Concept and Explorative Application of an EU-wide, Regional Agricultural Sector Model (CAPRI-Project)

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1 Introduction

The main objective of the project CAPRI (**C**ommon **A**gricultural **P**olicy **R**egional **I**mpact) was the development of an EU-wide economic modelling system able to analyse the regional impacts of the Common Agricultural Policy (CAP). The project was co-financed by EU under the FAIR program in the years 1997-1999.

In order to achieve its ambitious objective, the project relied on the functionality of a European research network. Each of the five main partners[1] was responsible for a specific cluster of Member States. They established research relationships with national sub-partners for data collection and interpretation of results. This paper introduces the concept and implementation of the CAPRI data base (section 2) and modelling system (section 3). Selected results of an explorative application to a reference run and an Agenda 2000 scenario are presented to illustrate the type of information which can be generated with the modelling system (section 4). A short outlook concludes (section 5)[2].

2 CAPRI Data Base

A major part of the CAPRI project was devoted to sample data and compile the regionalised CAPRI data base. The involvement of different teams, the necessity to create a EU-wide comparable information base, and the requirements of the economic modelling system demand a well defined data base. The Capri data base obeys the following principles:

- *Regional differentiation* of the European Union to 200 regional units (mostly according to NUTS II definition)
- *Production activity based break-down of agricultural production and input use*
- *Consistency* between sectoral and regional aggregates, i.e. data match official Eurostat statistics including the Economic Accounts of Agriculture (EAA)
- *Comprehensiveness:* complete coverage of product generation and input use according to the EAA, inclusion of activity levels, yields, input coefficients, prices, farm & market balances, economic performance, political instruments and environmental indicators

Currently, the data base is complete for the years 1990-1995 for all regions.

The key concept of the CAPRI data base is termed Activity Based Accounting System (ABAS, WOLF 1995) breaking down the agricultural production process for a each period to individual production and use activities, both in physical and valued terms. CAPRI differentiates between 60 outputs and 35 inputs, covering the whole agricultural sector according to EAA definitions, and about 50 crop and animal production activities.

The output and input coefficients are defined consistently to sectoral output generation and input use (see figure 1). *Use activities* which define so called "farm balances" for each output and input describe the fate of the outputs and input "generation". Output produced may be sold, added to stocks, fed, used as seed etc. Inputs may be bought, taken out of stocks or stem from intra-sectoral transactions, for example young animals may be produced by another production activity. In order to link the physical sphere with

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[1] The research teams involved are institutes in the field of agricultural economics from the Universities of Bonn, Valencia, Galway, Bologna, and Montpellier (plus Research Station Tänikon (Switzerland) and NILF, Oslo).

[2] This paper gives only a very limited account of the research performed within the CAPRI-project. The CAPRI web site (http://www.agp.uni-bonn.de/agpo/rsrch/capri/capri_e.htm) provides further information.

the EAA, national *unit value prices* are used. They are residually defined by definitorial equations underlying the methodology of the EAA.

Figure 1: Activity Based Accounting System (ABAS)

Physical Component			Price Component	Valued Component (Economic Accounts of Agricultural - EAA in gross and net concept)				
O-coefficients (x activity levels = output generation)	Farm balances for outputs (output use)	X	Output Prices	=	Gross Output	- Intermediate Output use	=	Net Output (EAA)
I-coefficients (x activity levels = input generation)	Farm balances for inputs (input use)	X	Input Prices	=	Gross Input	- Intermediate Input use	=	Net Input (EAA)
Income indicators per activity					Sectoral income indicators			Income (EAA)

At national level, the project could to a greater extent rely on the SPEL-EU data base (WOLF 1995) from EUROSTAT, which integrates different data bases, technological information and expert knowledge, and covers longer time series for all EU Member States. The REGIO domain of EUROSTAT represents the uniform regional data source which suffers, however, from incompleteness and a partially insufficient level of differentiation. Completely missing is information on CAP measures at regional level. Consequently, many statistical sources at national and even regional level had to be found, accessed, analysed, and compiled to achieve a uniform and complete data base. The two key factor of success for this enormous task were (1) the establishment of a network of researchers from all Member States and (2) the clear methodological concept.

The data base also comprises a set of *environmental indicators*. Useful indicators at this stage of the CAPRI information system are defined by (1) a direct link to the agricultural production system, (2) meaningful interpretation at CAPRI's current regional level of differentiation, i.e. the NUTS II level, and (3) being operational with respect to data availability. These definitions exclude indicators which describe states of environmental problems at local level or with respect to ecological systems defined by specific regional boundaries (e.g. water catching, landscape). CAPRI, however, offers the unique chance to apply appropriate indicators in a consistent and uniform manner across Europe relating to the regional agricultural production system. Based on these considerations the project implemented nutrient balances and gas emissions relevant for global climatic change for all regions in the system.

3 Modelling system

3.1 Overall concept

From a methodological point of view, the main challenge was the development of a modelling system which could combine deep regionalisation with complete coverage of the EU-agricultural sector. This set-up was necessary in order to simultaneously analyse the effect of commodity market and policy developments on agriculture in the individual regions as well as the feedback from the regions to EU and world markets.

Since market and activity specific policy instruments require a rather disaggregated model in terms of products, a simultaneous system which would optimise producer and consumer surplus for 200 regions and some 50 products was computationally infeasible. Consequently, the model system was conceptually split-up into a supply and a market component. The supply module consists of individual programming models for about 200 NUTS II regions. The market module follows the tradition of multi-commodity models. Based on aggregated supply quantities from the regional models, the market model returns market clearing prices. An iterative process between the supply and market component ultimately achieves a comparative static equilibrium.

3.2 Supply module

The supply module consists of independent regional programming models, well-suited for a high degree of activity differentiation and the direct representation of relevant farm policy measures (e.g. premiums, set-aside obligations) and ensure simulation results consistent with general resource constraints. The objective functions maximise the aggregated gross value added including CAP premiums minus a quadratic cost function based on Positive Mathematical Programming (PMP).

The choice of the optimal production mix is restricted by a relative small number of constraints: availability of arable and permanent grass land, selling quotas for milk and sugarbeets, set-aside obligations, base area related premium reductions, and upper bounds for voluntary set-aside according to CAP regulations. Feed costs are minimised endogenously by determining the optimal mix of a limited number of aggregated marketable (e.g. "cereals") and non-tradable feedingstuffs (e.g. "hay") subject to requirement constraints, ensuring a technologically plausible mix. Nutrient requirements of crops can be covered either by mineral or organic fertilisers, the latter restricted to the amount produced by the regional herds. Constraints ensure that a crop specific percentage of the nutrient need is covered by mineral fertiliser.

"Positive Mathematical Programming" (PMP) - known since the late eighties but formally introduced to the community of agricultural economists by HOWITT (1995) - allows to perfectly calibrate a programming model to observed data - in our case regarding activity levels and regional feed use. The basic idea of PMP is to introduce a non-linear objective function based on information contained in dual values of calibration constraints forcing the solution of the programming model to the observed allocation. Compared to linear models (LP), the introduction of a non-linear objective function allows solutions with more variables than binding constraints and results in a smoother, more realistic response behaviour of the model to changes in exogenous parameters. This advantage and the calibration property lead to a wide spread use of PMP in recent modelling exercises.

The conditions for perfect calibration are clearly defined and adopted by all PMP applications, but they allow for an infinite number of different parameter specifications, all perfectly calibrating the model to observed activity levels, but implying distinct differences with respect to the response in simulations (see: HECKELEI 1997 for a discussion). The non-linear parameters for the animal production activities in CAPRI are based on exogenous elasticities.

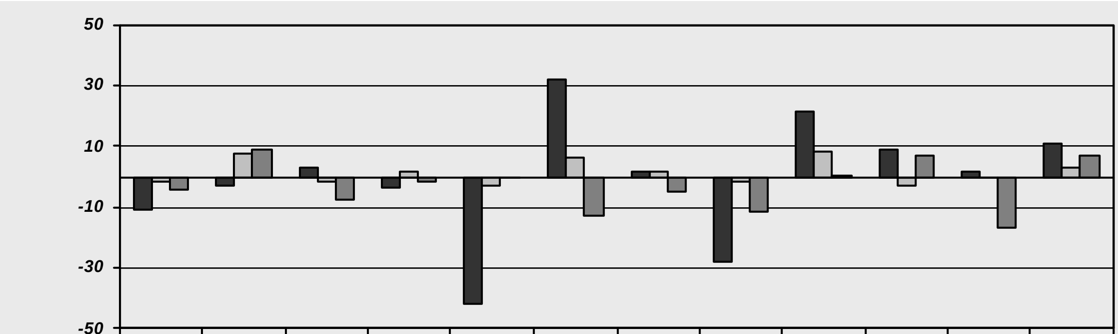
Since elasticities were not available for the differentiated set of crop production activities, the team explored the possibility to estimate multi-output quadratic cost functions based on a cross-sectional sample building upon an approach proposed by PARIS & HOWITT 1998. Their article showed the potential of applying Maximum Entropy estimation techniques in this context, but suffered from two important disadvantages: First, the method was just applied to a single observation, implying that the data did not contain any information on second derivatives of the cost function. Second, the employed reparameterisation of the cost function based on the Cholesky decomposition to impose correct curvature resulted in a somewhat arbitrary parameter specification.

The application in CAPRI could overcome both deficiencies by basing the estimation on cross sectional vectors of marginal costs and using the Cholesky decomposition of the matrix of second derivatives directly as constraints during estimation. In order to exploit the information contained in the sample, parameter restrictions across regions are introduced, based on the assumption that *relative* changes of marginal cost are equal across regions for same crop rotations and cropping conditions. In other words, the observed differences in marginal costs between regions are explained by regional differences in rotations and cropping conditions (measured as average revenue per ha). The resulting regional models were validated by an ex-post validation exercise: the newly developed methodology ("ME") and a standard PMP approach using one observation ("Standard")[3] were specified based on a three year average "1990". The models were then solved under the policy and market conditions for the three year average "1994". Figure 2 shows absolute percentage deviations of model results from observed activity levels for single and

[3] We chose the so called "average cost approach" which defines the parameters of crop specific quadratic cost functions such that it recovers the observed average cost of each production activity in the base year.

aggregated production activities. The overall absolute percentage deviation of the ME approach (green bars) is just 3 % and far better than the standard approach (red bars). As a reference, an "intelligent no-change" forecast (blue bars) taking into account the effect of the obligatory set-aside regime is also presented.

Figure 2: Percentage deviations of crop activity levels for different "model" specifications from observed levels in "1994" for France



	Wheat	Barley	Maize	Cereals	Sun-flowers	Rape	Oil-seeds	Pulses	Pota-toes	Arable Fodder	Fallow Set aside	Total
Standard	-11	-3	3	-4	-42	33	2	-28	22	9	2	11
ME	-2	8	-2	1	-3	6	1	-1	8	-3	0	3
No change	-4	9	-8	-2	-1	-13	-5	-12	0	7	-17	7

The *regional* forecasting accuracy of the ME-approach was also superior to the standard PMP application but generally less accurate (For details see HECKELEI & BRITZ 1999).

Note, that the employment of the PMP-methodology is indispensable with respect to the overall layout of the CAPRI modelling system. It provides an empirically validated supply response and, at the same time, allows to keep a "lean" layout of the regional programming model and the solution of the overall system computationally feasible. Furthermore, it avoids the use of weakly justified constraints often employed to guarantee a "plausible" simulation behaviour of programming models.

3.3 Market module

Methodological solutions for the market module are generally based on a the standard concept of multi-commodity models (BRITZ 1998), known since the days of SWOPSIM. Double log equations for supply and demand clear regional and international markets, driven by regional producer and consumer prices which are linked via price transmission functions to a uniform world market price. The parameters of the behavioural demand equations are not estimated, but instead calibrated under theoretical restrictions based on elasticity estimates taken from literature (WITZKE & BRITZ 1998).

The non-spatial net-trade model is regionalised at EU Member State level, Switzerland, Norway, and "Rest-of-the-World" (ROW). Data, behavioural parameters and exogenous shifts for ROW stem to a large extent from WATSIM, a world wide modelling system for trade in agricultural products (VON LAMPE 1998). Supply for all other regions is fixed to the results of the regional supply models. Price transmission functions cover tariffs, including flexible levies depending on internal price floors, as well as marketing and processing costs.

Processing of oilseeds is modelled explicitly assuming fixed extraction rates for cakes and oils from crushing. In the case of processed milk products (skimmed milk powder, butter and other), constraints equilibrate fat and protein content of processed quantities of raw milk and with the processed products. The price of raw milk and processed milk products is derived from uniform fat and protein prices weighted with their contents plus fixed per unit processing costs.

4 Application

The CAPRI modelling system was tested in late 1999 in an Agenda 2000 scenario (simulation run) compared to a continuation of the status quo policy for the European agricultural sector (reference run) for the year 2005. The subsequent description of scenario definition and selected model results is restricted to "cereals and oilseeds" and the "beef and dairy" sector, as the main target sectors of Agenda 2000.

4.1 Cereals and Oilseeds Sector

The political instruments of both scenarios for cereals and oilseeds are presented in the following table. Note that premiums in table 1 represent averages weighted by observed (base year) and projected (reference and Agenda scenario) regional activity levels so that the resulting values are partly endogenous. Furthermore, differences between base year and reference scenario are also caused by (1) the third step of the 92 CAP reform which was not fully implemented in the base year and (2) a set of already decided changes such as the adjustment of historical yields for some regions.

Table 1: Political variables for Cereals and Oilseeds

	Base year 1994	Reference 2005 (% change to base year)	Agenda 2005 (% change to reference)
Cereals			
Intervention price	143.5	123,0 (-14%)	104,6 (-15%)
Average premium per ha	211.6	274,4 (30%)	319,9 (17%)
Oilseeds			
Average premium per ha	449.8	443,9 (-1%)	275,3 (-38%)
Set aside			
Set aside rate (in %)	14.0	17.5	10.0
Average premium per ha	289.0	315,0 (9%)	303,4 (-4%)

Additionally, the following assumptions apply to the scenario definitions:

- + 1.33 % yield increase per year for cereals (EU average, regionalised at national level) + 1.45 % yield increase per year for oilseeds (EU average, regionalised at national level) (inputs adjusted accordingly with input saving technical progress of 0.5 % per year
- All oilseeds are cultivated under the main scheme (i.e. receive premiums)
- Small producer share is kept constant at base year levels

Table 2: Activity levels, Grandes Cultures (in 1000 hectares)

	Base year 1994	Reference 2005	Agenda 2005	Reference to Base year	Agenda to Reference
Cereals (excl. rice)	35012	32663	33796	-6.7%	3.5%
Wheat	16018	14990	15230	-6.4%	1.6%
Barley	11072	10352	10916	-6.5%	5.4%
Other cereals	7922	7321	7650	-7.6%	4.5%
Pulses	1680	1676	1699	-0.2%	1.4%
Oilseeds	5273	5141	4848	-2.5%	-5.7%
Rapeseed	2258	2359	2165	4.5%	-8.2%
Sunflower seed	2740	2512	2415	-8.3%	-3.9%
Soya beans	274	270	269	-1.6%	-0.4%
Non Food on set aside	618	935	777	51.3%	-16.9%
Set aside	4131	5468	4063	32.4%	-25.7%

At first we want to have a short look at aggregated EU-results. Table 2 presents activity levels for Grandes Cultures. The main developments from the *base year to the reference scenario* include a decrease of the cereal area by 6.7% to 32.7 million ha, mainly due to the increased set-aside rate. However, with technical progress driving up yields, the production is estimated to increase by 9.3% to about 192 million tons. Table 3 allows a differentiated look at market effects for wheat and barley. As domestic demand are nearly unchanged, net exports and/or intervention sales expand. Intervention prices for both cereals exceed simulated world market prices, as in many studies.

Table 3: Balance sheet cereals (in 1000 tons)

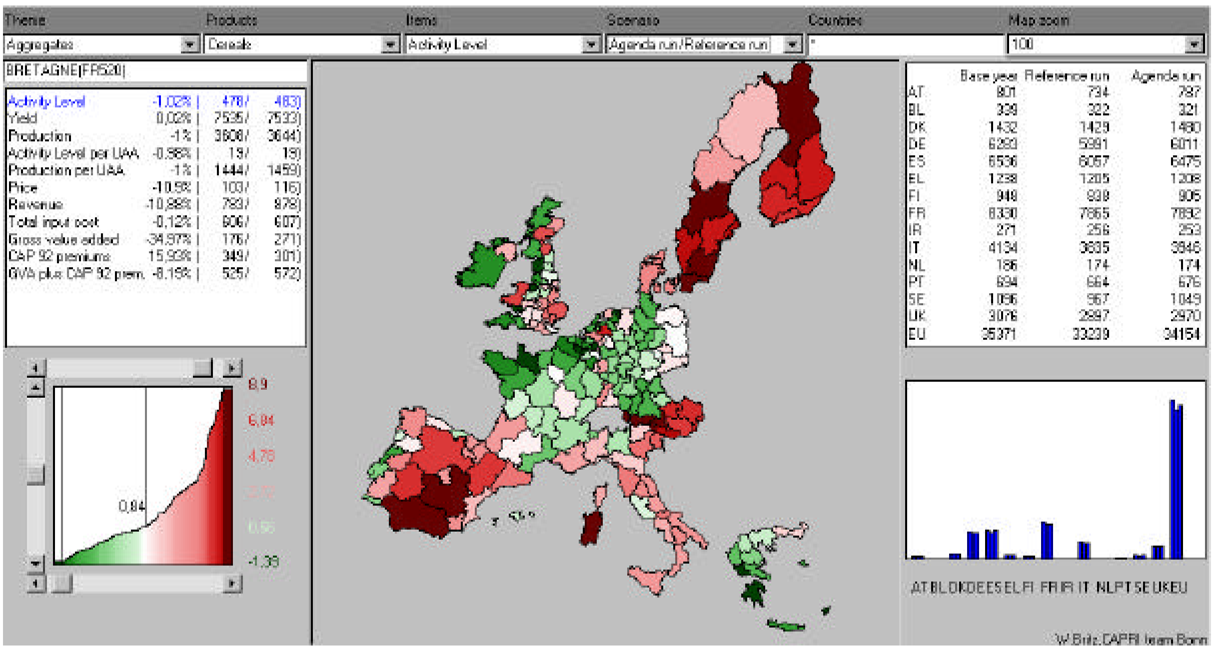
	Base year 1994	Reference 2005	Agenda 2005	Reference to Base year	Agenda to Reference
Wheat					
Domestic supply	81659	90325	91134	10.6%	0.9%
Domestic demand	67232	66676	66149	-0.8%	-0.8%
Feed use	30041	29499	28948	-1.8%	-1.9%
Intervention	7799	8348	0	7.0%	-100.0%
Barley					
Domestic supply	42468	46150	47752	8.7%	3.5%
Domestic demand	29250	29719	30129	1.6%	1.4%
Feed use	29026	29497	29906	1.6%	1.4%
Intervention	4469	6430	7624	43.9%	18.6%

Comparing *Agenda 2000 results to the reference run*, reduced set aside rates increase cereal production by 3.5% to 195.8 million tons. Lower prices cause slightly extended domestic use, but do not affect EU's status as a cereal net exporter. In opposite to the reference scenario, world market prices for wheat are simulated to lay above intervention price level, allowing wheat exports without subsidies and WTO restrictions. Consequently, net exports rise considerably (Table 3). However, the simulated difference between world market and intervention price is rather small. With respect to barley, the intervention price is still above world market price implying continuing problems since exports would require subsidies and are limited by WTO restrictions.

Production of oilseeds is simulated to expand as well in the reference compared to the base year despite a slight area reduction. In the Agenda 2000 scenario oilseed premiums decrease quite drastically to the level of cereal premiums. The loss of profitability results in an estimated 6 % reduction in oilseeds areas compared to reference run results (Table 2). Compared to the drastic premium cut, the simulation response of the model may at first look small. However, the following aspects should be taken into account:

- The Blair House agreement is no longer in effect. Consequently, the drop of the effective set-aside rate for oilseeds is larger than for cereals in many regions.
- Effective oilseeds premiums in the reference run are reduced in several Member States due to an simulated EU wide 8 % overshoot of base areas, so that a simple comparison between declared oilseed premiums before and after Agenda 2000 is misleading.
- Sunflower seeds are much more resistant to droughts, so that a substitution with cereals in southern regions is restricted by availability of irrigation.

Figure 3: Impacts of Agenda 2000 on cereal production



The aggregated results are already influenced by the model's capability to represent policy implementation at regional level which eliminates part of the aggregation error of aggregated models. Now we want have a closer look at some regional aspects of the policy impacts. Figure 3 shows the effect of Agenda 2000 on regional cereal activity levels. Compared to the reference run cereal area increases in most regions of Spain, Italy, Austria, east England, and the Scandinavian countries. It remains rather constant in the main cereal producing regions of France and Germany.

One reason for the differences are increased reference yields implying higher area premiums for cereals in some Spanish and Italian regions due to a special agreement in Agenda 2000. Premiums in Spain increase by about 27 %, in Italy by about 20 % and in the rest of Europe by 16 %. Another reason is the lower price reduction for maize and durum wheat. Whereas the intervention price for cereals falls by 15 % (from Reference to Agenda) the price for durum wheat falls by 13.7 % and for maize by only 2.6 %. Both crops (especially durum wheat) are primarily grown in southern Europe.

Due to the premium effect of adjusted historic yields the reduction of set aside in Mediterranean regions is generally in line with the changes of the official set aside rate. In the highly productive cereal regions of northern France and Germany, however, obligatory set aside reduction is partially compensated by increased voluntary set aside, because the under-compensation of the overall price cut in Agenda 2000 (only about 50% based on historic yields) diminishes gross value added considerably. This effective under-compensation in 2005 is even stronger in regions with high technical progress in cereal production, namely French and German regions.

4.2 Beef and Dairy Sector

As the main political instruments of both scenarios are widely discussed, the following table 4 just present average changes of the quantitative measures in the sector at EU level.

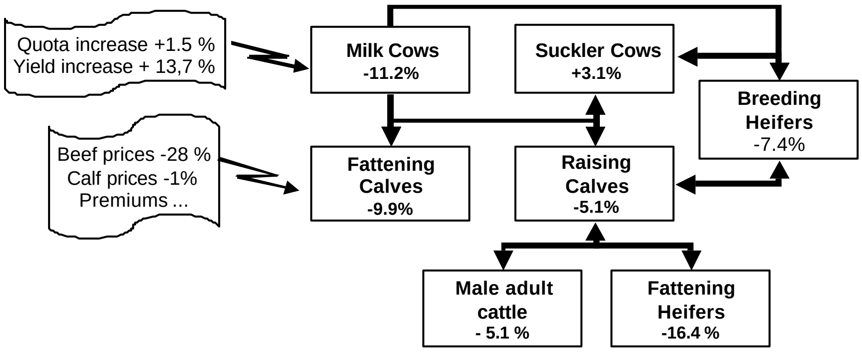
Table 4: Political variables for the Cattle sector

	Base year 1994	Reference 2005 (% change to base year)	Agenda 2005 (% change to reference)
Administrative prices			
Beef	4285	3475 (-19%)	2780 (-20%)
Butter	3202	2954 (-8%)	2511 (-15%)
Milk powder	2377	2055 (-14%)	1747 (-15%)
Premiums			
Milk cows	0	0	157
Suckler cows	133	164 (23%)	284 (73%)
Male adult cattle	105	136 (30%)	324 (138%)
Milk quota	113879	115577	120335

The following assumptions also apply:

- Milk yields increase due to technical progress (specific trend for each Member State)
- Long term trend to increased final weights continues to offset reduced availability of calves: + 10 % for male adult cattle and heifers fattening are assumed until 2005
- Adjustments of feed requirements according to yield development (milk, final weight) but 0.5 % increase in feed efficiency per year

Figure 4: Development of herd sizes in EU in reference run



Under both scenarios (reference run and Agenda 2000), the production of milk is clearly quota driven. Whereas production slightly increases following the quota expansion, the increase of average milk yields per cow leads to a distinct reduction of the dairy cow herd in Europe, affecting other cattle activities due to reduced output of calves as well as decreased demand for young cows.

Figure 4 shows the results from the reference run: the dairy cow herd is more or less exogenously determined by the slight quota increase (+1.5 %) combined with an average increase of milk yields by about 14 %. The reduced availability of calves keeps their prices relatively stable despite a drop of the beef price by 28 %. However, part of the price drop is compensated increasing premiums for male adult cattle. The stable calve prices favour suckler cows (herd size increases by 3.5 %). Reduced availability of calves decreases fattening of heifers (-17 %) and calves (-10 %).

The prices for final products relating to the cattle sector (beef, veal, milk and milk products) are mainly policy driven by the development of administrative prices. Effects on demand inside of the EU are rather low for these saturated markets. However, the outcome of the simulations runs depends on the endogenous prices for young animals. For further analysis of the cattle sector, two improvements are envisaged: a split-up of calves into male and female ones and endogenous final weights for fattening processes.

Table 5: Animal production in Europe, Physical production (1000 tons)

	Base year 1994	Reference 2005	Agenda 2005	Reference to Base year	Agenda to Reference
Meat	24268	24955	24753	2.8%	-0.8%
Beef	7694	7558	7471	-1.8%	-1.2%
Veal	849	775	824	-8.7%	6.3%
Sheep- and goatmeat	1284	1217	1220	-5.3%	0.3%
Pigmeat	16573	17397	17282	5.0%	-0.7%
Poultry	7757	7268	7246	-6.3%	-0.3%
Eggs	4893	5583	5579	14.1%	-0.1%
Milk (unprocessed)	129475	130436	135698	0.7%	4.0%
Cow milk	119741	121347	126497	1.3%	4.2%
Sheep and goats milk	9734	9089	9201	-6.6%	1.2%

Tables 5 summarise the results for the two scenarios. Changes inside the cattle sector in Agenda 2000 mainly result from a milk quota increase driving up the dairy cow herd (+4.6 %) and a larger suckler cow herd (+2.8 %) due to the premium raise. The higher availability of calves compared to the reference run favours the fattening activities. For other meat products, reactions mostly depend on the feed back from the market. The somewhat astonishing substitution between poultry and pig meat in the reference run is based on tariff reductions for poultry meat which leads to an exogenous price shift. Here, further insight in the application of trade policies in the meat markets is clearly necessary. It should be mentioned that tariff impacts on meat markets are generally a sensible and complicated field as instruments relate to specific cuts and qualities whereas the model deals with the combined effect on the raw product price. Presented results clearly reflect the current weighting scheme and must be carefully discussed and eventually re-designed by market experts. Additionally, pig and poultry markets are strongly influenced by assumed market developments in rest-of-the-world as well. Overall, the results show that the system is operational, but underlines the necessity for co-operation with market experts in order to better define trade policy measurements.

5 Conclusions

The CAPRI project has been successful in developing a regionalised agricultural information system for the EU. It is now in the position to establish an enduring usefulness for EU- and national policy makers to address the manifold expressed interest during the development phase. In order to insure a survival of the system, a regular update of the data base, partial methodological improvements as well as a systematic validation of the model are necessary. It is quite clear that this can only be achieved (1) in the network approach which ensures the in-depth knowledge of regional aspects of agricultural production and the access to national data sources and (2) in a close dialogue with policy makers to efficiently use the system for policy design and evaluation.

6 References

BRITZ W. (1998): A Synthetic Non-Spatial Multi-Commodity Model as Market Component for CAPRI, Capri Working Paper 98-07, University of Bonn

HECKELEI T. (1997): Positive Mathematical Programming: Review of the Standard Approach, Capri Working Paper 98-02, University of Bonn

HECKELEI T. & W. BRITZ (1999): Maximum Entropy Specification of PMP in CAPRI. CAPRI Working Paper 99-08, University of Bonn.

HOWITT, R.E. (1995): Positive Mathematical Programming. Amer. J. Agr. Econ, 77(2), pp. 329-42.

PARIS, Q., & R.E. HOWITT (1998): An Analysis of Ill-Posed Production Problems Using Maximum Entropy, Amer. J. Agr. Econ., 80(1), pp. 124-138.

WITZKE, H.P & W. BRITZ (1998): A Maximum Entropy Approach to the Calibration of Highly Differentiated Demand System, Capri Working Paper 98-06, University of Bonn.

WOLF W. (1995): SPEL system, Methodological documentation (Rev. 1), Vol. 1: Basics, BS, SFSS, EUROSTAT Luxembourg 1995.

LAMPE, VON, M.(1998)*:* The World Agricultural Trade Simulation System - An Overview. Agricultural and Resource Economics Discussion Paper 98-05, Institute for Agricultural Policy, University of Bonn.