fertiliser, pesticide and feed use, more efficient organisation of work, and more efficient use of land (e.g. through better timing, producing higher quality products). MAGNET is extended to include a direct link between human capital investments and technological change. As we have no empirical information from the literature or case studies about the factor bias or effectiveness of human capital expenditure within the rural development programmes, we assume that they have a similar rate of return as other general human capital investments and we also assume a Hicks-neutral rate of technological change. Evenson (2001) provides an overview on human capital investments, suggesting an internal rate of return of 40% for OECD countries. We explain the increase in labour productivity by the education and training expenditures per unit of output. The implementation in MAGNET of this internal rate of return implies that if 1% of total revenues are used for investment in human capital, output productivity increases by 0.40*1%= 0.40% (P2SUMCOEF ("humcapagri") = 0.4,).

The case studies and literature review in the Modulation study (Nowicki et al., 2009b) indicate that in some cases (e.g. in relation to the early retirement scheme), private investments are likely to have also been undertaken in the absence of Pillar II payments for human capital. In economic terms, there is a crowding out or deadweight effect. Precise estimates of the magnitude of this do not exist, and we have therefore taken a crude assumption that 0% of the funds used for investments in human capital fund investments would have been invested anyway (Coefficient CROWDOUT = 0.0). As this assumption is crude, we advise carrying out a sensitivity analyses with a deadweight effect of, for example, 25% or 50%. The deadweight element of the payments for human capital investments are considered an income payment (but without productivity effects).

It is important to note that human capital investments provide growth in productivity each year, so there will be a cumulative impact. Therefore, in MAGNET output productivity will be increased by 100% (i.e. 100% of the payments are assumed to be effective as deadweight is 0%) of 0.4% (i.e. the rate of return on investment in education) of investment per unit of output. In the case of 25%

deadweight loss, 75% of the payments are effective and the other part of the payments have no consequences for behaviour, but increase farm income.

2.2   Physical capital investments

Physical capital investments, according to the intervention logics for these measures, are likely to lead to an overall increase in productivity (Nowicki et al., 2009b). For example, new machines may automate feeding, improve the precision of fertiliser distribution (reducing use and increasing productivity) and save on labour use, but increase the cost of capital. We assume that physical capital investments each year provide a growth in productivity, so we are again interested in the cumulative impact.

Extra private investments may renew the capital stock, and therefore increase productivity because of capital embodied technological change.

As we do not have sufficient information from case studies or literature about the factor bias in technological progress, we assume a general productivity increase (Hicks neutral technological change) in the same manner used to model human capital investments. As we have no solid empirical evidence of the deadweight loss, we again assume a 0% deadweight effect in relation to investments in physical capital that would also have been undertaken without funding. A sensitivity analysis with a 25% or 50% deadweight effect can be carried out around this assumption.

Direct and indirect estimates of the vintage effects of investment in physical capital on productivity reviewed[11] in Nowicki and colleagues (2009b), suggest that the rate of return on investment in capital is 0.3, implying that investment of one dollar per unit of physical capital stock increases output productivity by 0.3%, an estimate we also use in MAGNET (P2SUMCOEF("InvAgri")=0.3). This means that in MAGNET, output productivity increases by 100% (because 100% of the payments are assumed to be effective – 0% deadweight loss) of 0.30% (because of the rate of return on investment) of investment per unit of physical capital stock. In the case of 25% deadweight loss, only 75% of the payments are effective and the other part of the payments have no consequences for behaviour, but increase farm income.

2.3   LFA land use support

LFA payments provide compensation for production under less efficient circumstances, with the aim of keeping land in marginal areas under production. Pufahl and Weiss (2009) analysed the effects of LFA payments schemes in Germany by comparing similar farms with and without LFA payments. They found that LFA payments keep land in production and have a small positive production effect.
In MAGNET, Pillar II payments to land are used as a proxy for LFA payments because in the current initial database there are no LFA payments. LFA data can be introduced in the initial dataset or they can be created with a modulation scenario, namely by transferring payments from Pillar I to Pillar II.

In the Modulation study (Nowicki et al., 2009b), data on current distribution across sectors from FADN was used to distribute LFA payments across sectors (e.g. pork and poultry and horticulture receive no agri-environment payments, relatively more payments are distributed to grassland than cropland). This mechanism is available in MAGNET (Coefficient CAPSUBLFADIS), but the distribution values should be updated.

2.4   Natura 2000 payments on agricultural land

In MAGNET, a land payment is used as a proxy for Natura 2000 payments as in the case of LFA payments. Like with LFA payments, Natura 2000 payments are not included in the current initial database. Data can be introduced in the initial dataset or they can be created with a modulation scenario. These payments are treated together with LFA payments in one category within the current MAGNET code as both can be implemented as land payments (called lfa in the set CAPBUD_TYPE). Therefore, in order to include them explicitly, the set CAPBUD_TYPE must be extended.

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[11] See e.g. Wolff, 1996; De Long and Summers, 1991; Gittleman et al., 2006

2.5   Agri-environment payments

The agri-environment measures (called agroenv in the set CAPBUD_TYPE) are intended to encourage farmers and other land managers to introduce or maintain production methods whose compatibility with the protection of the environment, the landscape and its features, natural resources, the soil and genetic diversity goes beyond mandatory standards. In terms of public funding, they accounted for the largest proportion of expenditures within Pillar II (see Nowicki et al., 2009b). They provide compensation for income foregone as a consequence of lower land productivity and extra labour and other costs. Pufahl and Weiss (2009) show that agri-environment payments can generate an increase in land use and, in particular, in marginal land that might otherwise have gone out of production. Furthermore, the share of grassland increases. The use of the agri-environment measures has resulted in the implementation of a rather diverse set of schemes and management options in individual Member States.

In MAGNET, a payment to land is used as a proxy for agri-environment payments. In contrast with the LFA payments, agri-environment measures will reduce labour and capital productivity. In order to capture the productivity effect, we assume in MAGNET that labour and capital productivity decreases by 5% of the CAP budget as fraction of the income of labour and capital.

An additional effect of these agri-environment payments should be improvements in biodiversity, landscape and environmental pollution. Because of a lack of information, this cannot be implemented directly in the model, but has to be assessed using other analytical tools, such as CAPRI and DynaCLUE (see Nowicki et al., 2009b).

In the current initial database, there are no agri-environmental payments. Agri-environmental data can be introduced in the initial dataset or, using MAGNET, they can be created with a modulation scenario.

In the Modulation study (Nowicki et al., 2009b), information from FADN was used so as to distribute payments across sectors (e.g. pork and poultry and horticulture receive no agri-environment payments, relatively more payments are distributed to grassland than to cropland). This mechanism is available in MAGNET (Coefficient CAPSUBLFADIS), but the distribution values should be updated.

2.6   Regional payments

Regional payments are a group of diverse measures mainly directed to non-agricultural sectors (called techall in the set CAPBUD-TYPE). According to the intervention logic in Nowicki and colleagues (2009b), the main objective of these measures is to reverse the trend towards the economic and social decline and depopulation of the countryside by promoting innovation and creating employment opportunities in rural areas, thereby increasing productivity in the wider rural economy.

In MAGNET, this diverse range of measures is treated as a Hicks neutral productivity increase. As in the case of human and physical capital payments in agriculture, we assume a 0% deadweight effect for investments and that impacts are dynamic in the sense that investments each year provide an increase in productivity (cumulative impact). We use the same proxy for the effects of regional payments on output productivity as we do for the physical capital investment: investment of 1 dollar per unit of output increases output productivity of all sectors by 0.3% (P2SUMCOEF("techall")) =0.3.

Box 2 summarises how Pillar II payments are implemented in MAGNET.

Box 2: Treatment of Rural Development measures*

01 – Human Capital Investment [111-115, 131-133]:

- Payments influencing the total factor productivity in agriculture.
- Rate of return on investment is 40% (Nowicki et al., 2009b, based on Evenson, 2001).
- Deadweight loss is assumed to be 0% (we recommend sensitivity analysis with, for example, 25%, 50%, etc.).

02 – Physical Capital Investment [121-126]:

- Payments which influence the total factor productivity due to capital investments in all agricultural sectors.
- Rate of return on investment is 30% (Nowicki et al., 2009b).
- Deadweight loss is assumed to be 0% (we recommend sensitivity analysis with, for example, 25%, 50% etc.).

03 – LFA Land Use Support [211, 212]:

- Income payments linked to land in agricultural sector. FADN data could be used to update how payments are distributed across agricultural sectors.

04 – Natura 2000 [213]:

- Income support linked to land in agricultural sector. FADN data could be used to update how payments are distributed across agricultural sectors.

05 – Agri-Environment measures [214-216]:

- On the one hand, income support linked to land in the agricultural sector and on the other hand a yield and labour productivity loss. FADN data could be used to update how payments are distributed across agricultural sectors.

Regional payments, namely 06 – Forestry [221-227], 07 – Diversification [311-313], 08 – General rural development [321-323, 331, 341], 09 – LEADER [411-413, 421, 431], 10 – Technical assistance [511, 611]:

- Investment support for non-agricultural activities that increase productivity.
- Rate of return on investment is 30%.
- Deadweight loss is assumed to be zero (we recommend sensitivity analysis with, for example, 25%, 50%, etc.).

The RD measure numbers are given between square brackets [#].

12.3   General limitations to the modelling methodology

Box 3 summarises the general limitations of modelling CAP measures in CGE models such as MAGNET.

Box 3: Overview of and limitations to the modelling methodology (based on Nowicki et al., 2009b)

1. Empirical information about the impact of modulation and especially the impact of second pillar measures is very scarce. Therefore, ex-post information hardly exists.
2. Public goods are not included in the modelling, although they are an important part of the second pillar.
3. Environmental impacts are difficult to generalise as the impacts vary locally.
4. Pillar II measures are complex and have different impacts depending on how they are implemented. Therefore, only a stylised approach for each measure can be implemented, and the approach taken includes grouping the measures (see Box 2).
5. Lack of empirical information about deadweight losses.
6. Transaction costs have not been addressed.

In addition to these general limitations, there are also limitations related to the fact that this module is based on the Modulation\Scenar (Nowicki et al., 2009a and 2009b) studies, both of which used the

GTAP version 6 database. Currently, the second pillar budgets are set to zero in 2007. A decent CAP analysis with GTAP version 8 data requires:
- Updating CAP budgets (first pillar, second pillar budgets per measure).
- Specifying the level of coupled versus decoupled payments.
- Specifying the decoupling impact of SFP measures: new empirical evidence; how decoupled are decoupled payments?
- Updating parameter values related to Pillar II measures (e.g. rate of investment and\or productivity impacts of second pillar measures).
- Specifying the distribution of payments (LFA, Nature 2000, Agri-Environmental) across sectors (can be done based on FADN and or CLUE data, see Modulation study, Appendix 1).
- Specifying the level of crowding-out effect (part of investments that are also done without subsidies).
- Specifying co-financing rates, which are not considered in the current version of MAGNET.

12.4   Approach

Domestic support is captured in the GTAP database by a wedge between the prices paid for endowments by farmers (VFA) and the market prices of those endowments (VFM). In the standard GTAP model, this wedge is handled as an ad-valorem tax,[12] that is, the tax is a fixed percentage of the value of the endowments at market prices. The percentage change in the tax, tf(i,j,r) (with i: production factors, j: sectors, r: regions), is used to adjust this tax rate.

CAP policies inevitably fall within domestic support and hence are captured inside the tax tf. However, modelling the CAP with an ad-valorem tax implies that the amount of subsidies changes in an analogous manner to price changes. For example, if the price of land increases, the total amount spent on land subsidies should also increase, and the latter conflicts with the definition of the CAP budget, which does not vary according to the prices of the endowments. This module adjusts the endowment subsidies so that the CAP budget remains fixed, in either real or nominal terms.

Limitations in modelling CAP policies arise from the highly aggregated representation of agricultural commodities into 12 primary sectors in the GTAP database and from the fact that the model includes a single regional household, which in turn hampers the modelling of direct income payments to farmers.

12.5   Modelling CAP in MAGNET

12.5.1 Definition of CAP budget

There are two possibilities for defining the overall CAP budget:

The 'GTAP database' method
The treatment of domestic support has been revised in past pre-releases of the GTAP 8 database with feedback from Hans Jensen, Martina Brockmeier and Urban Kirsten. The coefficient FBEP (header FBEP[13], in file ..\0_Database\1_GTAP\GTAP8_f1_2007\BaseData.har) includes the factor-based subsidies for agricultural production. For OECD countries, these are based on the OECD's PSE database. Jensen (2010) reports how the domestic support information for EU countries is adjusted in order to be entered into the GTAP database. Furthermore, the GTAP 8 database provides a detailed breakdown between non-decoupled, partly decoupled and fully decoupled payments for all OECD

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[12]   A subsidy in the GTAP database is considered a negative tax.
[13]   In the GTAP database, in general taxes have a positive sign and subsidies a negative one. However, this is not the case for FBEP. The sign is positive despite the fact that the payments concerned are subsidies. This should be taken into account when using these data.

countries in the default parameter file: \0_Database\1_GTAP\GTAP8_f1_2007\ Default.prm. The respective coefficient is 'PAYRATE' under the header 'PYRT'.

For EU Member States, it is assumed that the sum of the factor-based subsidies is the overall CAP budget.

The 'LEITAP' method
Factor-based subsidies in agriculture are calculated as the difference between value added at market prices and agent prices, taking into account that GTAP assumes an economy-wide tax rate for production factors. The subsidy rate within the GTAP database is equal to the factor tax rate within a sector and the economy-wide tax rate in this sector. For example, if the tax rate for labour in the GTAP database is 10% for wheat and the economy-wide tax rate for labour is 50%, then the subsidy rate for labour is 40% within wheat; that is, it is assumed that a general (non-factor specific) tax (REFTARIFF) is present in the economy. The sum of factor-based subsidies that are added to this general tax are ascribed to the CAP budget.

In detail, the factor-based subsidies ascribed to the CAP budget are defined as the difference between the value added at market prices assuming that a reference tax (REFTARIFF) would be applied, and the value added at agent prices (i.e. value added after all taxes and subsidies are considered; for the farmers this price corresponds to the notion of the producer effective price).

The code can be found under: ...\2_ModelDefinition\3_MagnetAgg\Code\Magnetagg.gmp:

```
Coefficient (all,e,ENDW_COMM)(all,i,PROD_SECT)(all,r,REG)
FBEP(e,i,r) # Factor-Based Subsidies from GTAP database#;
Read FBEP from file GTAPDATA header "FBEP";


Coefficient FBEPfactsubs
 # Create factor based subsidies FBEP with old LEI method instead of usin #;
Formula FBEPFactsubs = 0;
Read (ifheaderexists) FBEPfactsubs from file MCHOICE header "FBEP";
Formula (all,e,ENDW_COMM)(all,i,PROD_SECT)(all,r,REG:FBEPFactsubs=1)
FBEP(e,i,r)= VFM(e,i,r)*REFTARIFF(e,r)-VFA(e,i,r);
```

The way to activate the 'LEITAP' method (e.g. choosing that for specific regions the FBEPFactsubs=1) is described in Section 12.10.

The reference tax or 'normal' tax for production factors is equal across all sectors within the economy and it is taken from the 'services' sector within the calculations. The reference tax rate could have been taken from any other sector, but it is important to take it from a sector where no factor subsidies or taxes other than the economy tax rate are involved (the tax rate which can be found under header rTF in the baserate.har file). It is worth mentioning that the production factor tax on services is the same within each country across sectors but is different across countries.

```
Formula (all,i, ENDW_COMM)(all,r, REG)
 REFTARIFF(i,r) = sum{j,PROD_SECT,ASCAS_CHOICE(j,"ser")*VFA(i,j,r)}
/sum{j,PROD_SECT,ASCAS_CHOICE(j,"ser")*VFM(i,j,r)};
```

The selection between the two methods is coded in the file *2_ModelDefinition\3_MagnetAgg\Code\ CAPPolicy.gmp* and is enabled by putting the header FBEP of the model choices file \2_ModelDefinition \2_ModelStructure\ExtraData\StandardChoiceINI.HAR

The following types within the CAP budget are distinguished:
- Pillar I subsidies
- Pillar II measures
  - Human capital investments
  - Physical capital investments
  - Least Favoured Areas and Natura 2000 payments
  - Agro-environmental payments
  - Regional payments

The Pillar II budget is defined as the sum of factor-based subsidies for investment in agriculture, investment in human capacity, Least Favoured Areas and Natura 2000 payments, agro-environmental measures and regional payments (see section 12.2).

Section 12.2 showed that human capital investments, physical capital investments and regional payments mainly have a productivity impact, and LFA payments and agro-environmental payments mainly have a land subsidy impact. In addition to the subsidy impact, agro-environmental payments also have a (negative) productivity effect.

The Pillar I budget is defined as the difference between all factor-based subsidies and the Pillar II budget.

```
Coefficient (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,REG)
CAPSUBSFPIL(e,i,r) # EU first pillar CAP subsidies#;
Formula (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,REG)
CAPSUBSFPIL(e,i,r)=0;
Formula (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,REG)
CAPSUBSFPIL(e,i,r)=FBEP(e,i,r);
Formula (all,e,ENDWL_COMM)(all,i,AGRI_SECT)(all,r,REG)
CAPSUBSFPIL(e,i,r)=CAPSUBSFPIL(e,i,r)-sum{c,CAPLFA_type,CAPSUBSLFA(c,i,r)};
Set CAPSUBS_TYPE (firstpil, invagri,humcapagri, techall, lfa, agroenv);
Subset CAPLFA_type is subset of CAPSUBS_TYPE;
Coefficient (all,i,CAPSUBS_TYPE) (all,r,REG)
CAPBUDT(i,r);
Formula (all,i,CAPSUBS_TYPE) (all,r,REG)
CAPBUDT(i,r)=0;
Formula (all,r,REG)
CAPBUDT("firstpil",r)= sum{e,ENDW_COMM,sum{i,AGRI_SECT,CAPSUBSFPIL(e,i,r)}};
Formula (all,c,CAPLFA_type) (all,r,REG)
CAPBUDT(c,r)=sum{i,AGRI_SECT,CAPSUBSLFA(c,i,r)};
```

The definition of the CAP budget and the above mentioned equations are coded in the file *2_ModelDefinition\3_MagnetAgg\Code\CAPPolicy.gmp*

12.6 Distribution of CAP subsidies per measure within a region

In the first step, a distribution parameter is defined that determines how payments that are identified as part of the set CAPBUD_TYPE should be allocated per region and per sector. The default setting assumes that the marginal distribution per region and per sector is equal. The marginal distribution of the CAP budget over regions is determined in the routine \2_ModelDefinition\ 2_ModelStructure\Code\ModelStructure.gmp, and is set to 0.1 (determined exogenously and in an ad hoc manner). If better information is available this can be read-in explicitly. The distribution of the LFA and agro-environmental payments per agricultural sector and per region is defined as the sum of

factor payments per sector and per region over sum of factor payments for all agricultural sectors and all factors per region (in \2_ModelDefinition\2_ModelStructure\Code\ ModelStructure.gmp).

```
Coefficient (all,i,CAPBUD_TYPE) (all,r,REG)
CAPBUDDIST(i,r) #Marginal distribution of CAP budgets over budgets#;
Formula (all,i,CAPBUD_TYPE) (all,r,REG)
CAPBUDDIST(i,r)=0.1;
set CAPLFA_type (lfa, agroenv);
Subset CAPLFA_type is subset of CAPBUD_TYPE;
Coefficient (all,c,CAPLFA_type) (all,i,AGRI_SECT)(all,r,REG)
CAPSUBLFADIS(c,i,r) # Distribution of LFA and Agrenv money over sectors#;

Formula (all,c,CAPLFA_type)(all,i,AGRI_SECT)(all,r,REG)
CAPSUBLFADIS(c,i,r)=sum{e,ENDW_COMM,EVFA(e,i,r)} /sum{e,ENDW_COMM,sum{j,AGRI_SECT,EVFA(e,j,r
)}};
```

The coefficient EVFA (i,j,r) refers to producer expenditures on endowment i by production sector j in region r at agent prices. CAPSUBLFADIS is a coefficient distributing LFA-like (i.e. LFA and Natura 2000) and Agri environmental payments across sectors. The current values assign each sector the same percentage of value added at agent prices.

In a next step, absolute changes are defined of the Pillar I and Pillar II CAP subsidies. Variables of absolute changes are denoted as **d_xxx**. In the case that additional measures need to be captured, or scenarios involve creating new measures within the CAP where the initial level of payments is €0, these can be modelled only if absolute changes are determined, because a percentage change of zero always remains zero.

```
variable (change) (all,e,ENDW_COMM)(all,i,AGRI_SECT) (all,r,CAP_REG)
d_CAPSUBSFPIL(e,i,r) #change of first pillar CAP subsidies $$ #;
Coefficient (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,REG)
CAPSUBSFPIL(e,i,r) # EU first pillar CAP subsidies #;
!CAPSUBS has to be updated with a change, because the initial CAPSUBS can be zero, but one would like to
increase it!
Update (change) (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
CAPSUBSFPIL(e,i,r)=d_CAPSUBSFPIL(e,i,r);

!Second pillar CAP subsidies are read and update; by definition only lfa and agroenv
budgets have subsidies to endowments!
variable (all,c,CAPLFA_type) (all,i,AGRI_SECT)(all,r,CAP_REG)
d_CAPSUBSLFA(c,i,r) #change of second pillar LFA and agro-environmental CAP subsidies $$ #;
Coefficient (all,c,CAPLFA_type) (all,i,AGRI_SECT)(all,r,REG)
CAPSUBSLFA(c,i,r) # EU CAP subsidies on land for second pillar lfa and agro-environment#;
Read CAPSUBSLFA from file GTAPDATA header "LFA";
Update (change) (all,c,CAPLFA_type) (all,i,AGRI_SECT) (all,r,CAP_REG)
CAPSUBSLFA(c,i,r)=d_CAPSUBSLFA(c,i,r);
```

A slack variable pCAPBUDTSLCK is defined to fix the total CAP budget within a region. This swap variable becomes endogenous in the case that the total CAP budget is fixed. Furthermore, exogenous changes of CAP payments per measure are introduced. The changes can be either absolute (d_CAPBUDTExo) or percentage change (p_CAPBUDTExo), while the resulting shocks should be controlled for inflation (this is because GTAP values depend on the numeraire, and you do not want to have different results if the numeraire is changed).

A second variable, p_Modulation, allows changes to the distribution of the CAP budget from the first pillar to the second pillar within the same region. It represents the percentage reduction in first pillar payments which become available for all second pillar measures.

```
Variable (change) (all,i,CAPBUD_TYPE) (all,r,CAP_REG)
d_CAPBUDT(i,r) #change of CAP budget $$ #;
Variable (change) (all,i,CAPBUD_TYPE) (all,r,CAP_REG)
d_CAPBUDTExo(i,r) #exogenous absolute change of CAP budget $$ #;
Variable (all,i,CAPBUD_TYPE) (all,r,CAP_REG)
p_CAPBUDTExo(i,r) #exogenous percentage change of CAP budget $$ #;
Coefficient (all,i,CAPBUD_TYPE) (all,r,REG)
CAPBUDT(i,r);
Read CAPBUDT from file GTAPDATA header "CAPB";
Update (change) (all,i,CAPBUD_TYPE) (all,r,CAP_REG)
CAPBUDT(i,r)=d_CAPBUDT(i,r);
variable (all,r,CAP_REG)
pCAPBUDTSLCK(r) # Slack to make sum of budgets per region equal to total budget $$ #;
Variable (all,r,CAP_REG)
p_Modulation(r) #Percentage reduction in first pillar for modulation #;
! including pgdpwrld in the equations allows to adjust for inflation!
Equation d_CAPBUDT1_FPIL (all,i,CAPFPIL_TYPE) (all,r,CAP_REG)
d_CAPBUDT(i,r)=(CAPBUDT(i,r)/100)*(pgdpwrld+p_CAPBUDTEXO(i,r)
+p_Modulation(r)+pCAPBUDTSLCK(r))+d_CAPBUDTEXO(i,r);
Equation d_CAPBUDT1_SPIL (all,i,CAPSPIL_TYPE) (all,r,CAP_REG)
d_CAPBUDT(i,r)=(CAPBUDT(i,r)/100)*(pgdpwrld+p_CAPBUDTEXO(i,r)+pCAPBUDTSLCK(r))
        +if(sum{k,CAPSPIL_TYPE,CAPBUDT(k,r)}=0,pCAPBUDTSLCK(r))
       +d_CAPBUDTEXO(i,r) - (CAPBUDDIST(i,r)/sum{j,CAPSPIL_TYPE,CAPBUDDIST(j,r)})
         *(sum{k,CAPFPIL_TYPE,CAPBUDT(k,r)}/100)*p_Modulation(r);
```

12.6.1 Changing the overall CAP budget

The above mentioned changes were per pillar within a region. An analogous mechanism has been developed for simulating changes that concern the total CAP budget within a region.
The CAP budget in a region r is given as the sum of the CAP budget per type (measure).

```
Coefficient (all,r,CAP_REG) CAPBUD(r) # Total CAP budget #;
Formula (all,r,CAP_REG) CAPBUD(r)= sum{c,CAPBUD_TYPE,CAPBUDT(c,r)};
```

An exogenous shock, namely an increase or a decrease of the CAP budget, can be represented both in percentage and in absolute terms.

```
variable (change) (all,r,CAP_REG)
d_CAPBUD(r) #change of total CAP budget $$ #;
variable (change) (all,r,CAP_REG)
d_CAPBUDEXO(r) #exogenous change of total CAP budget $$ #;
variable (all,r,CAP_REG)
p_CAPBUDEXO(r) #exogenous percentage change of total CAP budget#;
variable (change) (all,r,CAP_REG)
dCAPBUDSLCK(r) # Slack to switch off the exogenous adjustment of total CAP budget $$ #;
```

The slack variable controls the distribution of the exogenous change of the total CAP budget over the pillars. In detail, two options are allowed:
1. If dCAPBUDSLCK is exogenous, the CAP budget per pillar (and further per type) changes with the same percentage as the overall CAP budget.
2. If dCAPBUDSLCK is swapped with pCAPBUDTSLCK (e.g. if pCAPBUDTSLCK is made exogenous and dCAPBUDSLCK endogenous), the total CAPBUDGET is determined as the sum of the changes in the CAP budgets per pillar.

Equation d_CAPBUD1 (all,r,CAP_REG)
d_CAPBUD(r)=(CAPBUD(r)/100)*(pgdpwrld+p_CAPBUDEXO(r))+ d_CAPBUDEXO(r)+dCAPBUDSLCK(r);

Equation dCAPBUDSLCK1 #Total CAP budget as sum of its elements# (all,r,CAP_REG)
d_CAPBUD(r)=sum{i,CAPBUD_TYPE,d_CAPBUDT(i,r)};

12.7 Consistency among shocks for specific budgets per region and EU-wide budget changes

Shifters are used to determine whether the sum of absolute changes of the pillar-specific CAP budget per endowment equals the changes in the overall CAP budget.

In detail, the shifter capsubsshift links Pillar I-specific payments per endowment and per agricultural sector with the region-wide Pillar I CAP budget for the entire agricultural sector.

variable (all,r,CAP_REG)
capsubsshift(r) #Shifter to make d_CAPSUBSFPIL consistent with d_CAPBUDT#;
Equation capsubsshift1 (all,r,CAP_REG)
sum{e,ENDW_COMM, sum{i,AGRI_SECT,d_CAPSUBSFPIL(e,i,r)}}=d_CAPBUDT("firstpil",r)
   +if((sum{e,ENDW_COMM,sum{i,AGRI_SECT,CAPSUBSFPIL(e,i,r)}}=0) or
   (sum{e,ENDW_COMM,sum{i,AGRI_SECT,VFA(e,i,r)}}=0),capsubsshift(r));

Whereas:

Equation d_CAPSUBSFPIL1 (all,e,ENDW_COMM)(all,i,AGRI_SECT) (all,r,CAP_REG)
d_CAPSUBSFPIL(e,i,r)=0*time+d_CAPSUBSDeco(e,i,r)
+if(VFA(e,i,r)>0,(CAPSUBSFPIL(e,i,r)/100)*capsubsshift(r));
(the variable d_CAPSUBSDeco(e,i,r) is discussed in section 12.5.2)

Equation capsubsshift1 forces the accounting identity that the sum of all budget changes equals the total budget, while equation d_CAPSUBSFPIL1 adjusts the variable capsubsshift to realise this accounting identity. In equation d_CAPSUBSFPIL1, a choice has been made to adjust each subsidy category with the same percentage.

In an analogous way, the shifter capLFAshift(c,r) links the changes of the LFA and agro-environmental budget per endowment and per agricultural sector to the regional CAP budget for those payments for the entire agricultural sector by taking into account the way these payments are distributed over the endowments.

variable (all,c,CAPLFA_type) (all,r,CAP_REG)
capLFAshift(c,r) #Shifter to make d_CAPSUBSLFA consistent with d_CAPBUDGET#;
Equation d_CAPSUBSLFA1 (all,c,CAPLFA_type) (all,i,AGRI_SECT) (all,r,CAP_REG)
d_CAPSUBSLFA(c,i,r)=0*time+if(sum{e,ENDWL_COMM,VFA(e,i,r)}>0,(CAPSUBSLFA(c,i,r)/100)*capLFAshift(c,r))
   +(CAPSUBLFADIS(c,i,r)/sum{j,AGRI_SECT:sum{e,ENDWL_COMM,VFA(e,j,r)}>0,
CAPSUBLFADIS(c,j,r)})* d_CAPBUDT(c,r)
   +if(sum{k,AGRI_SECT,CAPSUBSLFA(c,k,r)}=0,sum{e,ENDWL_COMM,VFA(e,i,r)}*capLFAshift(c,r));
Equation capLFAshift1 (all,c,CAPLFA_type) (all,r,CAP_REG)
sum{i,AGRI_SECT,d_CAPSUBSLFA(c,i,r)}= d_CAPBUDT(c,r);

12.7.1 Linking the CAP budget changes with tax rates

Given that the CAP budget is fixed when it is set as an ad valorem tax on the market price, a mechanism has to be in place that calculates the taxes needed to generate the changes in the CAP budget as defined above.

For land endowments, this tax is defined as the sum of first pillar and land-related second pillar taxes (e.g. LFAs and agro-environmental), while for non-land endowments there are only Pillar I taxes. LFA and agro-environmental payments by definition involve taxes (subsidies) on land only.

To enable this mechanism, the standard closure needs to be adjusted. The production factor tax tf has to be removed from MAGNET.sti, and should be added as an exogenous variable in the standard closure.

```
Variable (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
tf_FPIL(e,i,r) # First pillar tax rate variable #;
Variable (all,e,CAPLFA_type) (all,i,AGRI_SECT) (all,r,CAP_REG)
tf_lfa(e,i,r) #less favored area and agro-env second pillar taxes#;
Equation tf1_ENDWL (all,e,ENDWL_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
tf(e,i,r)=tf_FPIL(e,i,r) + sum{c,CAPLFA_type,tf_lfa(c,i,r)};
Equation tf1_ENDWNL (all,e,ENDWNL_COMM)(all,i,AGRI_SECT) (all,r,CAP_REG)
tf(e,i,r)=tf_FPIL(e,i,r);

Equation tf_FPIL1 (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
-(if(VFA(e,i,r)>0,VFA(e,i,r))+if(VFA(e,i,r)<=0,1))*tf_FPIL(e,i,r)
= 0*time+if(VFA(e,i,r)>0,100*d_CAPSUBSFPIL(e,i,r)-CAPSUBSFPIL(e,i,r)*(qf(e,i,r)+(pf(e,i,r)-tf(e,i,r))));

Equation tf_lfa1 (all,c,CAPLFA_type) (all,e,ENDWL_COMM) (all,i,AGRI_SECT) (all,r,CAP_REG)
-(if(VFA(e,i,r)>0,VFA(e,i,r))+if(VFA(e,i,r)<=0,1))*tf_LFA(c,i,r)
= 0*time+if(VFA(e,i,r)>0,100*d_CAPSUBSLFA(c,i,r)-CAPSUBSLFA(c,i,r)*(qf(e,i,r)+(pf(e,i,r)-tf(e,i,r))));
```

The equations simply use the idea that VFA*tf_LFA is 100 times the change in the tax, and that because the model is working in small percentage changes, the total of two percentage changes in tax rates can be approximated as the sum of the two percentage changes. The last line in tf_lfa1 relates the change in CAP subsidies that is calculated and corrects this change for changes in the CAP budget (in this case, LFA budget) that is changed because of changes in market price (calculated as pf-tf to simplify calculations) and changes in quantity.

12.7.2 Definition of decoupling

Decoupling of factor subsidies assumes that all Pillar I subsidies affect only land, and not any other production factor, with equal subsidy rates for all agricultural sectors. This assumption was developed in LEITAP for the Scenario 2020 studies (Nowicki et al., 2006 and 2009) and in the modulation study (LEI and IEEP, 2009).

The reader should note that this definition of decoupling is broader than the 'decoupled payments' that are associated with the Single Farm Payment.
The variable tf_OLDCAPSUB is used for denoting the tariff of Pillar I budget per endowment, agricultural sector and region, while the variable tf_NEWCAPSUB is used to denote the tariff summed Pillar I budget to land and all agricultural sectors per region.

The variable d_CAPSUBSDeco shows the absolute changes of the Pillar I budget per endowment due to decoupling. Regarding land, it is given as the value of land at market prices multiplied by the tax tf_NEWCAPSUB and the first pillar subsidies multiplied by the tax tf_OLDCAPSUB. The VFM is divided by 100 because the right-hand side of this equation refers to an absolute change while VFM is a percentage change (default setting in GTAP).

Regarding non-land endowments, these are calculated by multiplying the Pillar I subsidies by the respective tax. The division by 100 on the left-hand side is again because the right-hand side of the equation refers to an absolute change (not to a percentage change).

```
Variable (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
tf_OLDCAPSUB(e,i,r);
Coefficient (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
OLDCAPSUB(e,i,r);
Formula (initial) (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
OLDCAPSUB(e,i,r)=CAPSUBSFPIL(e,i,r);
Update (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
OLDCAPSUB(e,i,r)=tf_OLDCAPSUB(e,i,r);

Variable (all,r,CAP_REG) tf_NEWCAPSUB(r);
Equation tf_NEWCAPSUB1 (all,r,CAP_REG)
sum{e,ENDW_COMM, sum{i,AGRI_SECT,OLDCAPSUB(e,i,r)*tf_OLDCAPSUB(e,i,r)}}
= -sum{e,ENDWL_COMM, sum{i,AGRI_SECT, VFM(e,i,r)}}*tf_NEWCAPSUB(r);

Variable (change) (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
d_CAPSUBSDeco(e,i,r) #decoupling change of first pillar CAP subsidies $$ #;

Equation d_FBEPDeco1_ENDWL (all,e,ENDWL_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
d_CAPSUBSDeco(e,i,r) =
(VFM(e,i,r)/100)*tf_NEWCAPSUB(r)+(OLDCAPSUB(e,i,r)/100)*tf_oldCAPSUB(e,i,r);

Equation d_FBEPDeco1_ENDWNL (all,e,ENDWNL_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
d_CAPSUBSDeco(e,i,r) = (OLDCAPSUB(e,i,r)/100)*tf_OLDCAPSUB(e,i,r);
```

12.7.3 Second pillar technology effects

Some second pillar subsidies, such as human and physical capital investments, are assumed to increase the overall productivity aoall (e.g. output augmenting technological change). The regional or non-agricultural payments increase aoall in sectors other than agriculture. Agro-environmental payments imply an additional cost and a lower input productivity: afall (intermediate input augmenting technological change).

As discussed in Section 12.2, the increase in productivity depends *inter alia* on four coefficients which are determined exogenously and as far as possible based on the literature and capture the technology effects of the already defined types of Pillar II subsidies.
Regarding agro-environmental payments, they are considered as subsidies on land that partly compensate for lower productivity. For this reason, the P2SUMCOEF("agroenv") coefficient which shows the land productivity effects on agro-environmental payments is negative:

```
Formula (all,i,CAPBUD_TYPE) P2SUMCOEF(i)=0;
Formula P2SUMCOEF("humcapagri")=0.4;
Formula P2SUMCOEF("InvAgri")=0.3;
Formula P2SUMCOEF("techall")=0.3;
Formula P2SUMCOEF("agroenv")=-0.1;
```

The size of the coefficients is based on the literature (see section 12.2).
Part of the subsidies will not generate extra expenditures but come at the cost of private expenditures. It is *assumed* for the moment that -0% of the public expenditures are crowded out in this way, as direct evidence is not conclusive:

```
Coefficient CROWDOUT;
Formula CROWDOUT=0.0;
```

Sensitivity scenarios with a crowding out rate of 25% and 50% are recommended to identify the impact of crowding out effects.

Furthermore, productivity increases depend on the returns of the budget per type divided by the output to which the specific budget type refers.

Human and physical capital payments
The overall productivity of agricultural sectors increases by the rate of return of the budget for investment in human capacity over the percentage of the resulting added value (VOA), by the rate of return of the budget for investment in agriculture over the percentage of the value of physical capital stock (split by the rent share in trade sectors), and by the rate of return of the budget for investment in technology over the percentage of the resulted added value of traded commodities.

Equation aoall1_agri (all,j,Agri_SECT)(all,r,CAP_REG)
 aoall(j,r) =
        P2SUMCOEF("humcapagri")*(1-
CROWDOUT)*(CAPBUDT("humcapagri",r) /sum{k,Agri_SECT, VOA(k,r)})*100*time
      !Budget for human capital investment as percentage of value added created with this human capital!
        + P2SUMCOEF("InvAgri")*(1-CROWDOUT)*(CAPBUDT("InvAgri",r)

        /(sum{k,Agri_SECT,sum{i,ENDWC_COMM,EVFA(i,k,r)}}*VK(r)/sum{l,TRAD_SECT,sum{i,ENDWC_COMM,EVFA(i,l,r)}}))*100*time
      !Budget for physical capital investment as percentage of value of physical capital stock; we don't have a value of capital
    for agriculture separated, so, it is split by using rent share!
        + P2SUMCOEF("techall")*(1-
CROWDOUT)*(CAPBUDT("techall",r) /sum{k,TRAD_COMM, VOA(k,r)})*100*time;

Regional payments
The overall productivity of non-agricultural sectors is affected only by regional payments and is given as the rate of return of the budget for investment in technology over the percentage of the output of the resulting added value of traded commodities.

Equation aoall1_NAGRI (all,j,NAGRI_SECT)(all,r,CAP_REG)
 aoall(j,r) =P2SUMCOEF("techall")*(1-
CROWDOUT)*(CAPBUDT("techall",r)/sum{k,TRAD_COMM, VOA(k,r)})*100*time;

Negative productivity effects of agro-environmental payments
Agro-environmental payments are meant to compensate for the additional efforts a farmer has to make to fulfil the agro-environmental requirements. As these activities are not production oriented, they lead to lower productivity.

Equation afall_CAP (all,e,ENDWNL_COMM) (all,j,AGRI_SECT) (all,r,CAP_REG)
  afall(e,j,r)=P2SUMCOEF("agroenv")*(CAPBUDT("agroenv",r)
/sum{f,ENDWNL_COMM,sum{k,AGRI_SECT,EVFA(f,k,r)}}) *100*time;

12.8   Additional indexes

The following additional indices are calculated:
 1. Total endowment subsidies from the GTAP database:

Formula (all,e,ENDW_COMM)(all,i,PROD_SECT)(all,r,REG)
  TOTFSUBS(e,i,r)=VFM(e,i,r)-VFA(e,i,r);

 2. Non-production factor-based subsidies from the GTAP database:
     a. For the production sectors they are equal to the total endowment subsidies

Formula (all,e,ENDW_COMM)(all,i,PROD_SECT)(all,r,REG)
  NCAPSUBS(e,i,r)=TOTFSUBS(e,i,r);

b. For agricultural sectors they are given as the difference between the total endowment subsidies and the Pillar I CAP subsidies

Formula (all,e,ENDW_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
 NCAPSUBS(e,i,r)=TOTFSUBS(e,i,r)-CAPSUBSFPIL(e,i,r);

c. For land the relevant Pillar II subsidies are excluded

Formula (all,e,ENDWL_COMM)(all,i,AGRI_SECT)(all,r,CAP_REG)
 NCAPSUBS(e,i,r)=NCAPSUBS(e,i,r)-sum{c,CAPLFA_type,CAPSUBSLFA(c,i,r)};

3. Rate of ad valorem tariff of non-production factors
   a. for all primary commodities: the rate of value at agent prices over value at market prices

Formula (all,e,ENDW_COMM)(all,j,PROD_SECT)(all,r,REG)
 rTF_NCAPSUBS(e,j,r) = 100*[VFA(e,j,r)/VFM(e,j,r)-1];
   b. for agricultural sectors, the rate of value at market prices excluding non-production factor-based subsidies over value at market prices

Formula (all,e,ENDW_COMM)(all,j,AGRI_SECT)(all,r,CAP_REG)
 rTF_NCAPSUBS(e,j,r) = 100*[(VFM(e,j,r)-NCAPSUBS(e,j,r))/VFM(e,j,r)-1];

12.9 Additional data

No additional data are used for the time being.

12.10 Activating the CAP module

12.10.1 DSS settings to activate the module

DSS tab	DSS question	Actions	Comments
Database	-	-	-
Model	Includes for MAGNET	Select mobileendowments and newcap. It is also wise to include the production tree and the endogenous land module, otherwise important mechanisms that fundamentally influence the results cannot be implemented.	Adds the model code for the CAP module. The mobile endowments code is needed since some definitions are shared between the two modules. It does not need to be activated for the CAP module to work.
	When the file modelchoices.har opens	Can change FBEP header affecting how the CAP budget is computed. Default is 1 (LEI method). Set to 0 to compute the budget from the GTAP database.	This option is not available in Prepare Scenario or Scenario (Gemse) tab because it affects the aggregation of data by MAGNETagg (can thus not be changed once the base data are created)
Prepare Scenario	Closure file	Add the CAPbudget.cmf	Defines new (budget) variables as exogenous
Scenario (Gemse)	Closure file	Add the CAPbudget.cmf	Defines new (budget) variables as exogenous
	Model parameters file	Adjust file headers in Model-settings.prm as described in the table below. Be careful to save this file under a different name in order to save settings when re-running the Model tab of DSS. Try to set as much as possible correct by changing code in Modelchoice and MagnetAgg, and adjusting information in the MagnetChoiceIni file.	Assigns regions to an alternative factor market theories

12.10.2 Adjustments to headers in ModelSettings.prm file

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode, which allows the addition of modules
CAPP	For all regions with a CAP, put a 0 in the NOCAP row and a 1 in the CAP row	Parameter assigns regions to having a CAP or not. Check that each region in your model has a type of factor market assign to avoid closure errors (each column should sum to 1)
CAPD	Allows a change in the default marginal distribution of CAP budget over budgets	
CAPS	Allows a change in the default distribution of LFA and Agrenv money over sectors	

It obviously makes sense to activate the CAP module only for EU Member States and to avoid any conflicting settings. Attention should be paid to the regional aggregation and, in particular, to cases when EU Member States are aggregated with non-EU Member States for forming a regional block. For such regional blocks, the user should avoid activating the CAP module.

12.11 Closure for running simulations

The closure file CAPBUDGET.cmf should be included in DSS when running CAP scenarios. This file contains the exogenous CAP budgets, the tariff rate for old CAP subsidies (that is shocked in the case of decoupling), the slack variable pCAPBUDTSLCK that becomes endogenous in the case the total CAP budget is fixed, and the percentage modulation:

!Common agricultural policy (CAP) module closure
Exogenous
  p_CAPBUDEXO
  d_CAPBUDEXO
  p_CAPBUDTEXO
  d_CAPBUDTEXO
  tf_OLDCAPSUB
   !shock to reduce old Pillar I subsidies towards equal subsidy rate FBEP
 pCAPBUDTSLCK*!swap with dCAPBUDSLCK to fix total CAP budget, for example*
    !in case of modulation.
 p_Modulation;*!perc reduction of first pillar budget to increase to second pil*
Endogenous tf(ENDW_COMM,AGRI_SECT,CAP_REG)
    aoall(PROD_SECT,CAP_REG)
    afall(ENDWNL_COMM,AGRI_SECT,CAP_REG);

Furthermore, in the standard GTAP closure the tax tf should be declared as exogenous (as is always done in the current standard closure of MAGNET).

! closure

exogenous

! == Standard GTAP
tf   *!not omitted anymore because of CAP module*

12.12 Changes to MAGNET

Phase	Directory	Subfile & Description
Model Definition	*2_ModelDefinition\2_ModelStructure\Code*	*\NEWCAP.gmp* Defines the regional settings that have to be in place if the CAP module is used, namely initiates the regions that are relevant for including CAP policies It further defines how CAP payments should be distributed over the sectors *\ModelStructure.gmp* Added include statement for NEWCAP.gmp
	2_ModelDefinition\3_MagnetAgg\Code	*\CAPPolicy.gmp* Allows to choose whether to use the GTAP information on domestic subsidies or the LEITAP method. In case the latter is chosen, it calculates the total domestic subsidy budget and also the 1st and 2nd pillar budget. *\MAGNETagg.gmp* Added include statement for CAPPolicy.gmp
MAGNET code	*4_MAGNET\CodeMainProgram*	*\Module definition.gmp* Specific regional sets that have to be in place for using the module are defined. *\NEWCAP.gmp* Code for implementing the CAP module
MAGNET command files	*\4_MAGNET\CommandFiles\Closures*	CAPBudget.cmf Exogenous: Percentage and absolute changes of the CAP budget and of its distribution are considered as exogenous (namely p_CAPBUDEXO, d_CAPBUDEXO, p_CAPBUDTEXO, d_CAPBUDTEXO) as well as pCAPBUDTSLCK (slack making the sum of regional subsidies equal the total subsidy), p_Modulation (percentage reduction of 1st pillar subsidies because of modulation), tf_OLDCAPSUB. Endogenous: tf(ENDW_COMM,AGRI_SECT,CAP_REG), aoall(PROD_SECT,CAP_REG), afall(ENDWNL_COMM,AGRI_SECT,CAP_REG)

12.13 Include other modules

In order to conduct a CAP analysis, it is necessary to include other modules because the impact of CAP measures are very dependent on production trees, production quotas, land markets and imperfect factor (labour, capital) markets. The land market (land supply and allocation) is crucial as many CAP measures are related to land whereas land expansion versus land abandonment is crucial (e.g. environmental effects such as biodiversity). The non-homogenous factor markets are relevant to CAP effects, as agricultural-specific factor prices absorb a part of the impacts of changing or reducing the CAP. As an example, in the case of a reduction in CAP payments (budget cuts), factor prices will adjust downwards, which in turn results in more limited effects on production and employment. This is because farmers tend to accept lower land rents and wages and adjust their production instead of leaving agriculture. Last, but not least, production quotas are handled in a separate module.

It is necessary to include:
  i.   Flexible production structure
        a. Different structures for crop and livestock sectors
        b. Include land-feed nests in livestock sectors
        c. Optional: biofuel production trees
  ii. Land supply
  iii. Land allocation
  iv. Segmented factor markets
  v.   Production quota
  vi. Optional: Biofuel policies affect the agricultural sector and may hence interact with CAP policies. For some analyses inclusion of this module is essential.

vii.   Optional: For long-run analyses with CAP, it is recommended to include a consumption function correction to correct demand for food products; without this correction, demand is too high.

12.14   Testing the module

Examples of formulating shocks and testing the CAP module are given below:

1. Decoupling:

shock tf_OLDCAPSUB(ENDW_COMM,AGRI_SECT,CAP_REG)=**uniform** -100;

2. Cutting the first pillar CAP budget by 100%

shock p_CAPBUDTEXO(*"firstpil"*,CAP_REG)=**uniform** -100;
shock pfactwld_2 = 100;

whereas the variable pfactwld_2 is a world price index of primary factors, and this is used to show whether change in prices influences the quality of the result.

3. Abolition of Pillar I

shock p_CAPBUDTExo(*"firstpil"*,CAP_REG) = **uniform** -100;
where this shock removes all first pillar payments in the model.

4. Modulation (100%)

!First pillar CAP budget transferred into second pillar budgets!
swap pCAPBUDTSLCK = dCAPBUDSLCK;
shock p_modulation(CAP_REG)=**uniform** -100;

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13 Biofuel blending targets

One of the most important policy instruments used in the biofuel sector is the implementation of blending mandates**.**

Blending mandates are specific instruments for volume-based policies. In contrast to many other policy measures, for example the milk quota, they stipulate not the quantity supplied but the quantity demanded. However, blending mandates may affect the entire supply chain. If farmers were to increase their production of, for example, rapeseed, oil mills would increase their processing capacities. Additional investments would be made and additional labour forces employed. Thus, the growth of a whole economic sector relies on the blending mandates.

13.1 Aim

MAGNET's dedicated module on biofuel policies allows the possibility to target biofuel shares in transport. First, to capture obligatory blending, a biofuel share is introduced that can be targeted to impose policies, for example blending targets. Second, a subsidy on biofuel use is introduced to achieve a targeted blending rate. To keep biofuel policies budget-neutral, a tax may be introduced off-setting the biofuel subsidy. Third, there is an option to fix the total real budget on biofuel subsidies.

The biofuel module was developed to impose target blending rates of biofuels with fossil fuels. Whether these biofuels are produced using first- or second-generation technology depends on the chosen production structure of the biofuels sector. In the module, the presence of biofuels is taken as given and only the imposition of a target share is modelled.

13.2 Approach

We developed the biofuel blending module based on earlier LEITAP biofuel work as described in, for example, Banse and colleagues (2008 and 2011). Specifically, we developed the code using an example of a directive requiring a blending target for fuel used in transport.

For meaningful biofuel analyses, it is recommended to also include other MAGNET modules in the model. The flexible production structure (Chapter 6) is necessary to enable substitution between biomass-based ethanol and biodiesel and crude oil-based petrol. It is important to include the biodiesel and ethanol by-products, such as DDGS, molasses and oil cakes. As direct and indirect land use impacts are crucial, it is highly recommended to also include land markets as described in Chapter 7 (Endogenous land supply) and Chapter 8 (Allocation of land over sectors). Also useful are other characteristics of the agricultural sector, such as the segmented mobile factor markets as agricultural factor prices deviate from these prices in other sectors, and all agricultural policies such as EU CAP policy (Chapter 12) and production quotas (Chapter 11).

Although the GTAP database includes several transport sectors, these do not cover all fuel used for transport. Firms, private households and the government purchase petroleum products which are partly used for transport and partly for other uses like heating. In order to implement a biofuel blending mandate, we need to account for demand for petroleum products by the transport sectors as well as part of the intermediate and final demand for petroleum products by households and government.

To distinguish blended from non-blended petrol, one might introduce a new sector blending petroleum products with biofuels. This blended product would then be purchased by sectors with an imposed directive and by private households and government. Introducing a new sector, however, greatly increases the size of the model. We therefore model the blending sector implicitly as part of the petrol sector (the p_c sector in the GTAP database). The petrol sector thus demands biofuels, which is in line with the way in which the biofuels data are added to the MAGNET database. Not all household and government demand for petrol is used for transport (part of the petroleum products is used, for example, for heating). When calculating the share of biofuels in petrol we thus include only the part of petrol demand that is used for transport. This share is calculated from International Energy Agency (IEA) data, which provides both information on biofuel production and information on fuel use in transport.

With respect to the production of ethanol (biogasoline), the CES production function allows for substitution between different inputs like sugar cane, sugar beet, molasses, wheat and maize. For biodiesel, vegetable oil is used as an input. The production of ethanol allows for by-products like DDGS that can be used for animal feeding. For biodiesel, vegetable oil is used, where the (crude) vegetable oil sector has oilcake as a by-product. The animal feed sector and the animal sectors themselves are able to substitute different types of feed through a nested CES structure. In this manner, also the indirect effects of biofuel production through its by-products are taken into account.

Although developed for the case of blending of fossil fuels for transport, the code is set up in a general way allowing multiple blended commodities. If data are available on the use of biofuels in, for example, the chemical industry, these can be subjected to a target as well. The definition of one or more blended commodities is established in the AddAndModifyData step when the modified SAM is checked for activities using biofuels (part of the Data tab in DSS). Thus, when activities are added with data on the use of biofuels, these are automatically added to the set of blending sectors and commodities.

13.3   Modelling biofuel blending targets

The modelling of biofuel blending targets consists of four steps. We start be computing the share of biofuels in the commodities that are subject to a blending requirement. In the case of fossil fuels, this amounts to the share of biofuels in fuel used for transport. We then compute taxes needed to pay for the biofuel subsidy. The third step defines the total real budget allocated to subsidies. This allows us to fix the total amount spent on biofuel subsidies, in which case the blending target can no longer be fixed. The last step establishes the links between the biofuel directive module and the rest of the model through taxes and subsidies.

13.3.1 Activation is through closure swaps, not a regional subset

The biofuel blending module is defined over all regions in the model. The default closure, however, is such that the code does not affect model results. This is done by defining the biofuel subsidies and taxes that establish the link with rest of the model as exogenous. This setup allows the tracking of the development of biofuel and blended commodities, and the imposition or removal of a biofuel blending target at any time in a set of simulations.

13.3.2 Defining a biofuel blending target

The biofuel directive module requires a number of additional sets:

```
Set BIOFUELS # Biofuel commodities #
  read elements from file GTAPSETS header "BIOF";
Subset BIOFUELS is subset of TRAD_COMM;

Set BLEND_COMM # Commodities which are blended with biofuels #
  read elements from file GTAPSETS header "BLNC";

Set FUEL_COM = BLEND_COMM + BIOFUELS;
```

```
Subset FUEL_COM is subset of TRAD_COMM;

Set BLEND_SECT # Sectors producing blended commodities #
  read elements from file GTAPSETS header "BLNS";
Subset BLEND_SECT is subset of TRAD_SECT;
```

Which commodities and sectors belong to these sets is determined by the module adding biofuel sectors and commodities to the GTAP database. Here, the biofuel sectors are identified and the modified SAM is checked for sectors demanding biofuels to identify the blending sectors. In the MAGNETagg step, these disaggregated sectors are mapped to the sectors defined for the model aggregation, resulting in the above sets.

We need additional data to capture the petrol used for transport purposes that is subject to the biofuel directive. The computations of petrol for transport and biofuels used in blending account for the different energy contents of these commodities. The resulting data provide the starting point for the biofuel share calculations, which are read from a file. Below is an example for private demand for blended commodities:

```
! - private demand!
Variable(levels) (all,i,BLEND_COMM)(all,r,REG)
  PDBLEND(i,r) # Private demand for domestic blended commodity #;
  Read PDBLEND from file GTAPDATA header "PDBL";
Equation P_PDBLEND1 (all,i,BLEND_COMM)(all,r,REG)
  p_pdblend(i,r) = qpd(i,r);
Variable(levels) (all,i,BLEND_COMM)(all,r,REG)
  PMBLEND(i,r) # Private demand for imported blended commodity #;
  Read PMBLEND from file GTAPDATA header "PMBL";
Equation P_PMBLEND1 (all,i,BLEND_COMM)(all,r,REG)
  p_pmblend(i,r) = qpm(i,r);
```

Private households do not demand biofuels directly, thus the variable is restricted to BLEND_COMM. A distinction is made between domestic and imported blended commodities, as is done for all private consumption demand, allowing a simple equation to update these levels variables. A similar set of equations is defined for government consumption and intermediate demand. In the case of intermediate demand, we exclude the demand of the blending sectors for their own blended commodity when computing the initial values, but we do include the intermediate demand for biofuels by the blending sectors. Note that by defining these variables over all traded commodities and regions, we ensure that the initial values of these variables are updated even when the biofuel directive is not yet switched on.

Having computed the demands for blended commodities and biofuels, we can compute the total share of biofuels, which can serve as a target for implementing biofuel directives. The share is computed by dividing the total amount of biofuels used in the blending sector by the demand for the blended product that is subject to a directive. In our example, this would be the total use of biofuels in the petrol sector divided by the demand for petrol by the transport sector, private household and government.

In MAGNET this is translated as (all in levels):

```
Equation (levels) BIOFUEL_SHR1
  # Compute share of biofuels in total fuel use #
  (all,b,BLEND_COMM)(all,r,BFSHR_REG)
  BIOFUEL_SHR(b,r) =
            sum{j,BLEND_SECT: TRADC2TRADS(b) eq j,
            sum[i,BIOFUELS, IDBLEND(i,j,r)+IMBLEND(i,j,r)]}
           /[PDBLEND(b,r)+PMBLEND(b,r)+GDBLEND(b,r)+GMBLEND(b,r)
          + sum{j,TRAD_SECT, IDBLEND(b,j,r) + IMBLEND(b,j,r)}
          + sum{j,BLEND_SECT: TRADC2TRADS(b) eq j,
            sum[i,BIOFUELS, IDBLEND(i,j,r)+IMBLEND(i,j,r)]}];
```

The biofuel share (BIOFUEL_SHR) is computed for blended commodities (BLEND_COMM, petrol in our example) in regions that use biofuels (BFSHR_REG). The first part of the right-hand side then computes the total use of biofuels (BIOFUELS) in the sectors (from domestic and imported sources)

that are used to produce the blended commodity. The amount of biofuels used is divided by the amount of blended commodity (blended petrol, in our example) plus biofuels to arrive at the share of biofuels. The difference in energy content of biofuels and fossil fuels is accounted for when computing the initial demand. As long as the biofuel share is endogenous, this equation will only calculate the share but not change model outcomes. To implement a directive, we need to fix this share through a closure swap, which is discussed at the end of this chapter.

Note that this equation only works if the blended commodities are used only for blending in transport, and not for other purposes. Through the mapping from the sector to the commodity (MapTrToS), we assign all biofuels used by the blending sector to the blending commodity. If the blending sector were to produce two commodities that are both used for blending, this mapping from sector to commodities would result in double counting of the biofuels used (both blending commodities then get all biofuels of the blending sector allocated to them). Also note that we assume that any biofuels used by the blending sector are used for blending and thus qualify for the biofuel directive.

The calculation of the biofuel share is based on the domestic use of biofuels in the blending sectors (petrol) versus the total demand for domestic and imported blended commodities (blending petrol for fuel). We thus assume that all blending is done domestically (i.e. there is no trade in blended petrol). This approach could cause improbable results if the domestic petrol sector is really small while there is a considerable consumption of imported petrol for fuel. Since the domestic sector is absorbing the biofuels required for both domestic and imported blended petrol, but is only producing domestic petrol, the share of biofuels in domestic petrol could become unrealistically high and overshadow all other inputs in domestic petrol.

13.3.3 A budget-neutral implementation through endogenous taxes and subsidies

To induce the use of biofuels when a directive is imposed, we introduce a subsidy on biofuel used by the blending sectors. This subsidy is combined with a tax on the blending sector to make the policy budget-neutral:

```
!Tax and subsidy variables!
Variable (all,j,BLEND_COMM)(all,r,REG)
  tbdir_sub(j,r) #Subsidy (neg. tax) on use of biofuels in blending sectors#;
Variable (all,j,BLEND_COMM)(all,r,REG)
  tbdir_tax(j,r) #generic comm. tax to pay for biofuels subsidies in sector j#;
Variable (all,j,BLEND_COMM)(all,r,REG)
  tbdir_slck(j,r) #slack variable to break link between tax and subsidy#;
```

These subsidy and tax variables are defined as exogenous in the standard closure, while the slack variable is endogenous in the default closure setting. Since the subsidy and tax rates create the link to the rest of the model, this ensures that all calculations in the biofuel directive module do not affect the rest of the model.

There are various options when levying the tax that pays for the biofuel subsidies:

```
! Dummy determining taxing scheme for blending sector:
   0 = both final and intermediate demand taxed (default setting)
   1 = only final demand for blended commodity taxed
   2 = only intermediate demand for blended commodity taxed!
Coefficient(parameter) (all,j,BLEND_COMM)(all,r,REG)  BTAXSCHEME(j,r)
  #Blending sect tax scheme: 0 = final + int. demand; 1 = final, 2 = int. dem#;
   read BTAXSCHEME from file MODPARM1 header "BDTX";

! Create dummies based on setting of tax scheme!
Coefficient (parameter) (all,b,BLEND_COMM) (all,r,REG)
  BDIR_TAXF(b,r) # Final demand counts for computing base for biofuel tax#;
  Formula(initial) (all,b,BLEND_COMM) (all,r,REG)
    BDIR_TAXF(b,r) = 0
     + if{BTAXSCHEME(b,r)=0,1}
     + if{BTAXSCHEME(b,r)=1,1};
 Coefficient (parameter) (all,b,BLEND_COMM) (all,r,REG)
  BDIR_TAXI(b,r) # Intermediate demand counts for computing biofuel tax#;
  Formula(initial) (all,b,BLEND_COMM) (all,r,REG)
```

```
    BDIR_TAXI(b,r) = 0
      + if{BTAXSCHEME(b,r)=0,1}
      + if{BTAXSCHEME(b,r)=2,1};
```

The default setting is 0, taxing both final and intermediate demand for the blended commodity. Alternative settings are to tax only final demand (1) or only intermediate demand (2).

In order for the policy to be budget-neutral, we introduce a tax related to the biofuel directive and require that total expenses on biofuel subsidies (left-hand side of the equation below) are equal to total taxes levied on commodities (right-hand side of equation):

```
Equation T_BDIR1
 # Setting taxes to pay for biofuel subsidies #
(all,b,BLEND_COMM)(all,r,REG)
  sum{j,BLEND_SECT: TRADC2TRADS(b)=j, sum[i,BIOFUELS, VIFM(i,j,r)+VDFM(i,j,r)]}
  *(-tbdir_sub(b,r))
  =  {BDIR_TAXF(b,r)*{VDPM(b,r)+VIPM(b,r)+VDGM(b,r)+VIGM(b,r)}
     + BDIR_TAXI(b,r)*{
       sum[j,PROD_SECT: TRADC2TRADS(b)<>j, VDFM(b,j,r)+VIFM(b,j,r)]}
       }*tbdir_tax(b,r) + tbdir_slck(b,r);
```

Note that the tax rate is only specific to a blended commodity; both final and intermediate demand thus face the same tax rate. The tax scheme dummies (BDIR_TAXF and BDIR_TAXI) control whether final and/or intermediate demand are used for determining the tax rate on blended commodities needed to pay for the biofuel subsidy. When computing the tax on intermediate demand, we exclude own demand for the blended commodity by the blending sector (through the b<>j statement). Making the slack variable endogenous removes the relationship between the subsidy and tax rates.

13.3.4 A fixed biofuel budget implementation

With both subsidies and taxes endogenous, the implementation of the biofuel directive is budget-neutral. Taxes levied on the users of the blended commodity pay for the subsidies to the blending sectors. In some cases this may not reflect the actual implementation of a biofuel directive. An alternative specification is one with a fixed biofuel budget limiting the subsidy rate. In that case, the subsidy rate may not be enough to offset the additional costs of the biofuels and the (endogenous) biofuel share may not increase to the desired level.

The budget for subsidies on the demand for domestic blended commodities is determined as follows:

```
Coefficient (all,i,BIOFUELS)(all,j,BLEND_SECT)(all,r,REG)
  BUDGOV(i,j,r) # Government budget for domestic biofuels in blending sectors#;
  Read BUDGOV from file GTAPDATA header "BUDB";

Variable (change) (all,i,BIOFUELS)(all,j,BLEND_SECT)(all,r,REG) d_BUDGOV(i,j,r)
  #change in budget for biofuels per biofuel commodity in petro#;
Update (change) (all,i,BIOFUELS)(all,j,BLEND_SECT)(all,r,REG)
  BUDGOV(i,j,r)=d_BUDGOV(i,j,r);

Equation d_BUDGOV1
  # Change in budget required to pay for subsidy on domestic biofuel use#
  (all,b,BIOFUELS)(all,j,BLEND_SECT)(all,r,REG)
  d_BUDGOV(b,j,r) = (BUDGOV(b,j,r)/100)*[qfd(b,j,r) + pm(b,r)]
                !endogenous change in budget!
  +[(VDFA(b,j,r)/100) * sum{i,BLEND_COMM:TRADC2TRADS(i) eq j,tbdir_sub(i,r)}]
                !compensation of this change keeping total budget constant!;
```

Again, the initial budget is read from a file and updated with the change in budget. Since the subsidy is an ad valorem subsidy, the change in domestic budget (d_BUDGOV) is first of all determined by changes in the total value of the demand for biofuels which can be due to a change in quantity (qfd) or price (pm). A second factor is a change in the subsidy rate, captured by the second part of the equation. A similar equation is included for imported blended commodities, d_BUIGOV.

Together these determine the total change in government budget, bugovtot:

```
Equation BUGOVTOT1
   # Total government budget for subsidies by blending sector #
   (all,j,BLEND_SECT)(all,r,REG)
   sum{i,BIOFUELS,d_BUDGOV(i,j,r)+d_BUIGOV(i,j,r)} =
         sum{i,BIOFUELS,({BUDGOV(i,j,r)+BUIGOV(i,j,r)}/100)
         * (pgdp(r) + bugovtot(j,r))};
```

Note that if the budget is fixed, this is done in real terms. It can grow in nominal terms through the GDP price index, pgdp(r).

13.3.5 Linking the biofuel directive taxes to the rest of MAGNET

To complete the biofuel directive module we need to link the biofuel directive subsidies and taxes to existing tax rates in MAGNET. Only then will the production and consumption decisions adjust to achieve the blending targets. By linking to taxes already existing in MAGNET we reduce the need for adjusting the remainder of the code, like income equations and so on.

Redefining taxes in modified GTAP. To link the taxes from the biofuel directive to the rest of the model we redefine the taxes on final and intermediate demand in modified GTAP. Taxes related to the biofuel directive are added:

```
! Taxes related to biofuel directive!
Variable (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
  tbdir_i(i,j,r) #biofuel directive: tax on interm. demand for i by j in r#;
Variable (all,i,TRAD_COMM)(all,r,MREG)
  tbdir_f(i,r) #biofuel directive: tax on final demand for i in r#;
```

Taxes computed from the base data are referred to by a _b. So for the taxes in private household demand we get:

```
! Taxes equivalent to tfd and tfm in GTAP core model!
Variable (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
  tfd_b(i,j,r) # from basedata: tax on domestic i purchased by j in r#;
Variable (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
  tfm_b(i,j,r) # from basedata: tax on imported i purchased by j in r #;

! Define total tax on domestic and imported intermediates!
Equation TFD1_MREG (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
  tfd(i,j,r) = tfd_b(i,j,r) + tbdir_i(i,j,r);
Equation TFM1_MREG (all,i,TRAD_COMM)(all,j,PROD_SECT)(all,r,MREG)
  tfm(i,j,r) = tfm_b(i,j,r) + tbdir_i(i,j,r);
```

Similar adjustments are made for taxes on government and intermediate demand.

Final demand by households and government. In the modified GTAP closure we make taxes on final demand in regions with a biofuel directive endogenous and establish a link with the taxes needed to pay for the subsidies:

```
!Final demand taxed to pay for biofuel subsidy (depending on tax regime) !
Equation TBDIR_F1 (all,i,BLEND_COMM)(all,r,MREG)
   tbdir_f(i,r) = BDIR_TAXF(i,r)*tbdir_tax(i,r);
```

Just as in the tax calculations above, the BDIR_TAXF dummy controls whether or not final demand is being taxed.

Intermediate demand by sectors with no biofuel directive. Intermediate demand is taxed if the taxing scheme includes taxing sectors (BDIR_TAXI). Own demand for the blending commodity by the blending sector is not taxed:

```
! Purchases of blended commodities as intermediate inputs are taxed, except
  for purchases of own blended commodities by blending sectors (depending on
  tax regime)!
Equation TBDIR_I1 (all,i,BLEND_COMM)(all,j,PROD_SECT)(all,r,MREG)
    tbdir_i(i,j,r) = BDIR_TAXI(i,r)*if[TRADC2TRADS(i)<>j, tbdir_tax(i,r)];
```

The last equation links the subsidies on biofuels used by the blending sectors to the rest of the model:

```
! Purchases of biofuels by blending sectors are subsidized!
Equation TFD1_BDIR_BIOFUEL (all,i,BIOFUELS)(all,j,BLEND_SECT)(all,r,MREG)
    tbdir_i(i,j,r) = sum[b,BLEND_COMM: TRADC2TRADS(b)=j, tbdir_sub(b,r)];
```

Note that for computational reasons, we do not use a complementarity condition to impose the biofuel target. If biofuels become competitive, the subsidy will drop to zero but the blending rate will not exceed the target. Thus, if the biofuel subsidy drops to zero in a solution it may be worthwhile to either remove the biofuel directive (i.e. undo the swap used to activate the target), which will allow the biofuel share to rise above the previously imposed target, or expand the target to a binding level if this is deemed more realistic.

13.4   Activating the biofuel directive module

In order to derive a meaningful analysis of biofuel directives, we need to not only activate the module itself, but also ensure that the production structure allows substitution between biofuels and fossil fuels.

In a full-fledged biofuels model, the ProdTree module can be used to set up any desired substitution structure for energy and fuels. For the biofuel directive to make sense (and the model to solve!), the chosen production structure should allow for the share of biofuels in the production of the blended commodity to vary. In the case the biofuel share is fixed – for example, because it is treated as an intermediate input in a Leontief nest, like in the standard GTAP production structure – the model will tend to generate warnings on updated coefficients not satisfying negativity checks and most likely fail to converge when a directive is imposed. Elasticities in the chosen production structure are crucial for determining the impact of a biofuel directive. When unexpected responses occur, determining the implied substitution possibilities of the biofuels can provide clues.

Apart from allowing the share of biofuels to change through proper elasticities, it is also important to model the blending at the proper place in the production tree. All data calculations for blending petrol (which account for the energy content of fuels) are based on blending occurring at the top of the production tree. Thus, first unblended petrol is produced using production factors and non-biofuel intermediate inputs. Then the resulting production is blended with biofuels to yield the blended petrol commodity. For initial data on use of biofuels and blending transport fuel to make sense, this blending at the top of the production tree needs to be maintained. The production of unblended petrol can be made as complex as needed. The example production tree below (Figure 13.1) is from the production version where the production of unblended petrol (vaen and its sub-nests) has a simple structure. Ethanol/biogasoline (biog) and biodiesel (biod) can be substituted for each other before getting blended with petrol.
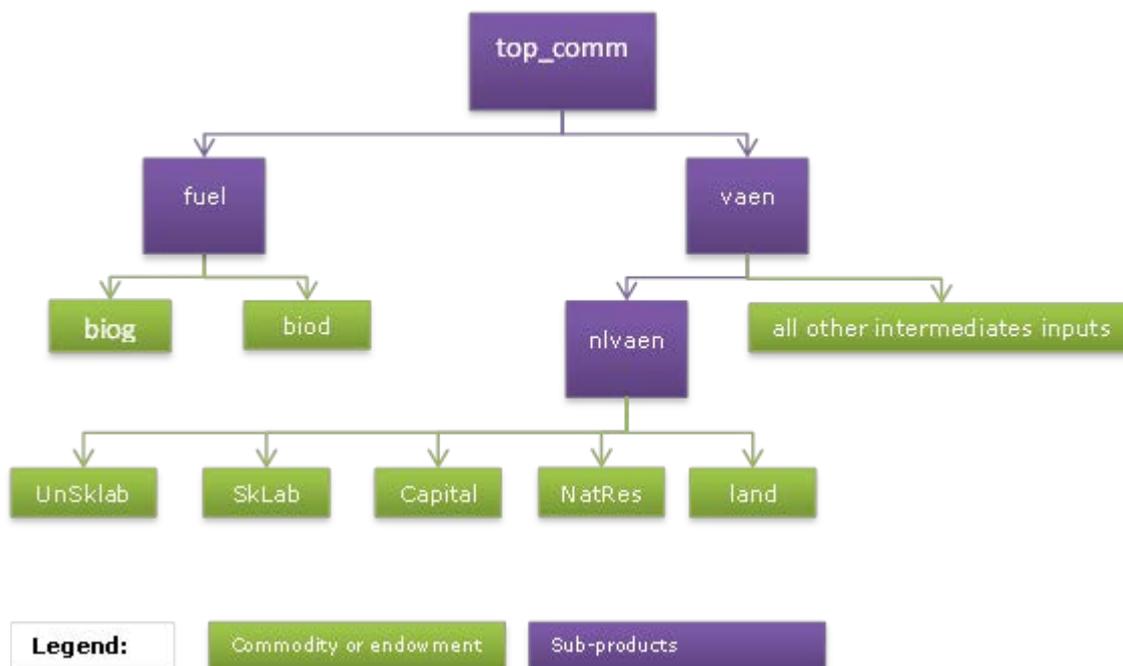
Figure 13.1 *Example of production tree with proper place for blending of petrol*

13.4.1 DSS settings to activate the module

Although this module does not have a regional choice parameter, there are a couple of DSS settings required to run the model with a biofuel directive.

First of all, the database used should include biofuel and blending sectors. Consult the documentation on the addition of biofuel sectors in the AddAndModfyData step for the proper DSS settings in the DSS database tab.

As stated before, meaningful analyses of biofuel targeting require other MAGNET modules: a flexible production structure (Chapter 6) to enable substitution between biomass-based ethanol and biodiesel and crude oil-based petrol. It is important to include the biodiesel and ethanol by-products such as DDGS, molasses and oil cakes. As direct and indirect land use impacts are crucial, it is highly recommended to also include the land markets as described in Chapter 7 (Endogenous land supply) and Chapter 8 (Allocation of land over sectors). Other characteristics of the agricultural sector are also useful, such as the segmented mobile factor markets, as agricultural factor prices deviate from these prices in other sectors, and all agricultural policies such as EU CAP policy (Chapter 12) and production quotas (Chapter 11).

DSS tab	DSS question	Actions	Comments
Model	Includes for MagnetAgg	Select biofueldirective	Adds a module to MagnetAgg to aggregate additional data needed by the biofuel directive module.
	Commodity aggregation	It is sensible to keep the blending and biofuel sectors as separate sectors; you can rename for the model aggregation.	Aggregating these sectors may lead to meaningless model results.
Model	Includes for MAGNET	Select biofueldirective	Adds the model code for the biofuel directive module
Prepare Scenario	Closure file	Add BiofuelDirectiveClosure.cmf to the closure list	Default closure sets biofuel subsidies and taxes exogenous so inclusion of the module does not affect model results.
Scenario (Gemse)	Model parameters file	Add BiofuelDirectiveClosure.cmf to the closure list	Default closure sets biofuel subsidies and taxes exogenous so inclusion of the module does not affect model results.

13.4.2 Adjustments to headers in ModelSettings.prm file

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode, which allows the addition of modules
BDTX	Choose tax regime on demand for blended commodity	0 = intermediate and final demand are taxed; 1= only final demand is taxed 2 = only intermediate demand is taxed

13.4.3 Closure swaps to activate the biofuel directive

There are various options for activating the biofuel directive governed by closure swaps. The following table summarises these options.

		(1) Module inactive	(2) Budget-neutral		(3) Fixed budget
			(a) no target	(b) target	(a) no target
Biofuel share	**p_biofuel_shr**	N	N	X	N
Biofuel subsidy	**tbdir_sub**	X	X	N	N
Biofuel tax	**tbdir_tax**	X	N	N	N
Tax slack	**tbdir_slck**	N	X	X	X
Biofuel budget	**p_BUGOVTOT**	N	N	N	X

Where N = endogenous, X =exogenous

(1) Module inactive: In the first (default) closure the module has no impact on the model solutions; both the subsidy and tax rate are exogenous and these establish the link to the remainder of the model. So none of the changes occurring within the biofuel directive module is translated to the rest of the model. By having the biofuel share and budget endogenous, we can trace changes in these variables in the absence of any additional biofuel policies.

(2) Budget-neutral: in this setup the budgetary implications of the biofuel directive are offset by an adjustment in tax rates. There are two variations:
(a) *no target*: in this setup there is no target on the biofuel share. If either the quantity or the price of the blended commodity changes, the budget needed for the biofuel subsidies changes. This is accommodated by the changes in the tax rate on users of the blended commodity. This is accomplished by swapping the slack on the tax equation with the tax rate
(b) *target*: in this setup a specific share of biofuels is targeted by an endogenous subsidy rate by swapping the subsidy rate with the target. Again, the taxes adjust to ensure that the implementation is budget-neutral.

(3) Fixed budget: in this setup taxes are fixed while the subsidies adjust to maintain a fixed budget.

    (a) *no target*: in this setup there is no target on the biofuel share. If either the quantity or the price of the blended commodity changes, the budget needed for the biofuel subsidies changes. This is accommodated by the changes in the subsidy rate. This is accomplished by swapping the subsidy rate with the budget, making the subsidies endogenous and the budget exogenous. Taxes adjust to raise the budget for the subsidies.

The biofuel directive closure file includes examples of the possible slacks that are commented out:

```
! Example swaps to activate the module

!1: budget neutral, no target
!swap tbdir_tax(BLEND_COMM,MREG) = tbdir_slck(BLEND_COMM,MREG);

!2: budget neutral & biofuel share target
!swap tbdir_tax(BLEND_COMM,MREG) = tbdir_slck(BLEND_COMM,MREG);
!swap tbdir_sub(BLEND_COMM,MREG) = p_BIOFUEL_SHR(BLEND_COMM,MREG);

!3: budget neutral & fixed real budget for subsidies
!swap tbdir_tax(BLEND_COMM,MREG) = tbdir_slck(BLEND_COMM,MREG);
!swap tbdir_sub(BLEND_COMM,MREG) = bugovtot(BLEND_SECT,MREG);
```

These examples can be adjusted to apply only to specific blended commodities, regions or have different regimes in different regions.

13.5   References

Banse, M., H. van Meijl, A. Tabeau and G. Woltjer (2008) Will EU Biofuel Policies affect Global Agricultural Markets, European Review of Agricultural Economics, 35: 117-141.

Banse. M. A. Tabeau, H. van Meijl, G. Woltjer and A Prins (2011) Global impact of multinational biofuel mandates on land use, feedstock prices, international trade and greenhouse gas emissions. Paper prepared for the 14th Annual Conference on Global Economic Analysis, 'Governing Global Challenges: Climate Change, Trade, Finance and Development', Venice, June 16-18, 2011. Available from www.gtap.org.

14 Investment

The plain vanilla GTAP model was developed for comparative-static analyses. MAGNET, however, is often used for long-term projections describing changes in an economy over time. This type of analysis is generally done with reference to a baseline projection, describing developments in the global economy given current policies and projections. Such a baseline can be created with MAGNET using a specific closure and a set of exogenous assumptions on developments in population, GDP, land productivity and capital. When capital is shocked for a long-term projection, the standard GTAP investment equations may no longer be valid. Alternative options for modelling investments have therefore been added to MAGNET.

14.1 Aim

The alternative investment specification is designed to improve the standard GTAP investment specification, which at times causes improbable baselines or might even cause the model to fail for certain baseline shocks.

The Dixon investment module modifies the standard GTAP investment equations to ensure that the pattern of investment distribution in the world is consistent with exogenously imposed changes in capital stocks over time. Be aware that this does not guarantee that growth in the capital stock on a global scale is consistent with investment on a global scale; rather, only that differences at the end of a period are the same for each country.

14.2 Two approaches to modelling regional investment in standard GTAP

Standard GTAP includes two alternative approaches to modelling regional investment. The choice between the two is governed through the parameter RORDELTA, which is read from the model parameters file (GTAPPARM, which in the standard setup refers to the file ..\4_MAGNET\BaseData\Par\Parameters.prm).

14.2.1 Investment behaviour in GTAP when RORDELTA = 1

The default setting for RORDELTA is 1, and implies that regional investment responds to changes in regional rates of return. As a result, the expected regional rates of return (rore(r)) are equalised across regions, that is, they become equal to the average worldwide rate of return (rorg):

$$\text{rore(r) = rorg} \tag{1}$$

In the MAGNET code this equation is included in RORE1_G:

```
Equation RORE1_G   !RORGLOBAL!
# either gross investment or expected rate of return in region r (HT 59) #
(all,r,GINTCAP_REG) (all,w,GWorld)
    RORDELTA * rore(r)
    + [1 - RORDELTA]
    * [[REGINV(r) / NETINV(r)] * qcgds(r) - [VDEP(r) / NETINV(r)] * qk(r)]
        = RORDELTA * rorg(w)
            + [1 - RORDELTA] * globalcgds(w) + cgdslack(r);
```

Setting RORDELTA to 1 simplifies this equation to:

```
 Equation RORE1_G    !RORGLOBAL!
# either gross investment or expected rate of return in region r (HT 59) #
(all,r,GINTCAP_REG) (all,w,GWorld)
    rore(r)= rorg(w);
```

When allocating investments across regions, we assume decreasing returns. In other words, the expected regional rate of return (rore(r)) declines when capital stock grows:

$$RORE(r) = RORC(r) * [KE(r) / KB(r)]^{- RORFLEX(r)} \qquad (2)$$

where RORC is the current net rate of return to capital in region r, KE(r) is the end-of-period capital stock, KB(r) is the beginning-of-period capital stock, and RORFLEX(r) is a flexibility parameter governing the response of the rate of return to a growth of capital stock. If we have a low value of RORFLEX, expected rates of return change slowly when capital stock grows. This implies that to maintain the same rates of return across regions, large adjustments will be required in capital stocks, namely large changes in regional investments will occur. Vice versa, a large value of RORFLEX will make rates of return very sensitive to changes in capital stock and thus smaller changes in capital stock are needed to maintain the same rate of return across regions. The default value of RORFLEX(r) is 10, namely there will be limited shifts in investments. Equation (2) is included in the model in percentage changes:

```
Variable (all,r,GINTCAP_REG)
   rore(r) # expected net rate of return on capital stock in r #;

 Equation QKE1       !ROREXPECTED!
# expected rate of return depends on the current return and investment (HT 58) #
(all,r,GINTCAP_REG)
    rore(r) = rorc(r) - RORFLEX(r) * [qke(r) - qk(r)];
```

This equation is in practice slightly different. qke is the growth rate of capital stock if investment continues at the current level, while qk is the exogenously given growth rate of capital stock. So, the equation tells us that the difference in the growth rate of expected returns compared with current returns depends on the difference between the two growth rates.

In the case of investment responding to regional rates of return, the percentage change in the global supply of new capital (globalcgds) is given by:

$$globalcgds = \Sigma_r \{[REGINV(r) /GLOBINV]*qcgds(r) - [VDEP(r) / GLOBINV] * gk(r)\} \qquad (3)$$

where REGINV(r) is gross investment (value of the capital goods output), GLOBINV is global expenditures on net investment, qcgds(r) is the regional investment (equal to the output of the capital sector) and VDEP(r) is the value of capital depreciation. Equations 1 and 3 together determine investments in the case that investments respond to regional rates of return.

In MAGNET this equation is included in GLOBALCGDS1_G:

```
 Equation GLOBALCGDS1_G    !GLOBALINV!
# either expected global rate of return or global net investment (HT 11) #
(all,w,GWorld)
    RORDELTA * globalcgds(w)
  + [1 - RORDELTA] * rorg(w)
 = RORDELTA * sum(r,GINTCAP_REG,
            [REGINV(r) / GLOBINV] * qcgds(r) - [VDEP(r) / GLOBINV] * qk(r))
 + [1 - RORDELTA] * sum(r,GINTCAP_REG, [NETINV(r) / GLOBINV] * rore(r));
```

Setting RORDELTA to 1 simplifies this to:

```
Equation GLOBALCGDS1_G      !GLOBALINV!
# either expected global rate of return or global net investment (HT 11) #
(all,w,GWorld)
    globalcgds(w) = sum(r,GINTCAP_REG,
            [REGINV(r) / GLOBINV] * qcgds(r) - [VDEP(r) / GLOBINV] * qk(r));
```

14.2.2 Investment behaviour in GTAP when RORDELTA = 0

The alternative setting for RORDELTA is 0. This second approach to investment takes an extreme position in stating that the regional composition of capital stocks is fixed and thus does not respond to differences in regional returns. This means that equation 1 above no longer applies (regional returns will now vary). Instead, the average global rate of return is computed from the regional rates of return:

$$rorg = \Sigma_r\ [NETINV\ (r)\ /GLOBINV]*rore(r) \tag{4}$$

where NETINV(r) is regional net investment.

Global net investment will now move together with regional investment:

$$globalcgds = [REGINV(r)/NETINV(r)]*qcgds(r) - [VDEP(r)/NETINV(r)]*kb(r). \tag{5}$$

Equations 4 and 5 together determine the investments in the case of fixed regional rates of investment.

In MAGNET these two equations are implemented by simplifying the equations above, but now with RORDELTA set to 0:

```
Equation GLOBALCGDS1_G      !GLOBALINV!
# either expected global rate of return or global net investment (HT 11) #
(all,w,GWorld)
  rorg(w) = sum(r,GINTCAP_REG, [NETINV(r) / GLOBINV] * rore(r));


Equation RORE1_G    !RORGLOBAL!
# either gross investment or expected rate of return in region r (HT 59) #
(all,r,GINTCAP_REG) (all,w,GWorld)
    REGINV(r) / NETINV(r)] * qcgds(r) - [VDEP(r) / NETINV(r)] * qk(r)]
        = globalcgds(w) + cgdslack(r);
```

14.3   Making within-period investment consistent with shocks: the Dixon investment module

The standard GTAP investment equations can lead to inconsistencies when used in baseline projections that include an exogenous shock in capital.[14] Therefore, an alternative investment theory has been included. It is referred to as the Dixon investment, since it was devised by Peter Dixon and Maureen Rimmer. The code discussed below can be found in Inv_Dixon.gmp.

---

[14]   The following is adjusted from the report 'Notes on base case forecasts generated by the Leitap2 model' prepared by Peter B. Dixon and Maureen T. Rimmer (31 October 2008) and 'Notes on projects by Peter B. Dixon and Maureen T. Rimmer' (12 December 2012).

14.3.1 Making shocks to capital consistent with within-period investment

In equation (1), the relationship between the capital stock and the expected rate of return (equation 2) can be rewritten as:

$$KE(r) / KB(r) = A(r) * [RORC(r) / RORG]^{1/RORFLEX} \qquad (6)$$

where A(r) is a parameter. RORG can be interpreted as a worldwide average rate of return, but more accurately, it is a shift variable used to reconcile world investment with world saving. The parameter A(r) is not made explicit in the GTAP model, since it is assumed to be one.
By making A(r) explicit we can derive a value for it using the fact that all equations in the model need to be satisfied by the base-period data. In order for 6.6 to hold with base-period data, the value of A(r) must be set according to

$$A(r) = [KE\_base(r) / KB\_base(r)]* [RORC\_base(r)/ RORG\_base]^{-1/RORFLEX} \qquad (7)$$

where _base denotes base period values for the variables.

If we then combine (6) and (7) we obtain:

$$KE(r) / KB(r) =$$

$$[KE\_base(r) / KB\_base(r)]*[\{RORC(r)/RORC\_base(r) \}/\{RORG/RORG\_base\}]^{1/RORFLEX} \qquad (8)$$

This equation states that capital growth (KE/KB) in region r during the period being simulated by the current model run is equal to the capital growth contained in the base data (KE_base/KB_base) for region r, modified by changes in rates of return in region r (RORC/RORC_base) and the world (RORG/RORG_base).

A key point in equation (8), in relation to using MAGNET for projections over time, is that the investment rate (or capital growth) is in principle determined by capital growth rates in the base-period data (with some adjustments reflecting changes in regional rates of returns). When running projections, however, we assume certain rates of investment and modify capital stocks accordingly. This exogenous information on investments in the period of simulation between periods of simulation is not taken into account in the standard formulation of investment in GTAP as captured in (8). What can happen is that capital endowments are shocked exogenously to reflect projected rates of growth. Due to the relation between capital stock and returns to growth, this will imply a sharp reduction in the rate of return. A low initial rate of return (KE_base/KB_base) from the base data (reflecting low investments in the base period) coupled with a sharp decline in return may result in negative gross investments in the model. This finding is then inconsistent with the exogenous projected growth in capital.

When employing MAGNET for projections, we thus need to account for the exogenous developments in investment that are not captured in the base data. To achieve this we rewrite the investment equation as:

$$\frac{KE(r)}{KB(r)} = D(r) \cdot \left[\frac{KB(r)}{KB\_base(r)}\right]^{1/\tau} \cdot \left[\frac{RORC(r)/RORC\_base(r)}{RORG/RORG\_base}\right]^{1/RORFLEX} \qquad (9)$$

where τ is the length of the period being simulated in years, and D(r) is now a variable rather than a parameter.

Compared with standard GTAP investment (equation 6), the Dixon fix includes an additional KB(r)/KB_base term to capture any exogenous shocks applied to the base capital stock. Raising this to the power of 1/ τ converts a shock over a multi-year period into an annual growth rate (required since all data in the model refer to a one-year period).

We then initialise D(r) to:

$$D\_initial(r) = KE\_base(r) / KB\_base(r) \qquad (10)$$

to ensure that base period data are consistent with (9). We then set D(r) during the simulation to the value of 1:

$$D\_final(r) = 1 \tag{11}$$

which ensures that growth during the period being simulated by the model is equal to the projected average annual growth rate over the period being simulated (therefore we need to include the length of the period τ), modified by changes in the rate of return.

In the model code this amounts to the following equation for the variable v_d(r):

```
Equation V_D_1
 # Dixon variable to assure investment eq. satisfies the based data #
  (all,r,GDINTCAP_REG)
  v_d(r) = (100/C_D(r))*(1 -C_D_B(r))*zero2one;
```

14.3.2 Reducing the volatility of changes in the rate of return, logistic function

When testing the model with equation (9) in place, we ran into a problem. If the rate of return is very low it becomes subject to extremely large percentage changes. This can make KE(r)/KB(r) highly volatile even with the rorflex exponent set as low as 0.1. To remedy this, the equation is modified by driving KE(r)/KB(r) by changes rather than percentage changes in rate of return. To this end, we replaced (9) with:

$$KE(r)/KSB(r) = D(r) \cdot [KB(r)/KB\_base(r)]^{1/\tau} \cdot G[RORC(r) - RORC\_base(r)] \cdot RORG \tag{12}$$

where:

RORG can be interpreted as a shift variable reconciling world saving and investment; and
G is a logistic function controlling the changes in the rate of return relative to the base.

The percentage change terms version of 12 is given by

$$ke(r) - kb(r) = d(r) + 1/\tau* kb(r) + g(r) + rorg \tag{13}$$

where lowercase symbols represent percentage changes in the corresponding uppercase symbols. In the model code this is the Dixon module equation for variable qke(r) (replacing the standard GTAP equation which is defined over GSINTCAP_REG):

```
Equation QKE1_GDINTCAP   !ROREXPECTED!
# Expected rate of return depends on the current return and investment (HT 58) #
(all,r,GDINTCAP_REG) (all,w,MWORLD)
   [qke(r) - qk(r)] = v_d(r) + (1/TAU)*qk(r) + v_g(r) + rorg(w);
```

The G function allows for an increase in the rate of return on capital in region r in period τ relative to its value in the base period [RORC(r) − RORC_B(r)] to increase capital growth across period τ.

The particular form of the G function is a logistic:

$$G[Y(r)] = [A + B \cdot e^{C \cdot Y(r)}] / [1 + e^{C \cdot Y(r)}] \tag{14}$$

where A, B and C are parameters with C positive, and

$$Y(r) = RORC(r) - RORC\_base(r). \tag{15}$$

To calculate this function we require three pieces of information, corresponding to the three parameters. We choose A = 0.9, B=1.1 and apply the constraint G(0.05) = 1.08. This constraint enables us to estimate C (= 43.94449) via

$$G[0.05] = [0.9 + 1.1 \cdot e^{C \cdot 0.05}] / [1 + e^{C \cdot 0.05}] = 1.08. \qquad (16)$$

We can then see that $G(0) = 1$ and that G is an increasing function of Y and its values are constrained to lie between 0.9 and 1.1. This G function is as shown in Figure 14.1. Note that G is restricted to be no more than 10% above its base value of 1 (when $Y = 0$) and no less than 10% below this base value. When RORC(r) is 0.05 above its base value then G is 8 per cent above its base value.
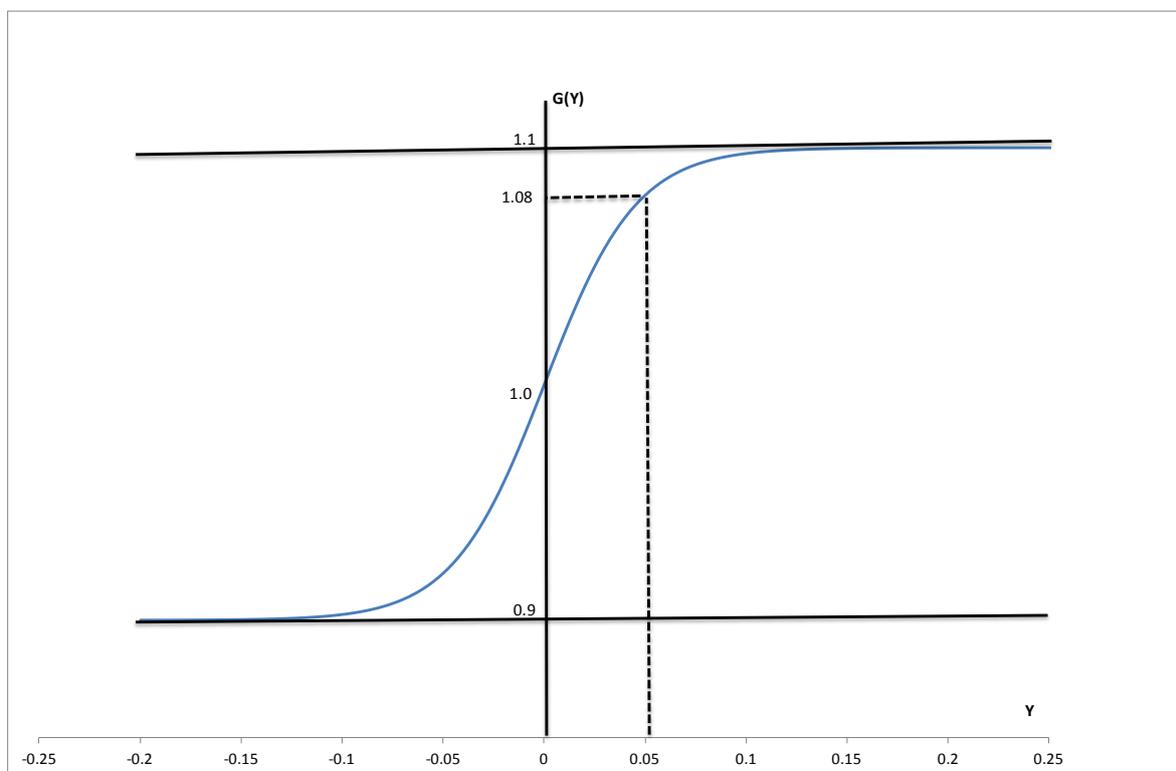

Figure 14.1 *G function calibrated as A=0.9, B=1.1 and constraint on G(0.05)=1.08*

In the implementation in MAGNET we read the lower bound A (G_L), upper bound B (G_U) and the coordinate on which G(Y(r)) is constrained (G_X=0.05, G_Y=1.05) from the parameter file. With these values we then compute the C parameter governing the slope of the G function (G_C):

```
! Calibrate the slope of the logistic function!
Coefficient (parameter)
 G_S # Defines slope of logistic function of capital rate of return #;
 Formula (initial)
  G_S = [1/G_X]*LOGE[(G_Y - G_L)/(G_U - G_Y)];
```

If necessary, the logistic function can thus be adjusted by modifying the default parameter values. The percentage change version of (14) is for variable v_g:

```
Equation V_G1
 # Change in rate of return on capital from base data value #
 (all,r,GDINTCAP_REG)
   v_g(r)= [(G_U - G_L)* exp(G_S*D_ROR(r))
          /{(G_L + G_U * exp(G_S*D_ROR(r)))*(1+exp(G_S*D_ROR(r)))}]
          *100*G_S*d_v_y(r);
```

Where D_ROR(r) is Y(r) and d_v_y(r) is the change in Y(r).

Reducing the volatility of changes in the rate of return, adjustment costs

When testing the model with equation (13) in place, volatility remained a problem. The cause of this can be explained by reference to Figure 14.2.
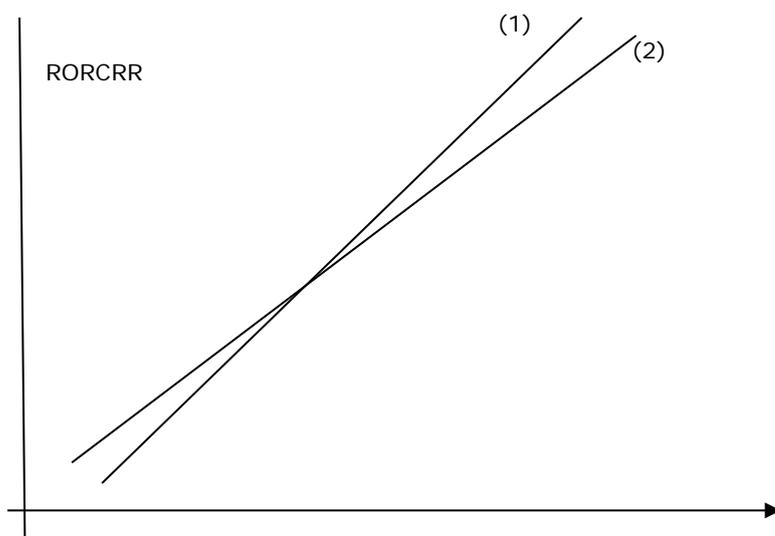
Figure 14.2 *Unstable investment solution; two positive relationships between investments and rate of return*

In Figure 14.2, relationship 1 can be thought as the direct relationship between rates of return and investment as specified in equation 3. Relationship 2 represents the indirect relationship that works through the terms of trade: if investment is high then exports are squeezed out, which generates an increase in the terms of trade which in turn causes an increase in rates of return. As can be seen from Figure 14.2, the movement in investment in response to a shock that causes a horizontal shift in relationship 1 can be unstable. For example, if relationship 1 approaches relationship 2 from below, a rightward shift causes an increase in investment. If relationship 1 approaches relationship 2 from above, a rightward shift causes a reduction in investment.

To make the model more stable, we made an alteration that in effect flattens relationship 2. We did so by introducing an adjustment cost that increases costs to investors of units of capital in response to a strong increase in investment. Adjustment costs in country r are specified as:

$$ADJCOST(r) = [(VINT(r)/VINT\_B)/(INCOME(r)/INCOME(r))]^{\alpha} \tag{17}$$

where:
VINT(r) is the value of investments in country r,
INCOME(r) is income in country r (GNP),
_B denotes base period value,

and α is a parameter with the value 0.5.

In percentage change form, the adjustment cost function is implemented as:

```
Equation ADJ_COST1
 # adjustment costs increase cost of strong investment response #
(all,r,GDINTCAP_REG)
 adj_cost(r) = C_ALPHA*[qcgds(r) + pcgds(r) -  y(r)];
```

With adjustment costs present the rate-of-return variable that drives investment in equation (13) is now written as:

$$RORC(r) = [(RENTAL(r)/VK(r))/ADJCOST(r)] - D(r) \tag{18}$$

where
RENTAL(r)   is rental on capital in country r;
VK(r)   is value of capital stock in country r, and;
D(r)   is rate of depreciation in country r.

Since the base rate of return (RORC_base) is fixed, the change in RORC(r) determines the change in Y(r), which appears in the percentage change version of the logistic function g(r). Using (18) we can define the percentage change equation for d_v_y(r) as:

```
Equation E_d_v_y
   # changes in rate of return affected by adjustment costs #
   (all,r,GDINTCAP_REG)
d_v_y(r) = 0.01*[Sum(h,ENDWC_COMM, VOA(h,r))/(VK(r)*ADJCOST(r))]*
   (sum(h,ENDWC_COMM, ps(h,r)) - (pcgds(r) + adj_cost(r)));
```

14.3.3 Making shocks to capital consistent with within-period investment, other model changes

To implement the Dixon investment module in MAGNET we first need to remove the standard GTAP equation for investment. The relevant equation (QKE1) is defined over GINTCAP_REG. To be able to remove this equation from the model, we define two regions subsets of GINTCAP_REG defined by the model choice to activate the Dixon fix:

```
Coefficient (parameter) DIXONFIX;
Formula (initial) DIXONFIX = 0+if(REG_INV_CH("Dixon")=1,1);
Set GSINTCAP_REG # regions with static GTAP investment theory #
   =(all,r,GINTCAP_REG: DIXONFIX=0);
Set GDINTCAP_REG # regions with Dixon investment theory  #
   =(all,r,GINTCAP_REG: DIXONFIX=1);
```

By redefining the domain of the QKE1 equation to GSINTCAP_REG we can introduce an alternative equation defining the capital stock defined over GDINTCAP_REG.

The Dixon investment module requires that rore(r) = rorg, which is controlled by the RORDELTA parameter. To eliminate the effect of RORDELTA we redefine the domain of the relevant equation RORE1_M which now runs over GSINTCAP_REG (was GINTCAP_REG):

```
Equation RORE1_M
     # When RORDELTA=1 rorg is Walras shifter, when RORDELTA=0 globalcgds#
   (all,r,GSINTCAP_REG) (all,w,MWorld)
   RORDELTA * (rore(r)-rorg(w)+walrasshift(w))
     !regional rate of return equals global rate of return, where the
      walrasshift guarantees that the system is consistent!
   +[1 - RORDELTA]*([[REGINV(r) / NETINV(r)] * (qcgds(r)+cgdslack(r))
         - [VDEP(r) / NETINV(r)] * qk(r)-globalcgds(w)+walrasshift(w)])=0;
```

Thus, it is possible to have a modified GTAP version running that uses the standard GTAP investment theory.

In the Dixon investment module, we provide an alternative equation for cases when the module is activated and not affected by RORDELTA:

```
Equation RORE1_D
     # rorg is the Walras shifter with the Dixon investment theory activated #
   (all,r,GDINTCAP_REG) (all,w,MWorld)
   rore(r) - rorg(w) + walrasshift(w) = 0;
```

The Dixon module uses a variable that is expected to be of more general use and defined in DynamicsDefinitions.gmp of the modified GTAP part of the code:

```
Variable  (change) !del_unity!
   zero2one # Shifts from zero to one $$#;
```

14.3.4 DSS settings to activate the module

DSS tab	DSS question	Actions	Comments
Database	-	-	-
Model	Includes for MAGNET	Select Investment	Adds model code for investment that includes the Dixon fix
Prepare Scenario	Model parameters file	Set Dixon to 1 and all other entries to 0 in header RINV	Selects the Dixon investment theory
Scenario (Gemse)	Model parameters file	Set Dixon to 1 and all other entries to 0 in header RINV	Selects the Dixon investment theory
Downscale	-	-	-

Note on reading of length of period (TAU) from file

The length of the time period (TAU) is a parameter needed to translate a shock to capital endowments into annual change. It is read from the YEAR header in the GTAPPARM file, which is not period-specific. However, when the model is run in DSS the header YEAR is adjusted to contain the proper length of the current period, making this header consistent with the length of the period being run. Although not very transparent, this effectively makes the GTAPPARM file period-specific. If the model is run outside DSS, period-specific GTAPPARM files need to be created (with the length of the period in the YEAR header) and referred to in the cmf file used to run the model.

15   Bilateral tariff rate quota module

15.1   Aim

The bilateral tariff rate quota (BTRQ) module allows for the modelling of tariff rate quota on bilateral imports in MAGNET. Tariff rate quota emerged from the Uruguay Round Agreement on Agriculture as a new policy mechanism that ensures both tariffication and market access.
BTRQs combine elements of both tariffs and quotas; imports up to some fixed quantity are subject to a lower tariff (in-quota tariff), while imports above that quantity are subject to a higher tariff (over-quota tariff).

Tariff rate quotas may be described by a complementarity condition that states that either imports are in quota and the in-quota tariff rate is effective, or imports are over quota and the over-quota tariff rate is effective, or imports are on quota (and the actual tariff is somewhere in between). In the latter two cases, positive quota rents are generated and accrue either to importers or to exporters or are shared depending on the way in which BTRQs are administered (see Skully 2001a).

15.2   How to model bilateral tariff rate quota in MAGNET using GEMPACK

15.2.1 Approach in GEMPACK

In contrast to, for example, GAMS, the linearisation used by GEMPACK complicates the implementation of complementarities. Fortunately, a two-pass method for accurately solving models containing complementarity conditions has been developed (see Harrison et al., 2004).

Step 1: The approximate simulation
A single Euler computation, of limited accuracy, is used to discover which constraints will finally bind. The basic Euler procedure is modified with: (1) Newton corrections after each Euler step so as to force the solution path back on the appropriate branch of the complementarity condition, and; (2) variable step length to minimise overshooting. The two modifications ensure that the solution path in the first, approximate run 'hugs' complementarity equations very closely and so enables an accurate prediction of the final state.

Step 2: The accurate simulation
Using the results from step 1 to predict which constraints will finally bind, the complementarity condition is replaced by one of three statements: the in-quota tariff rate is effective (imports are in quota), the over-quota tariff rate is effective (imports are over quota), or imports are on quota (and the actual tariff is somewhere in between).

GEMPACK checks that the post-simulation variable values are consistent with the final complementarity states that were predicted by the approximate simulation and were used to set closure and shocks for the second, accurate simulation. If not, an error message is given. If automatic accuracy is used, the process is repeated automatically using more, smaller steps in the first approximate simulation.

The complementarity condition in GEMPACK is formulated as follows (using our example of BTRQ):

```
=================================================================
==Complementarity (Variable = TMSTRQ, Lower_Bound = 1, Upper_Bound = TMSTRQOVQ)
  TMSTRQ1      # Complementarity expression for actual extra power of import tariff #
    (all,j,BTRQ_COMM)(all,r,BTRQ_SREG)(all,s,BTRQ_DREG)  1-BTRQ_RATIO(j,r,s);
=================================================================
```

A few additional variables have been introduced so as to create a complementarity variable, namely TMSTRQ, with a lower bound of one. Specifically, TMSTRQOVQ is the full extra power of the over-quota import tariff (calculated as TMSOVQ/TMSINQ), and TMSTRQ is the actual extra power of the import tariff (calculated as TMS1_TRQ/TMSINQ). BTRQ_RATIO is the ratio of bilateral imports to the quota level. Now, following the complementarity statement, one of three situations may hold:

(1)   TMSTRQ, the complementarity variable, equals 1, and 1-BTRQ_RATIO, the quota expression, exceeds 0 (imports are in quota). Notice that this implies that the actual power of the import tariff, TMS1_TRQ, equals TMSINQ;

(2)   1<=TMSTRQ<=TMSTRQOVQ, and 1-BTRQ_RATIO equals 0 (imports are on quota). Notice that this implies that the actual power of the import tariff, TMS1_TRQ, is somewhere between TMSINQ and TMSOVQ;

(3)   TMSTRQ=TMSTRQOVQ, and 1-BTRQ_RATIO < 0 (imports are over quota). Notice that this implies that the actual power of the import tariff, TMS1_TRQ, equals TMSOVQ.

Figure 1 in the appendix contains a graphical exposition of the three cases. As can be seen, the quota-related variables are levels variables and are redefined in ratios. This is done to ensure that they have values of the same order of magnitude (around 1) and avoids potential scaling problems. The above formulation is based on GEMPACK documentation, GPD-3, Chapter 16, 16.8.4, which draws from Elbehri and Pearson (2000), but with complementarity statements. (An alternative formulation, using the actual power of the tariff as the complementarity variable with the powers of the in- and over-quota tariff rates as lower and upper bounds, respectively, is provided in GPD-3, Chapter 16, 16.8.5).

15.2.2 Linking bilateral tariff rate quota to the remainder of the model

The BTRQ module is linked to the remainder of the model by:

- Specifying how the (percentage change in the) BTRQ ratio for BTRQ triples relates to (the percentage change in) bilateral imports and the (percentage change in the) quota level.
- Linking the actual power of the import tariff (TMS1_TRQ, which feeds into the, otherwise identical, percentage change variable tms_trq) for triples with BTRQ to the, normally exogenous, percentage change in the actual power of the bilateral import tariff (tms).
- Adjusting regional income for BTRQ rents generated by BTRQ triples (see below).

15.2.3 Rents and import tariff revenues associated with bilateral tariff rate quota

All imports pay the same import tariff under the current treatment of BTRQ. In particular, if imports are over quota, all imports pay the full over-quota tariff TMSOVQ, not just those that came 'after' the first quota volume of imports. The quota rent (and in-quota tariff revenue) is thus included in the on- or over-quota bilateral import tariff (see appendix, Figure 2). Moreover, in standard GTAP all import tariff revenues automatically accrue to the importing region, so that the revenues arising from the actual power of the bilateral import tariff, including any rents, also automatically accrue to the regional household of the region imposing the BTRQ (i.e. the importing region). Using BTRQSHARE_X (the share of the rent accruing to the exporting region), rents can be reallocated to the exporting region. In order to maintain consistency with the base data, this share should initially be set to 0 (that is, if the base data have not been adjusted), but, if necessary, it can be shocked to its true value using the model. The results of such a preliminary simulation can then be used as a starting point for further analysis (see Elbehri and Pearson 2000, section 6.9.1).

The calculation of import tariff revenues associated with bilateral tariff rate quotas (BTRQs) distinguishes between revenues associated with the endogenous bilateral import tax (BTRQ_TREV) and the endogenous bilateral import tax plus the exogenous generic import tax (BTRQ_TTREV),[15] for imports that are in quota (TINQ_REV, TINQ_TREV) or over quota (TOVQ_REV, TOVQ_TREV), and for the individual BTRQ flow and the importing region in total (indicated by _M).

All BTRQ rent and import tariff revenue variables are 'levels, change' variables such that results are reported in absolute rather than relative (%) changes (this is suitable for variables with a starting value of zero).

If part of the BTRQ rents that are generated accrue to exporting regions, regional income has to be adjusted. Specifically, the total rent that importing region r pays to exporters for BTRQ commodities should be taken out of the regional income of region r, whereas the total rent that r as an exporter receives for BTRQ commodities should be added to its regional income. This is achieved by adjusting two equations:

- Equation DEL_TAXRIMP1 (renamed DEL_TAXRIMP_BTRQ in the BTRQ module): total rents that importing r pays to exporters for BTRQ commodities (TBTRQRENT_TR) is subtracted from import tax income of region r (defined over BTRQ_DREG).
- Equation Y1 (renamed Y_BTRQ in the BTRQ module): total rent that r as exporter receives for BTRQ commodities (TBTRQRENT_X) is added to regional income of r (defined over BTRQ_SREG).

The equations DELTAXRIMP1 and Y1 as present in GTAP.gmp have been redefined over GNBTRQDREG and GNBTRQSREG, respectively.

Concerning regional welfare, the calculation of EV is correct. However, the alternative EV (EV_ALT) is not and should have the same terms subtracted (TBTRQRENT_TR) and added (TBTRQRENT_X) to its equation. Moreover, in the welfare decomposition, a separate equation and variable could be added to account explicitly for the welfare contribution of BTRQ rent transfers.

---

[15] Notice that the bilateral import tax (and its components), TMS, is in addition to the generic import tax, TM.

15.2.4 Overview of changes to MAGNET

Phase	Directory\File	Subfile
Model structure	*ModelDefinition\ModelStructure*	
	ModelStructure.gmp	BTRQ.gmp Specification of choice parameter, REG_BTRQ_CH (see BTRQ_activate.gmp)
Data	*ModelDefinition\MagnetAgg*	
	MagnetAgg.gmp	BTRQ.gmp Three arrays of external data are needed to model BTRQ, namely the quota levels and the associated in- and over-quota tariff rates. The actual power of the import tariff also needs to be initialised. Standard GTAP data are used to initialise the BTRQ module: initialisation of BTRQ at current value of bilat. exports (= imports!) at market prices in source region r (VXMD), at which bilateral exports, i.e. imports, (QXS) are also initialised (with PM = 1), i.e. the BTRQ that are present are binding the power of the in-quota tariff rate is set to 1 the power of the over-quota tariff rate is set to 8 the actual power of the import tariff is set to VIMS/VIWS (i.e. the way it is normally calculated)
Model code	*MAGNET\CodeMainProgram*: MAGNET.GMP	
	ModuleDefinition.gmp	BTRQ_activate.gmp new choice parameter, REG_BTRQ_CH, defined over traded commodities and regions which: activates the BTRQ module (indirectly via sets; see below) used to limit domain of BTRQ-related equations to sector *and* (source & destination) region combinations with BTRQ in place new sets based on the choice parameter: BTRQ_SREG: source regions that face at least one BTRQ BTRQ_DREG: destination regions that impose at least one BTRQ BTRQ_COMM: traded commodities with at least one BTRQ GTAP non-BTRQ source and destination region sets (GNBTRQSREG, GNBTRQDREG) have been created so as to be able to adjust the relevant regional income equations
	BTRQ.gmp	BTRQ_history.gmp development of module based on set up of MAGNET Quota module using GEMPACK example G5BTRQ.TAB (see GEMPACK documentation, GPD-3, 16.8.4), derived from Elbehri and Pearson (2000)
		BilImportTax.gmp The change in the bilateral import tax (tms) now has an equation linking it to the (endogenous) import tax change derived from the BTRQ module (tms_trq): tms is made endogenous for sectors, source and destination regions with quota (elements of BTRQ_SREG, BTRQ_DREG and BTRQ_COMM) otherwise, for regions (and sectors) without BTRQ, tms is exogenous as before tms is defined as the percentage change in the power of the tax TMS(=PMS/(PCIF*TM)) and so is tms_trq
		BTRQ_implement.gmp Specification of BTRQ: initial BTRQ taxes and levels are read in over traded commodities and regions so as to allow switching on and off without needing to recreate database choice parameter is used as a dummy to further restrict the equations to only those region and sector combinations with BTRQ in multi-period runs, the initial quota level is updated to current value, since initialisation is based on value of bilateral exports at market prices (VXMD) complementarity statement governs the modelling of BTRQ. It has been formulated over variables in levels, with most variables as ratios close to one to avoid scaling problems: TMSINQ: power of the in-quota import tariff TMSOVQ: power of the over-quota import tariff TMSTRQOVQ: full extra power of over-quota import tariff (calculated as TMSOVQ/TMSINQ) TMS1_TRQ: actual power of the import tariff – linked up with tms_trq TMSTRQ: actual extra power of the import tariff (calculated as TMS1_TRQ/TMSINQ)

BTRQ: quota level
BTRQ_RATIO: ratio of bilateral imports to the quota level
the complementary statement distinguishes the following cases:
State 1: imports are in quota (BTRQ_RATIO <1, TMSTRQ =1)
State 2: imports are on quota (BTRQ_RATIO=1,
1<=TMSTRQ<=TMSTRQOVQ)
State 3: imports are over quota (BTRQ_RATIO>1,
TMSTRQ=TMSTRQOVQ)
the complementarity statement is the only equation which cannot be
limited to BTRQ triples

BTRQ_rents.gmp
Calculating and allocating rents of bilateral tariff rate quota, as well as
import tariff revenues associated with in-quota and over-quota imports:
allocation of rents according to exogenously specified BTRQSHARE_X
(share of rents going to exporting region)
in standard GTAP all import tariff revenues accrue to the importing
region, hence, in line with the GTAP base data, BTRQSHARE_X has to be
set to 0 initially (if necessary, use the model to shock the share to its
true value)
calculation of tariff revenues associated with:
the endogenous bilateral import tax
the endogenous bilateral import tax plus the exogenous generic import
tax
for imports that are:
in quota or
over quota
and for:
the individual BTRQ flow
and the importing region in total

BTRQ_regincome.gmp
Adjusting regional income equations for BTRQ rents:
equation DEL_TAXRIMP1 (renamed to DEL_TAXRIMP_BTRQ in the BTRQ
module): total rents that importing r pays to exporters for BTRQ
commodities (TBTRQRENT_TR) is subtracted from import tax income of
region r (defined over BTRQ_DREG)
equation Y1 (renamed to Y_BTRQ in the BTRQ module): total rent that r
as exporter receives for BTRQ commodities (TBTRQRENT_X) is added to
regional income of r (defined over BTRQ_SREG)
redefined equations DEL_TAXRIMP1 and Y1 as present in GTAP.gmp over
GNBTRQDREG and GNBTRQSREG respectively

Closure	MAGNET\CommandFiles\ Closures	BTRQClosure.cmf Endogenous: tms(BTRQ_COMM,BTRQ_SREG, BTRQ_DREG) Exogenous: BTRQ(TRAD_COMM,REG, REG) TMSINQ(BTRQ_COMM,BTRQ_SREG, BTRQ_DREG) TMSOVQ(BTRQ_COMM,BTRQ_SREG, BTRQ_DREG) BTRQSHARE_X(BTRQ_COMM,BTRQ_SREG, BTRQ_DREG)

15.2.5 Switching the bilateral tariff rate quota module on and off using sets

The scheme below illustrates how the bilateral tariff rate quota module is linked to the core MAGNET
model.

MAGNET
tms(TRAD_COMM, REG,
REG)

tms_trq(j,r,s)
only for btrq_comm,
btrq_sreg and btrq_dreg;
else tms(j,r,s) remains
exogenous

Bilateral tariff rate quota
BTRQ_SREG *E* REG
BTRQ_DREG *E* REG
BTRQ_COMM *E* TRAD_COMM
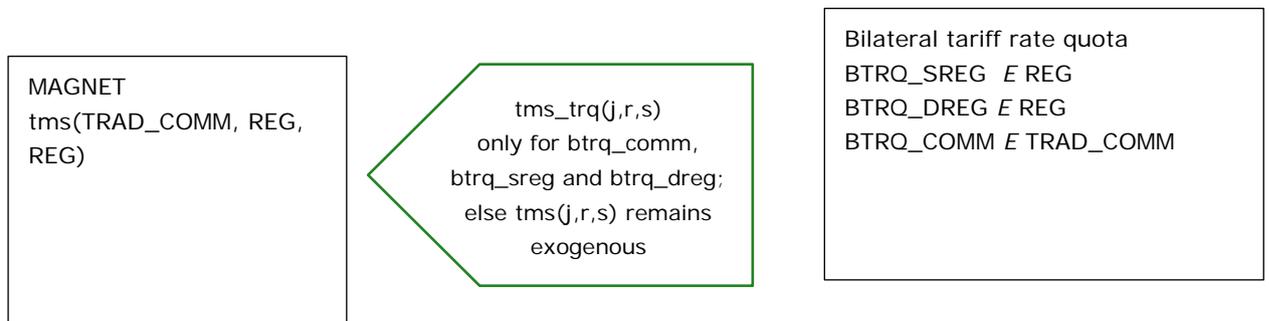
BTRQ_COMM: traded commodities with at least one BTRQ. BTRQ_SREG: source regions with at least one BTRQ. BTRQ_DREG: destination regions with at least one BTRQ. As a result, tms will be exogenous for (source, destination) regions without BTRQ and for sectors without BTRQ, and endogenous otherwise (and will then result from the BTRQ module).

By implication, triples with zeros may be included in the BTRQ module. Such cases are dealt with in the BTRQ module by further restricting equations to only those sectors, source *and* destination region combinations with BTRQ (as defined by the choice parameter, REG_BTRQ_CH).

Equations of the main model that need adjusting rather than being added, namely those with respect to regional income, are redefined over GTAP non-BTRQ source and destination region sets, GNBTRQSREG and GNBTRQDREG, respectively, so that the accompanying equations in the BTRQ module, defined over BTRQ_SREG and BTRQ_DREG, can be adjusted.

15.3   Additional data

Three arrays of external data are needed to model BTRQ, namely the quota levels and the associated in- and over-quota tariff rates.[16] We also need to initialise the actual power of the import tariff.

Lacking better data, we use standard GTAP data to initialise the BTRQ module. Specifically, we initialise BTRQ at current bilateral export value levels (VXMD), as qxs (at least, the associated levels variable) is also initialised using this value (with PM=1). We thus assume that the BTRQs are binding. The power of the in-quota tariff rate is set to 1. The power of the over-quota tariff rate is set to 8 (random number which must exceed 1; very high so that it is prohibitive). The actual power of the import tariff is set to VIMS/VIWS (the way it is normally calculated; implying that rents are likely to be present).

If external data are used, these need to be made consistent with GTAP data (see Elbehri and Pearson 2000 for a procedure on how to do this). In that case this procedure needs to be replaced. For a procedure to aggregate external quota data at more detailed tariff line levels to the GTAP database see Lips and Rieder (2002).

---

[16] Elbehri and Pearson (2000) and the GEMPACK elaboration suggest using three different arrays, namely TMSTRQOVQ, and the value of the quota volume of imports at world prices and the value of the quota volume of imports at the world price plus the in-quota tariff rate. This approach is motivated by the fact that GTAP data are in values. Even though TMSINQ, TMSOVQ and the quota level can indirectly be inferred from these data, it is more likely that outside estimates of these variables are obtained directly (rather than estimates of the value data on the quota volume and TMSTRQOVQ), which then have to be made consistent with GTAP data. This is therefore also our preferred approach.

15.4 Activating and using the bilateral tariff rate quota module in DSS

15.4.1 Settings in DSS

DSS tab	DSS question	Actions	Comments
Database	-	-	-
Model	Includes for MAGNET	Select btrq	Adds the model code for the btrq module
Prepare Scenario	Closure file	Add BTRQClosure.cmf to the closure list	Fixes BTRQ levels, in- and over-quota tariff rates and share of rents going to exporters (zero)
Scenario (Gemse)	Closure file	Add BTRQClosure.cmf to the closure list	Fixes BTRQ levels, in- and over-quota tariff rates and share of rents going to exporters (zero)
	Model parameters file	Adjust headers in ModelSettings.prm as described in table below	Assigns btrq to sectors, source and destination region combinations

15.4.2 Adjustments to headers in ModelSettings.prm file

Header	Required setting	Comments
MODG	1	Sets MAGNET in modified GTAP mode which allows to add modules
BTRQ	A matrix of sectors and source and destination regions; putting a 1 in a cell imposes a btrq	A 0 in this matrix implies that there is no btrq for the combination in question; a 1 implies that there is a btrq

15.4.3 Options for solution method command file

It is also useful to know that there are various options or command file statements available for the solution method of complementarity simulations (see 16.6 of GPD-3, Chapter 16). Options include:

- Specify the number of Euler steps in the approximate run (optional if default is not satisfactorily).
- Omit the approximate run (if you think the shocks will not cause any state changes) to save time. Default is YES. Check results carefully!
- Do not redo a step if state changes occur during approximate run (can slow down accurate run, but is more accurate). Default is YES.
- Step length when redo step. Default is 0.005.
- Treat state or bound errors as warnings only (normally such errors are fatal, unless using automatic accuracy in which case the subinterval is redone automatically). Default is FATAL.
- Omit the accurate run, for example if your model is large and takes a long time to solve, and are happy with the results of the approximate run (statement: complementarity do_acc_run = no;). Default is YES (so put an exclamation mark in front of the statement so as to stick to the default). Note restrictions on when this can be applied (notably: if you carry out only the approximate run you must switch off automatic accuracy and Euler must be used as solution method. Gragg may also be used in accurate run).

15.5 Analysis of results

The most likely simulations that will be carried out are those concerning the liberalisation of BTRQs, that is, reducing the in-quota tariff, reducing the over-quota tariff or expanding the quota level. What happens to market access depends on which of the BTRQ regime elements currently constrain imports and which element or elements are likely to constrain imports in the future. Naturally, rents may also be affected. See Skully (2001b) for more on the economics behind tariff rate quota liberalisation. The log file, which can be found in the MAGNET\Scenarios directory of the accompanying scenario, reports the results of the approximate and accurate simulation. Specifically you can find:

- The numbers in pre- and post-sim states 1, 2 and 3 (imports are respectively in, on or over quota).
- Whether there are state changes (and if so, when they occur).
- Any error messages will be included in here. For example, if post-sim states are not the same as those found after the approximate run, or post-sim values of complementarity variables are outside specified bounds (search for '%%' to find error messages).

Search for 'complementarity' throughout the file to see how each of the stages went and, if any, when state changes occur.

In <u>AnalyseGE</u> you can open the accompanying solution file (ending with .sl4; it can be found in MAGNET\Solutions directory of accompanying scenario). Again, search for complementarity, right click and select 'show state and variable values'. The resulting table shows (for all combinations of the elements of BTRQ_SREG, BTRQ_DREG and BTRQ_COMM, i.e. may include non-BTRQ triples):
- Pre- and post-sim states: state-pre, state-post (1 = in, 2 = on, 3 = over quota)
- Pre- and post-sim values of the complementarity variable (TMSTRQ): var-pre, var-post
- Pre- and post-sim values of the complementarity expression (1-BTRQ_RATIO): exp-pre, exp-post
- Pre- and post-sim values of the lower bound of the complementarity variable: lb-pre and lb-post (set to one)
- Pre- and post-sim values of the upper bound of the complementarity variable: ub-pre and ub-post (set to TMSTRQOVQ, which has the value of eight)

You can also directly open the solution file (with extension .sl4) in <u>ViewSol</u>. It will contain extra variables that are introduced to model the complementarity condition for the bilateral tariff rate quota on imports:
- $TMSTRQ@D: dummy variable in complementarity, used during approximate run to switch on the equation during the approximate run and to switch off the equation during the accurate run (contains zeros)
- cTMSTRQ1@E: change in the complementarity expression (if positive, then quota ratio has fallen, otherwise it has risen)
- cTMSTRQ1@U: change in the difference between the complementarity variable and the upper bound in the complementarity. Needed since the upper bound is a variable and not a known value (as is the lower bound)

These are of no concern to the user (see 16.7 of GPD-3, Chapter 16 and Harrison et al., 2004, section 3.3. for an explanation of how GEMPACK treats complementarities during a simulation and which variables are introduced along the way. These variables are included in the log file). The only concern for the user is that all components of the complementarity variable, TMSTRQ, are endogenous. Other relevant results to check (in ViewSol):
- p_ibtrq: change in initial bilateral import quota level (%)
- p_BTRQ: change in bilateral import quota level (%)
- p_BTRQ_RATIO: change in import quota ratio (%)
- p_TMSOVQ: change in power of the over-quota bilateral import tariff (%)
- p_TMSINQ: change in power of the in-quota bilateral import tariff (%)
- p_TMSTRQOVQ: change in the full extra power of the over-quota bilateral import tariff (%)
- p_TMSTRQ: change in the actual extra power of the bilateral import tariff (%)
- p_TMS1_TRQ: change in the actual power of the bilateral import tariff resulting from BTRQ module (%)
- tms: change in the bilateral import tariff (%)
- tms_trq: change in the bilateral import tariff that results from the BTRQ module (%)
- qxs: change in bilateral imports (%) = p_QXS_L. NB. Exports from r to s are imports by s from r!
- pms(j,r,s): change in domestic price of good j (including generic and bilateral import taxes), supplied from r to s (%).

Note: P_TMS1_TRQ = tms_trq = tms for BTRQ triples!

To see how r_tms has changed (calculated ex-post), open the update_tax file (it can be found in MAGNET\Updates directory) of the accompanying scenario in ViewHar and compare it with its values in the base data (MAGNET\BaseData directory).

BTRQ rent and tariff revenue variables (in ViewSol):

- c_BTRQ_RENT: absolute change in BTRQ rent associated with a BTRQ triple
- c_BTRQSHARE_X: absolute change in share of a BTRQ rent that accrues to the exporting region
- c_BTRQRENT_M: absolute change in value of a BTRQ rent that accrues to the importing region
- c_BTRQRENT_X: absolute change in value of a BTRQ rent that accrues to the exporting region
- c_TBTRQRENT_M: absolute change in total rents (over all BTRQ flows) captured by importing region r
- c_TBTRQRENT_TR: absolute change in total rents (over all BTRQ flows) transferred by importing region r to foreign suppliers
- c_TBTRQRENT_X: absolute change in total rents (over all BTRQ flows) captured by exporting region r
- c_TBTRQRENT_jr: absolute change in total rents associated with BTRQ commodity j imposed by importing region r
- c_BTRQ_TREV: absolute change in tax rev from bilat. import tax levied by s on BTRQ comm. j from r
- c_BTRQ_TREV_M: absolute change in total tax rev. from bilat. import taxes levied by s on BTRQ comm. j
- c_BTRQ_TTREV: absolute change in total tax rev. from import taxes levied by s on BTRQ comm. j from r
- c_BTRQ_TTREV_M: absolute change in total tax rev. from import taxes levied by s on BTRQ comm. j
- c_TINQ_REV: absolute change in in-quota bilat. import tax rev. in s on BTRQ comm. j from r
- c_TINQ_REV_M: absolute change in total in-quota bilat. import tax rev. in s on BTRQ comm. j
- c_TINQ_TREV: absolute change in total in-quota import tax rev. in s on BTRQ comm. j from r
- c_TINQ_TREV_M: absolute change in total in-quota import tax rev. in s on BTRQ comm. j
- c_TOVQ_REV: absolute change in over-quota bilat. import tax rev. in s on BTRQ comm. j from r
- c_TOVQ_REV_M: absolute change in total over-quota bilat. import tax rev. in s on BTRQ comm. j
- c_TOVQ_TREV: absolute change in total over-quota import tax rev. in s on BTRQ comm. j from r
- c_TOVQ_TREV_M: absolute change in total over-quota import tax rev. in s on BTRQ comm. j

15.6   References

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15.7   Appendix
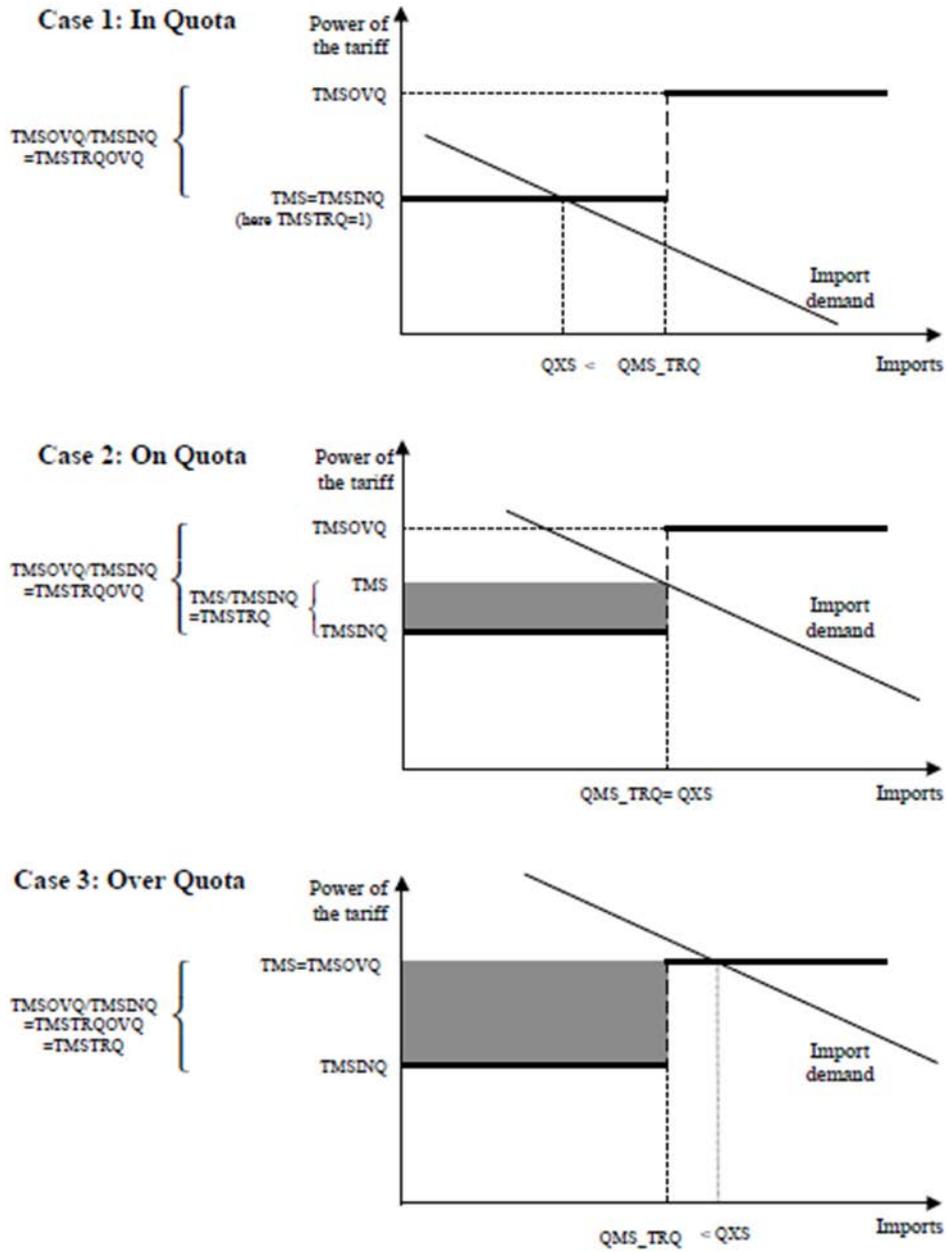
Source: adapted from Elbehri and Pearson (2000; Figure 2, p.7)

Figure 1: Key variables in a bilateral tariff rate quota regime
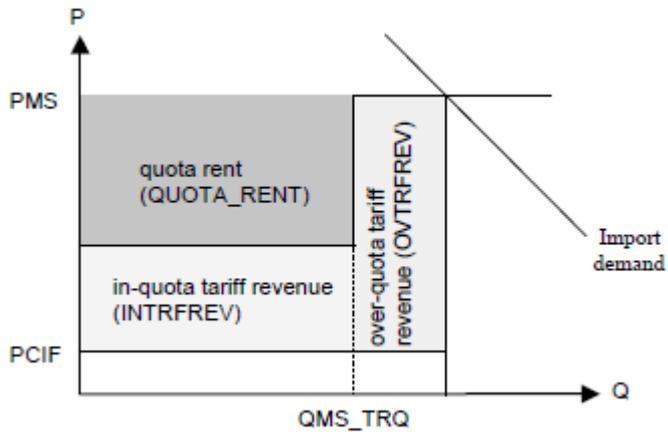
Source: adapted from Elbehri and Pearson (2000; Figure 4, p.19)

Figure 2: *Quota rents and tariff revenues*

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