Detailed description of the CAPRI model

CAPRI is a success story of an economic model developed by European Commission research funds, the first one 1996-1999. Operational since more than a decade (1999), it supports decision making related to the Common Agricultural Policy and Environmental policy related to agriculture based on sound scientific quantitative analysis. CAPRI models exclusively the agricultural sector paying special attention to the European Union. CAPRI is only viable due to its Pan-European network of researchers which based on an open source approach tender together for projects, develop and maintain the model, apply it for policy impact assessment, write scientific publications and consult clients based on its results. The full documentation is downloadable (229 p, http://www.capri-model.org/docs/capri_documentation_2011.pdf). A compact overview and comparison with GTAP is given by Britz and Keeney (https://www.gtap.agecon.purdue.edu/resources/download/4715.pdf). In the following we will describe the key elements in some detail.

1 Database

Models and data are almost not separable. Methodological concepts can only be put to work if the necessary data are available. Equally, results obtained with a model mirror the quality of the underlying data. The CAPRI modelling team consequently invested considerable resources to build up a data base suitable for the purposes of the project. From the beginning, the idea was to create wherever possible sustainable links to well-established statistical data and to develop algorithms which can be applied across regions and time, so that an automated update of the different pieces of the CAPRI data base could be performed as far as possible.
The main guidelines for the different pieces of the data base are:

- Wherever possible link to harmonised, well documented, official and generally available data sources to ensure wide-spread acceptance of the data and their sustainability.
- Completeness over time and space. As far as official data sources comprise gaps, suitable algorithm were developed and applied to fill these.
- Consistency between the different data (closed market balances, perfect aggregation from lower to higher regional level etc.)
- Consistent link between ‘economic’ data as prices and revenues and ‘physical data’ as farm and market balances, crop rotations, herd sizes, yields and input demand.

According to the different regional layers interlinked in the modelling system, data at Member State level (in terms of modelling) -currently EU27 plus Norway and Western Balkan countries - need to fit to data at regional level -administrative units at the so-called NUTS 2 level, about 300 regions for EU25- and data at global level, currently 23 non-EU regions. A further layer consists of georeferenced information at the level of clusters of 1x1 km grid cells which serves as input in the spatial down-scaling part of CAPRI. This data base is discussed along with the methodology and not in the current chapter. As it would be impossible to ensure consistency across all regional layers simultaneously, the process of building up the data base is split in several parts:

- Building up the data base at *national or Member State level.* It integrates the EAA (valued output and input use) with market and farm data, with areas and herd sizes and a herd flow model for young animals.
- Building up the data base at *regional or NUTS 2 level* , which takes the national data basically as given (for purposes of data consistency), and includes the allocation of inputs across activities and regions as well as consistent acreages, herd sizes and yields at regional level.
- Building up the *global data base*, which includes supply utilisation accounts for the other regions in the market model, bilateral trade flows, as well as data on trade policies (Most Favourite Nation Tariffs, Preferential Agreements, Tariff Rate quotas, export subsidies) plus data domestic market support instruments (market interventions, subsidies to consumption).
- Given the extent of public intervention in the agricultural sector, policy data complete the database. They are partly supply oriented CAP instruments like premiums and quotas and partly data on trade policies (Most Favourite Nation Tariffs, Preferential Agreements, Tariff Rate quotas, export subsidies) plus data domestic market support instruments (market interventions, subsidies to consumption).

1.1 Production Activities as the core

The economic activities in the agricultural sector are broken down conceptually into 'production activities' (e.g. cropping a hectare of wheat or fattening a pig). These activities are characterised by physical *output and input coefficients*. For most activities, total production quantities can be found in statistics and *output coefficients* derived by division of activity levels (e.g. 'soft wheat' would produce 'soft wheat' and 'straw', whereas 'pigs for fattening' would produce 'pig meat' and NPK comprised in manure). However, for some activities other sources of information are necessary (e.g. a carcass weight of sows is necessary to derive the output coefficient for the pig fattening process). For manure output engineering functions are used to define the output coefficients.
The second part characterising the production activities are the *input coefficients*. Soft wheat, to pick up our example again, would be linked to a certain use of NPK fertiliser, to the use of plant protection inputs, repair and energy costs. All these inputs are used by many activities, and official data regarding the distribution of inputs to activities are not available. The process of attributing total input in a region to individual activities is called input allocation. It is methodologically more demanding than constructing output coefficients. Specific estimators are developed for young animals, fertilisers, feed and the remaining inputs, which are discussed below.
Multiplied with average farm gate prices for outputs and inputs respectively, output coefficients define farm gate revenues, and input coefficients variable production costs. The average farm prices used in the CAPRI data base are derived from the EEA and hence link physical and valued statistics. However, in some cases as young animals and manure which are not valued in the EEA, own estimates are introduced.
In order to finalise the characterisation of the income situation in the different production activities, subsidies paid to production must be taken into account. The CAPRI data base features a rather complex description of the different CAP premiums allocated to the individual activities. However, the problem of subsidies outside of CAP for the EU Member States remains so far unsolved. The following table gives an example for selected activity related information from the CAPRI data base.

Example of selected data base elements for a production activity

	SWHE [Soft wheat production activity]	Description	Unit
Outputs			
SWHE	7853.84	Soft wheat yield	kg/ha
STRA	9817.30	Straw yield	kg/ha
Inputs			
NITF	175.52	Organic and anorganic N applied	kg/ha
PHOF	49.57	Organic and anorganic P applied	kg/ha
POTF	62.51	Organic and anorganic K applied	kg/ha
SEED	70.91	Seed input	const Euro 1995/ha
PLAP	59.85	Plant protection products	const Euro 1995/ha
REPA	53.27	Repair costs	const Euro 1995/ha
ENER	25.15	Energy costs	const Euro 1995/ha
INPO	79.25	Other inputs	const Euro 1995/ha
Income indicators			
TOOU	825.26	Value of total outputs	Euro/ha
TOIN	522.13	Value of total inputs	Euro/ha
GVAP	303.13	Gross value added at producer prices	Euro/ha
PRME	328.86	CAP premiums	Euro/ha
MGVA	631.99	Gross value added at producer prices plus premiums	Euro/ha
Activity level and data relating to CAP			
LEVL	609.91	Hectares cropped	1000 ha
HSTY	5.22	Historic yield used to define CAP premiums	t/ha
SETR	8.63	Set aside rate	%

Source: CAPRI data base, Denmark, three year average 2000-2002

1.2 Linking production activities and the market

The connection between the individual activities and the markets are the activity levels. Total soft wheat produced is the sum of cropped soft wheat hectares multiplied with the average soft wheat output coefficient. In cases like pig meat, as mentioned before, several activities are involved to derive production.
The produced quantities enter the farm and market balances. Production plus imports as the resources are equal to the different use positions as exports, stock changes, feed use, human consumption and processing. These balances are only available at Member State, not at regional level. Production establishes the link to the EAA as well, as average farm gate prices are unit values derived by dividing the values from the EAA by production quantities.
There are three basic identities linking the different elements of the data base. The first equation implies that total production or total input use (code in the data base: GROF or gross production/gross input use at farm level) can be derived from the input and output coefficients and the activity levels (LEVL):

Equation 1 $$GROF_{io} = \sum_j LEVL_j IO_j$$

The second type of identities refers to the farm and market balances:

Equation 2

$$\begin{aligned} GROF_{io} - SEDF_{io} - LOSF_{io} - INTF_{io} &= NETF_{io} \\ NETF + IMPT_{io} &= EXPT_{io} + STCM_{io} \\ &+ FEDM_{io} + LOSM_{io} \\ &+ SEDM_{io} + HCOM_{io} \\ &+ INDM_{io} + PRCM_{io} \\ &+ BIOF_{io} \end{aligned}$$

The farm balance positions are seed use (SEDF) and losses (LOSF) on farm (only reported for cereals) and internal use on farm (INTF, only reported for manure and young animals). NETF or net trade on farm is hence equal to valued production/input use and establishes the link between the market and the agricultural production activity. Adding imports (IMPT) to NETF defines total resources, which must be equal to exports (EXPT), stock changes (STCM), feed use on market (FEDM), losses on market (LOSM), seed use on market (SEDM), human consumption (HCOM), industrial use (INDM), processing (PRCM), and use for biofuel production (BIOF), which has been introduced recently (Section **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**).
The third identity defines the value of the EAA in producer prices (EAAP) as sold production or purchased input use (NETF) in physical terms multiplied with the unit valued price (UVAP):

Equation 3 $$EAAP_{io} = UVAP_{io} NETF_{io}$$

The following table shows the elements of the CAPRI data base as they have been arranged in the tables of the data base.

Main elements of the CAPRI data base

	Activities	**Farm- and market balances**	**Prices**	**Positions from the EAA**
Outputs	Output coefficients	Production, seed and feed use, other internal use, losses, stock changes, exports and imports, human consumption, processing	Unit value prices from the EAA with and without subsidies and taxes	Value of outputs with or without subsidies and taxes linked to production
Inputs	Input coefficients	Purchases, internal deliveries	Unit value prices from the EAA with and without subsidies and taxes	Value of inputs with or without subsidies and taxes link to input use
Income indicators	Revenues, costs, Gross Value Added, premiums			Total revenues, costs, gross value added, subsidies, taxes
Activity levels	Hectares, slaughtered heads or herd sizes			
Secondary products		Marketable production, losses, stock changes, exports and imports, human consumption, processing	Consumer prices	

1.3 The Complete and Consistent Data Base (COCO) for the national scale

The COCO database is established by the application of two modules:

- COCO1 module: Prepare national database for all EU27 Member States the Western Balkan Countries, Turkey and Norway

  It is basically divided into three main parts:
  - A data import "part" that is not a single "module" but rather a collection activity to prepare a large set of very heterogeneous input files
  - Including and combining these partly overlapping input data according to some hierarchical overlay criteria, and
  - Calculating complete and consistent time series while remaining close to the raw data.

  Data preparation (part 1) and overlay (part 2) form a bridge between raw data and their consolidation to impose completeness and consistency. The overlay part tries to tackle gaps in the data in a quite conventional way: If data in the first best source (say a particular Eurostat table from some domain) are unavailable, look for a second best source and fill the gaps using a conversion factor to take account of potential differences in definitions. To process the amount of data needed in a reasonable time this search to second, third or even fourth best solutions is handled as far as possible in a generic way in the GAMS code of COCO where it is checked whether certain data are given and reasonable. However there are a few special topics that are explained in separate sections.
- COCO2: The finishing step estimates consumer prices and some supplementary data for the feed sector (by-products used as feedstuffs, animal requirements on the MS level, contents and yields of roughage) . Both tasks run simultaneously for all countries and build on intermediate results from the main (COCO1) part of COCO like human consumption and processing quantities.

The main sources used to build up the national data base are shown in the following table.

Data items and their main sources

Data items	Source
Activity levels	Eurostat: Crop production statistics, Land use statistics, herd size statistics, slaughtering statistics, statistics on import and export of live animals New Member States: Eurostat supplemented with FAOstat and a few ARIANE[1] data Western Balkan Countries and Turkey: Eurostat supplemented with national statistical yearbooks, data from national ministries, results from FP7 project AgriPolicy[2], FAOstat production statistics
Production	Eurostat: Farm and market balance statistics, crop production statistics, slaughtering statistics, statistics on import and export of live animals New Member States: Eurostat supplemented with FAOstat

[1] The consulting firm "ARIANE II" was responsible for the year 2006 Eurostat project (related to CAPSIM): Extension of the agricultural sector model to Candidate Countries and establishment of a dataset for use in agricultural sector modelling for Candidate Countries , lot 2:" Establishment of a dataset for use in agriculture sector modelling for Acceding countries ". The dataset compiled during this project will be called "ARIANE data" in the following.

[2] AgriPolicy" supported by the European Commission under the 7th Framework Programme (**FP7**).(http://www.europartnersearch.net/agripolicy/)

	and a few ARIANE data Western Balkan Countries and Turkey: Eurostat supplemented with national statistical yearbooks, data from national ministries, results from AgriPolicy, FAOstat production statistics
Farm and market balance positions	Eurostat:Farm and market balance statistics FAOSTAT2: Trade and Food Balance Sheets[3] New Member States: Supplemented with a few ARIANE data
Sectoral revenues and costs	Eurostat: Economic Accounts for Agriculture (EAA) For New Member States: Eurostat supplemented with a few ARIANE data
Producer prices	Derived from production and EAA For Western Balkan Countries and Turkey: Supplemented with national statistical yearbooks, data from national ministries, results from AgriPolicy, FAOstat price statistics
Consumer prices	Derived from macroeconomic expenditure data (Eurostat, supplemented with UNSTATS) and International Labour Office data on food prices
Output coefficients	Derived from production and activity levels, engineering knowledge

1.4 The Regionalised Data Base

CAPRI aims at building up a Policy Information System of the EU's agricultural sector, regionalised at NUTS 2 level with an emphasis on the impact of the CAP. The core of the system consists of a regionalized agricultural sector model using an activity based non-linear programming approach. One feature of such a highly disaggregated, activity based agricultural sector model is the detailed information resulting from *ex-ante* simulations of policy scenarios concerning the output and input of specific agricultural production activities and their relationships. This information is also a pre-condition to judge possible impacts of agricultural production on the environment. However, these systems require as well this kind of information (data) *ex-post*, at least partially. It is especially necessary to define for each region in the model, at least for the basis year, the matrix of I/O-coefficients for the different production activities together with prices for these outputs and inputs. Moreover, for calibration and validation purposes information concerning land use and livestock numbers is necessary.

Already during the first CAPRI meeting, the REGIO domain of EUROSTAT was identified as the only harmonized data source available on regionalized agricultural data in the EU. REGIO is one of several parts of NEWCRONOS and is itself broken down in domains, one of which covers agricultural and forestry statistics.

In the agricultural and forestry domain [AGRI] the following tables are available:

- Land use [A2LAND]

[3] Resulting from two EuroCARE projects for FAOstat, Consistency and Completeness of SUA and Trade Matrices Based on Entropy Estimators, Division: ESSD, 2004, 2005 (http://www.eurocare-bonn.de).

- Crop production - harvested areas, production and yields [A2CROPS]
- Animal production - livestock numbers [A2ANIMAL]
- Cows's milk collection - deliveries to dairies, % fat content [A2MILK]
- Agricultural accounts on regional level [A2ACCT]
- Structure of agricultural holdings [A2STRUC, A3STRUC]
- Labour force of agricultural holdings [A2WORK]

1.5 The world Data Base

The global data base of CAPRI comprehends macro-economic data for different world regions, policy data and global agricultural production data. Several data sources can be mentioned:

- Data on bilateral trade between the CAPRI world regional aggregates are mainly relying on FAOSTAT.
- Data on policy variables such as applied and scheduled tariffs, tariff rate quotas or bilateral trade agreements are obtained from the AGLINK Model (OECD) and the Agricultural Market Access Database (AMAD).

While updating the CAPRI base year to 2004 (2003-05) some problems were encountered. The last FAOSTAT1 dataset for years 1986 to 2003 offered a list of products which ensures a complete mapping to all CAPRI products, including new products whey powder and casein.

However, for years 2004 to 2005 alternative datasets had to be used as FAOSTAT1 is discontinued. For this purpose the relative changes to 2002 are calculated in the alternative datasets. The old FAO selection is then extrapolated using these changes (FAOSTAT2 and AGLINK).

1.6 Policy data

The data base first of all includes policy data linked to production activities in Europe:

- Sugar and milk quotas
- Premiums, including various ceiling and distribution keys

However it also covers policy data linked to European and international markets

- Tariffs and Tariff Rate Quotas
- Export subsidies
- Producer subsidies
- Consumer subsidies
- Public Intervention purchases and sales

2 Baseline Generation

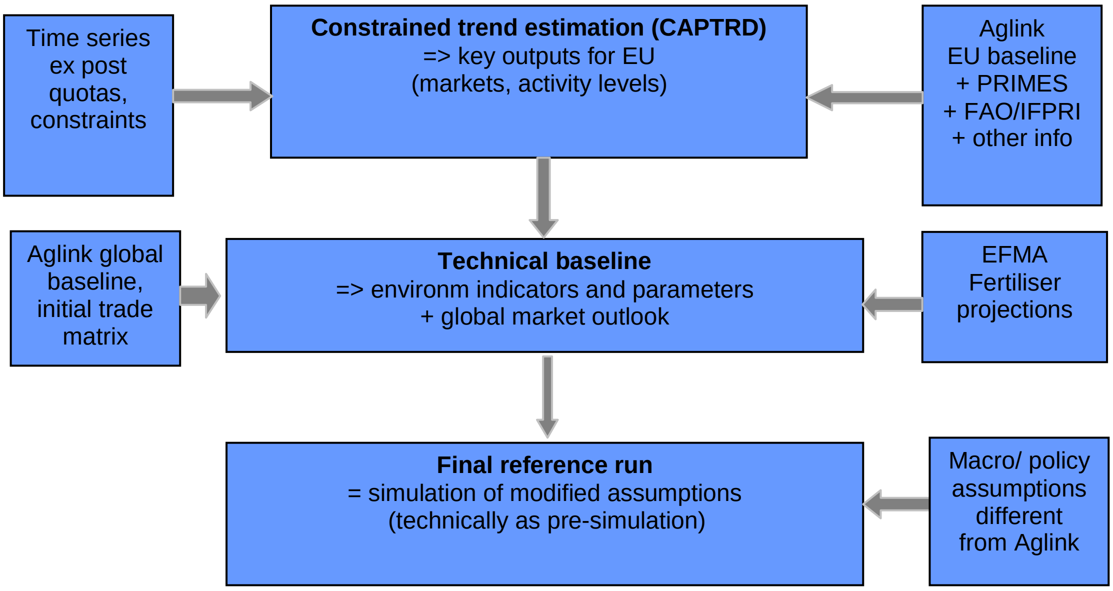
The purpose of a baseline is to serve as a comparison point or comparison time series for counterfactual analysis. The baseline may be interpreted as a projection in time covering the most probable future development or the European agricultural sector under the status-quo policy and including all future changes already foreseen in the current legislation.
Conceptually, the baseline should capture the complex interrelations between technological, structural and preference changes for agricultural products world-wide in combination with changes in policies, population and non-agricultural markets. Given the complexity of these highly interrelated developments, baselines are in most cases not a straight outcome from a model but developed in conjunction of trend analysis, model runs and expert consultations. In this process, model parameters such as e.g. elasticities and exogenous assumptions such as e.g. technological progress captured in yield growth are adjusted in order to achieve plausible results (as regarded by experts, e.g. European Commission projections). It is almost unavoidable that the process is somewhat intransparent. Two typical examples are AGLINK and FAPRI.
As is the case in other agencies, the CAPRI baseline is also fed by external ("expert") forecasts, as well by trend forecasts using data from the 'COCO' database. The purpose of these trend estimates is, on the one hand, to compare expert forecasts with a purely technical extrapolation of time series and, on the other hand, to provide a 'safety net' position in case no values from external projection are available. Usually the projections for a CAPRI baseline are a combination of expert data (e.g. from FAO, European Commission, World Bank, other research teams and even private entreprises) and simple statistical trends of data contained in the CAPRI data base.
The tool providing projections for European regions (CAPTRD) operates in several steps:

- Step 1 involves *independent trends* on all series, providing initial forecasts and statistics on the goodness of fit or indirectly on the variability of the series.
- Step 2 imposes *constraints* like identities (e.g. production = area * yield) or technical bounds (like non-negativity or maximum yields) and introduces specific *expert information* given on the MS level or for specific sectors (like PRIMES for bioenergy).
- Step 3 includes expert information on aggregate EU markets. Because this requires some disaggregation to single MS but also because it often the key information steering the outcome, it is treated in a step distinct from (2).
- Depending on the aggregation level chosen the MS result may be disaggregated in subsequent steps to the regional level (NUTS2) or even to the level of farm types.

The constrained trends from CAPTRD are simultaneously subject to the consistency restrictions in steps 2 and 3. Hence they are not independent forecasts for each time series and the resulting estimator is hence a system estimator under constraints (e.g. closed area and market balances). Nonetheless it is to be acknowledged here that the trend remain mechanical in that they try to respect technological relationships but remain ignorant about behavioural functions or policy developments[4].
However it should be explained that the CAPTRD results are in turn only the first of several steps before a full CAPRI baseline is ready to use. There are at least one and often two steps following:

[4] The only exception are the quota regime on the milk and sugar markets which are recognised in the trend projections.

Figure 1. Overview on CAPRI baseline process



1. The constrained trend estimation merges the information in the ex post time series with external information. The result of this first step is a first projection for the key variables in the agricultural sector (activity levels and market balances) of Europe.
2. The "technical baseline" calibrates missing parameters and in this context also calculates missing variables that are related to the key variables, in particular complete nutrient balances in the crop and livestock sectors and all non EU market balances and the bilateral trade matrix.
3. A third step may give the final reference run if some assumptions made in steps one or two need to be revised to obtain the desired starting point for further analysis. In some studies it turned out useful, for example to modify the macro assumptions of the "agricultural" expert sources (AGLINK, FAO, IFPRI).

3 Simulations

The CAPRI simulation tool is composed of a supply and market modules, interlinked with each other. In the ***supply module***, regional agricultural supply of annual crops and animal outputs is modelled by an aggregated profit function approach under a limited number of constraints: the land supply curve, policy restrictions such as sales quotas and set aside obligations and feeding restrictions based on requirement functions. The underlying methodology assumes a *two stage decision process*.

In the *first stage*, producers determine *optimal variable input coefficients* per hectare or head (nutrient needs for crops and animals, seed, plant protection, energy, pharmaceutical inputs, etc.) for given yields, which are determined exogenously by trend analysis (data from EUROSTAT) and updated depending on price changes against the baseline. Nutrient requirements enter the supply models as constraints and all other variable inputs, together with their prices, define the accounting cost matrix.

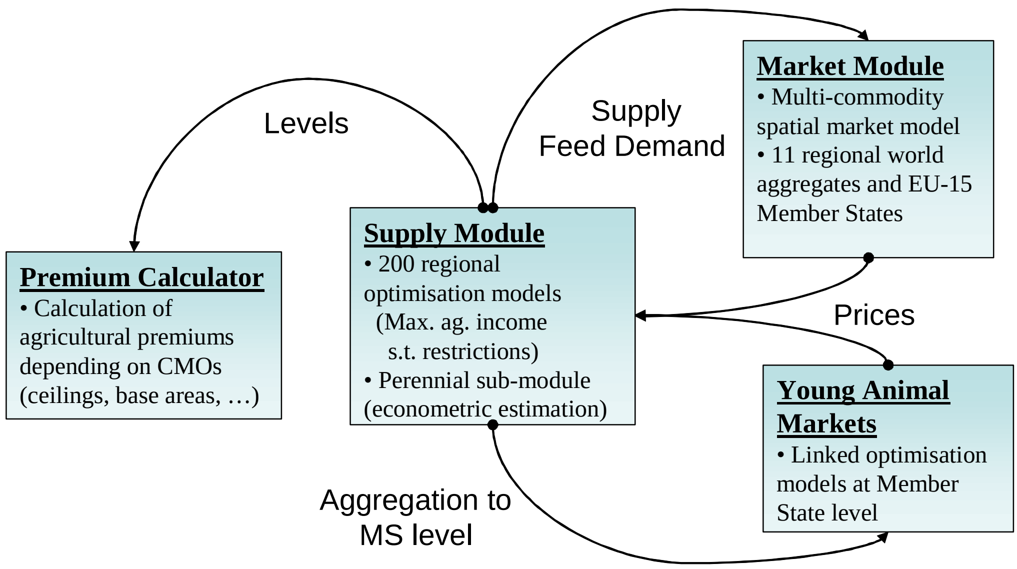
In the *second stage*, the *profit maximising mix of crop and animal activities* is determined simultaneously with cost minimising feed and fertiliser in the supply models. Availability of grass and arable land and the presence of quotas impose a restriction on acreage or production possibilities. Moreover, crop production is influenced by set aside obligations and animal

requirements (e.g. gross energy and crude protein) are covered by a cost minimised feeding combination. Fertiliser needs of crops have to be met by either organic nutrients found in manure (output from animals) or in purchased fertiliser (traded good).
A cost function covering the effect of all factors not explicitly handled by restrictions or the accounting costs –as additional binding resources or risk- ensures calibration of activity levels and feeding habits in the base year and plausible reactions of the system. These cost function terms are estimated from ex-post data or calibrated to exogenous elasticities.
Fodder (grass, straw, fodder maize, root crops, silage, milk from suckler cows or mother goat and sheep) [5] is assumed to be non-tradable, and hence links animal processes to the crops and regional land availability. All other outputs and inputs can be sold and purchased at fixed prices. Selling of milk cannot exceed the related quota, the sugar beet quota regime is modelled by a specific risk component. The use of a mathematical programming approach has the advantage to directly embed compensation payments, set-aside obligations, voluntary set-aside and sales quotas, as well as to capture important relations between agricultural production activities. Not at least, environmental indicators as NPK balances and output of gases linked to global warming are directly inputted in the system.
The *market module* breaks down the world into 28 country aggregates or trading partners, each one (and sometimes regional components within these) featuring systems of supply, human consumption, feed and processing functions. The parameters of these functions are derived from elasticities borrowed from other studies and modelling systems and calibrated to projected quantities and prices in the simulation year. Regularity is ensured through the choice of the functional form (a normalised quadratic function for feed and supply and a generalised Leontief expenditure function for human consumption) and some further restrictions (homogeneity of degree zero in prices, symmetry and correct curvature). Accordingly, the demand system allows for the calculation of welfare changes for consumers, processing industry and public sector. Policy instruments in the market module include bilateral tariffs and producer or consumer subsidy equivalent price wedges (PSE/CSE). Tariff rate quotas (TRQs), intervention purchases and subsidised exports under the World Trade Organisation (WTO) commitment restrictions are explicitly modelled for the EU 15.
In the market module, special attention is given to the processing of dairy products in the EU. First, balancing equations for fat and protein ensure that these make use of the exact amount of fat and protein contained in the raw milk. The production of processed dairy products is based on a normalised quadratic function driven by the regional differences between the market price and the value of its fat and protein content. Then, for consistency, prices of raw milk are also derived from their fat and protein content valued with fat and protein prices.
The market module comprises of a bilateral world trade model based on the Armington assumption (Armington, 1969). According to Armington's theory, the composition of demand from domestic sales and different import origins depends on price relationships according to bilateral trade flows. This allows the model to reflect trade preferences for certain regions (e.g. Parma or Manchego cheese) that cannot be observed in a net trade model.
The equilibrium in CAPRI is obtained by letting the *supply and market modules* iterate with each other. In the first iteration, the regional aggregate programming models (one for each Nuts 2 region) are solved with exogenous prices. Regional agricultural income is therefore maximised subject to several restrictions (land, fertiliser need, set-aside, etc). After being solved, the regional results of these models (crop areas, herd sizes, input/output coefficients, etc.) are aggregated and enter a small, non-spatial Multi-Commodity Models for young animal trade, separately for EU15, EU10, Bulgaria & Romania, Norway, Western Balkans

[5] A detailed description can be found in: Wolfgang Britz & Thomas Heckelei (1999): Calibration of Feed Requirements and Price determination of feed in CAPRI, CAPRI working paper 99-06, available on the project web site. (http://www.agp.uni-bonn.de/agpo/rsrch/capri/capri_e.htm)

and Turkey., as shown in Figure 2. In the second iteration, supply and feed demand functions of the market module are first calibrated to the results from the supply module on feed use and production obtained in the previous iteration. The market module is then solved at this stage (constrained equation system) and the resulting producer prices at Member State level transmitted to the supply models for the following iteration. At the same time, in between iterations, premiums for activities are adjusted if ceilings defined in the Common Market Organisations (CMOs) are overshot.

Figure 2. Link of modules in CAPRI



Source: CAPRI Modelling System

4 Post model analysis

4.1 Dual analysis

According to theory of (non)-linear optimization under constraints, there is a symmetric presentation of the primal model (the one we solve) by a dual one. The dual one would minimize the costs of "using" the constraints under the condition that marginal revenues of the endogenous variables cover marginal costs (including those for resource use) as long as the endogenous variables are not bouncing against lower limits. The equality of marginal revenues and costs provides important insights in the functioning of a programming model.

4.2 Decomposition of changes in aggregates yields and activity related income indicators

The idea behind the decomposition is to analyze which factors drive the change in yields and income indicators using growth rates. Take for example the market income of cereals per ha at EU level. Its change in a simulation against the baseline depends on the change in prices and the change in yields. The change in yields in turns depends on the effect of the yield elasticity, the change in the shares of low and high technology variants, the change in the regional shares and, in weights of low and high yielding regions. And finally, the share of high and low yielding cereals such as soft what and rye in the total aggregate might change. The following results are available:

- *Result*: Final result from the simulation

- *Effect of endogenous IO coefficients*: Result calculated by using the final IO coefficients, but keeping all other factors (technology shares, prices, regional weights, activity levels) at trend levels.
- *Effect of technology shares*: Result calculated by only updating the technology shares, but keeping all other factors (IO coefficients, prices, regional weights, activity levels) at trend levels.
- *Effect of prices*: Result calculated by only updating the prices shares, but keeping all other factors (IO coefficients, technology shares, regional weights, activity levels) at trend levels.
- *Effect of regional composition*: Result calculated by only updating the activity levels shares, but keeping all other factors (IO coefficients, technology shares, activity levels) at trend levels
- *Effect of other factors*: Difference between the start values and result, after all other effects above had been accounted for. Comprises the multiplicative cross-effects of the different effects, the effect of changed premiums in the case of the MGVA, and of change in the activity aggregate composition.

4.3 Post model sensitivity analysis with features in the supply model

The behaviour of the CAPRI supply model depends on the interaction between endogenous variables such as production and feeding activities both via the objective function and the constraints. Recently, the template of the supply model was extended by features such as the land supply curve, substitution between grass and arable land or the introduction of price dependent inputs and output coefficients for production activities

Result interpretation in explicit optimisation models can be cumbersome as no closed form representation of the behavioural response (such as supply quantities as a function of prices and policy instruments) is available. The analysis can be improved and might draw less on assumptions by systematically analysing the contribution of the different allocative mechanisms in the model. Therefore, a relatively small and easy part for was added to the CAPRI simulation model.

The basic idea consists in evaluating how the result at given prices would have looked like if certain endogenous model features would not have been used. Less rich model variants are generated by changing the template, and then used to simulate the impacts. The results of these simpler variants can then be compared to the version used for the real production run:

1. *Price dependent input and output coefficients*, by re-introducing the I/O coefficient from the baseline, i.e. those underlying the calibration point of the model.
2. The *land supply curve*, by treating arable and grass land as fixed endowment.

3. Substitution between *low and high yield technology variants*, by forcing the model to use equal shares of the available technology.

4. The *PMP cross terms between crop groups*, only leaving the diagonal terms while recalibrating the linear term such that the model would still calibrate at baseline price and policies.

4.4 Welfare analysis

A key element in analysing policy changes from an economic viewpoint is to look at welfare changes. The "classical" elements of a welfare analysis are changes in consumer and producer rents and for the tax payer. That concept is also followed in CAPRI. For consumers, CAPRI uses the money metric concept. It can be broadly understood as a measurement for changes in the purchasing power of the consumer. The concept is linked to the so-called indirect utility function.

On the producer side, CAPRI uses changes in the gross value added (GVA) plus premiums as the main indicator. The gross value added is the different between revenues (output quantities valued at farm gate prices) and intermediate input costs (input quantities with the exemption of the primary factors land, capital and labour multiplied with their farm gate prices). The GVA plus premiums is hence the sum the farming sector can spend to remunerate labour, capital and land, independent on property rights of these factors. It should not be confused with "farm profits", which depend on ownership and some accounting rules for depreciation of capital, and where also non-family labour costs are already remunerated.

Tax payer costs in CAPRI refer to those policy instruments explicitly covered, i.e. premiums paid to farmers, cost of public market interventions and export subsidization and some subsidies paid for demanders of agricultural goods, minus revenues from import tariffs. For premium schemes, financing rates for the EU and national budgets as well as for pillar I and II of the CAP can be defined, which allow to allocate costs to those different budgets.

4.5 Spatial results

Not at least due to the so-called multi-functional model of European agriculture, there is growing interest in modelling environmental effects of the agricultural sector in the EU. In many cases, results beyond rather crude passive indicators can only be obtained linking biophysical models to economic models for policy impact analysis. An important methodological problem in this context is "bridging" the scales: whereas most bio-physical models work on field scale, comprehensive EU-wide economic models generally work on large administrative regions.

Within these administrative boundaries the natural conditions of soil, relief and climate usually differ in such a manner, that the assumption of identical cropping pattern, yields or input use cannot be maintained. Simulations with bio-physical models thus require breaking down results from the economic models into a smaller regional scale, so called Homogeneous spatial Mapping Units (HSMU).

The aim of building HMSU is the definition of areas inside an administrative region where approximate homogeneity according location factors may be assumed. The HMSU serve then as simulation units for the bio-physical models and are constructed by overlaying different maps (land cover, soil map, climatic factors etc.). In order to allow for a manageable number of HSMUs, the most important factors must be selected, and continuous parameters must be grouped in classes. The HSMU is regarded as similar both in terms of agronomic practices and the natural environment, embracing conditions that lead to similar emissions of greenhouse gases or other pollutants.

4.5.1 Crop shares

Combining the LUCAS survey with digital maps provides us with several observations of crops grown at a defined point with a set of natural conditions. Using an adequate estimation model we can regress the probabilities of finding a crop at a certain location on the natural conditions. As this probability can be interpreted as the share of the crop in a homogeneous region, applying these estimated coefficients to the average natural conditions in a certain HSMU yields normally distributed predictions of crop shares for HSMU under corresponding assumptions on the stochastic processes governing crop choice. These a priori information on cropping shares are generally not consistent with the “known” cropping area in the Nuts II region. The “best” set of data-consistent shares given the prior information is identified by a Bayesian *highest posterior density* approach.

4.5.2 Yield

The crop yield estimation combines three different types of a priori information in a HPD estimation framework to derive simultaneously spatially explicit yield estimates and irrigation shares per crop. A first input data set in the estimation process is the irrigation map from FAO used to provide per HSMU an estimate of the share of irrigated agriculture. Secondly, the FSS delivers data for irrigated areas for certain crops at administrative level and, thirdly, MARS offered potential yields for rainfed and fully irrigated agriculture. The FSS data about irrigated hectares at regional scale had been used via regressions to find some basic relations between soil properties and climatic parameters and the irrigated share per crop or crop group. From those regression models, forecasts are derived at the level of single HSMUs about the irrigated share per crop. The HDP framework minimizes simultaneously deviations from the estimated crop specific irrigation shares per HSMU, from the irrigation shares per HSMU derived from the FAO map and from the potential yields. Constraints ensure that firstly the area weighed average of the yields per HSMU is equal to the one found in regional statistics, and secondly that the irrigated area per HSMU exhaust the irrigated area at regional level found in the FSS.

4.5.3 Fertilizer application

Organic and mineral fertilizer application rates are a highly relevant factor for environmental impacts of agricultural production as they dive realized crop yields and nutrient surpluses, and consequently the whole nutrient and carbon cycle in agriculture. Unfortunately, even at Member State level, data on typical organic and inorganic fertiliser application rates for crops are not available from harmonized European statistics. However, the International Fertilizer Manufacturer Association (IFMA) kindly agreed to let the project team access the results of expert surveys on inorganic application rates for crops or group of crops at Member State level. Those data are used in the process of building the regional data base of CAPRI to define regional fertilizer application rates per crop, taking into account regional yields, manure availability, average regional soil parameters and emission factors lined up with the MITERRA and RAINS models (Oenema et.al. 2007).

4.5.4 Linkage to process-based modelling (DNDC)

Processed-based models are adequate to analyze the impact of changing farming practices, as they are able to cope with the complex interplay of environment and anthropogenic activities. But the accuracy of simulated fluxes with process-based models such as DNDC (Denitrification Decomposition) Model (Li et al., 1992) is largely dependent on the quality and resolution of input data. Spatial downscaling for EU27 of crop shares, yields, stocking densities, fertilizer application rates significantly improves the quality of input data. Our simulations are done using DNDC V.89, however introducing several modifications allowing a more flexible simulation of a large number of pixel-cluster. These modifications enabled us to simulate an un-limited number of agricultural spatial modelling units with individual farm and crop parameterization and with the option to individually select up to 10 different crops to be simulated in a specific calculation unit.

5 Annex:

List of activities in the supply model

Group	Activity	Code
Cereals	Soft wheat	SWHE
	Durum wheat	DWHE
	Rye and Meslin	RYEM
	Barley	BARL
	Oats	OATS
	Paddy rice	PARI
	Maize	MAIZ
	Other cereals	OCER
Oilseeds	Rape	RAPE
	Sunflower	SUNF
	Soya	SOYA
	Olives for oil	OLIV
	Other oilseeds	OOIL
Other annual crops	Pulses	PULS
	Potatoes	POTA
	Sugar beet	SUGB
	Flax and hemp	TEXT
	Tobacco	TOBA
	Other industrial crops	OIND
Vegetables	Tomatoes	TOMA
Fruits	Other vegetables	OVEG
Other perennials	Apples, pear & peaches	APPL
	Citrus fruits	CITR
	Other fruits	OFRU
	Table grapes	TAGR
	Table olives	TABO
	Table wine	TWIN
	Nurseries	NURS
	Flowers	FLOW
	Other marketable crops	OCRO
Fodder production	Fodder maize	MAIF
	Fodder root crops	ROOF
	Other fodder on arable land	OFAR
	Graze and grazing	GRAS
Fallow land and set-aside	Set-aside idling	SETA
	Non food production on set-aside	NONF
	Fallow land	FALL
Cattle	Dairy cows	DCOW
	Sucker cows	SCOW
	Male adult cattle fattening	BULF
	Heifers fattening	HEIF
	Heifers raising	HEIR
	Fattening of male calves	CAMF
	Fattening of female calves	CAFF
	Raising of male calves	CAMR

Group	Activity	Code
	Raising of female calves	CAFR
Pigs, poultry and other animals	Pig fattening Pig breeding Poultry fattening Laying hens Sheep and goat fattening Sheep and goat for milk Other animals	PIGF SOWS POUF HENS SHGF SHGM OANI

Output, inputs, income indicators, policy variables and processed products in the data base

Group	Item	Code
Outputs		
Cereals	Soft wheat Durum wheat Rye and Meslin Barley Oats Paddy rice Maize Other cereals	SWHE DWHE RYEM BARL OATS PARI MAIZ OCER
Oilseeds	Rape Sunflower Soya Olives for oil Other oilseeds	RAPE SUNF SOYA OLIV OOIL
Other annual crops	Pulses Potatoes Sugar beet Flax and hemp Tobacco Other industrial crops	PULS POTA SUGB TEXT TOBA OIND
Vegetables **Fruits** **Other perennials**	Tomatoes Other vegetables Apples, pear & peaches Citrus fruits Other fruits Table grapes Table olives Table wine Nurseries Flowers Other marketable crops	TOMA OVEG APPL CITR OFRU TAGR TABO TWIN NURS FLOW OCRO
Fodder	Gras Fodder maize Other fodder from arable land Fodder root crops Straw	GRAS MAIF OFAR ROOF STRA
Marketable products from animal product	Milk from cows Beef	COMI BEEF

Group	Item	Code
	Pork meat	PORK
	Sheep and goat meat	SGMT
	Sheep and goat milk	SGMI
	Poultry meat	POUM
	Other marketable animal products	OANI
Intermediate products from animal production	Milk from cows for feeding	COMF
	Milk from sheep and goat cows for	SGMF
	feeding	YCOW
	Young cows	YBUL
	Young bulls	YHEI
	Young heifers	YCAM
	Young male calves	YCAF
	Young female calves	YPIG
	Piglets	YLAM
	Lambs	YCHI
	Chicken	MANN
	Nitrogen from manure	MANP
	Phosphate from manure	MANK
	Potassium from manure	
Other Output from EAA	Renting of milk quota	RQUO
	Agricultural services	SERO
Inputs		
Mineral and organic fertiliser	Nitrogen fertiliser	NITF
	Phosphate fertiliser	PHOF
Seed and plant protection	Potassium fertiliser	POTF
	Calcium fertiliser	CAOF
	Seed	SEED
	Plant protection	PLAP
Feedings tuff	Feed cereals	FCER
	Feed rich protein	FPRO
	Feed rich energy	FENE
	Feed based on milk products	FMIL
	Gras	FGRA
	Fodder maize	FMAI
	Other Feed from arable land	FOFA
	Fodder root crops	FROO
	Feed other	FOTH
	Straw	FSTRA
Young animal	Young cow	ICOW
Other animal specific inputs	Young bull	IBUL
	Young heifer	IHEI
	Young male calf	ICAM
	Young female calf	ICAF
	Piglet	IPIG
	Lamb	ILAM
	Chicken	ICHI
	Pharmaceutical inputs	IPHA
General inputs	Maintennce machinery	REPM
	Maintennce buildings	REPB

Group	Item	Code
	Electricity	ELEC
	Heating gas and oil	EGAS
	Fuels	EFUL
	Lubricants	ELUB
	Water	WATR
	Agricultural services input	SERI
	Other inputs	INPO
Income indicators	Production value	TOOU
	Total input costs	TOIN
	Gross value added at producer prices	GVAP
	Gross value added at basic prices	GVAB
	Gross value added at market prices plus CAP premiums	MGVA
Activity level	Cropped area, slaughtered heads or herd size	LEVL
Policy variables Relating to activities	Premium ceiling	PRMC
	Historic yield	HSTY
	Premium per ton historic yield	PRET
	Set-aside rate	SETR
	Premium declared below base area/herd	PRMD
	Premium effectively paid	PRME
	Premium amount in regulation	PRMR
	Type of premium application	APPTYPE
	Factor converting PRMR into PRMD	APPFACT
	Ceiling cut factor	CEILCUT
Processed products	Rice milled	RICE
	Molasse	MOLA
	Starch	STAR
	Sugar	SUGA
	Rape seed oil	RAPO
	Sunflower seed oil	SUNO
	Soya oil	SOYO
	Olive oil	OLIO
	Other oil	OTHO
	Rape seed cake	RAPC
	Sunflower seed cake	SUNC
	Soya cake	SOYC
	Olive cakes	OLIC
	Other cakes	OTHC
	Gluten feed from ethanol production	GLUE
	Biodiesel	BIOD
	Bioethanol	BIOE
	Palm oil	PLMO
	Butter	BUTT
	Skimmed milk powder	SMIP
	Cheese	CHES
	Fresh milk products	FRMI
	Creams	CREM
	Concentrated milk	COCM
	Whole milk powder	WMIO

Group	**Item**	**Code**
	Whey powder	WHEP
	Casein and caseinates	CASE
	Feed rich protein imports or byproducts	FPRI
	Feed rich energy imports or byproducts	FENI