RECENT DEVELOPMENTS IN EU POLICIES – CHALLENGES FOR PARTIAL EQUILIBRIUM MODELS

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Abstract

This paper gives an overview on current and prospective modelling challenges for agricultural partial equilibrium (PE) models focussing on EU policies. Starting from a certain policy context, the paper highlights the current capabilities and limitations of existing PE models and, if available, develops some ideas on future modelling directions to advance the usefulness of quantitative information provided.

Key words: Policy impact assessment, agricultural partial equilibrium models, Common Agricultural Policy

1. Introduction

The reform of the Common Agricultural Policy (CAP) is moving forward. The stepwise implementation of the 2003 reform is still under way and further sectors such as sugar, fruits, vegetables, and wine are integrated into the single farm payment scheme. At the same time new steps are already discussed: The currently published communication of the EU commission to the parliament and council relating to the so-called "health check" (EU Commission, Nov. 20, 2007) sets up a new reform agenda targeting the milk quota regime and dairy markets, questioning the remaining supply controls and market intervention measures, and proposing changes in the implementation of the single farm payment scheme. Some of these first pillar related proposals imply a further extension of the second pillar budget to address potentially negative environmental and social side effects in a region-specific, targeted fashion. These developments clearly indicate that integrated impact assessment of the CAP reform process will remain an important activity in the medium term future.

Hence, there is ample room for the application of quantitative modeling, with partial equilibrium models certainly remaining an important instrument given their ability to flexibly integrate the different CAP policy instruments, to take advantage of specific data sets for the agricultural sector and to represent outputs, inputs and externalities in physical units. Here we define a partial equilibrium model as single quantitative simulation model or a combination of simulations models which cover both supply and demand for agricultural products, but do not integrate all sectors of the economy. This definition consequently excludes both, Computable General Equilibrium (CGE) models and stand-alone supply models, but does cover "model chains" where, for example supply and demand representations are linked to form market models.

What are most notable advances in the last decade in agricultural PE models? From our point of view, three major developments deserve to be mentioned: The first is the emergence of agent based approaches integrating markets for primary factors – most often agricultural land – and product markets, at least at the regional scale (e.g. Happe et al. 2006). Secondly, the increasing activities of more or less formally linking different models aiming to exploit the comparative advantages of different components without creating inflexible "super models" with high maintenance and management cost. (e.g. Flichman 2006, Jansson 2007). And thirdly, the increasing integration of agri-environmental interactions in PE models.

But naturally, there exists uncountable examples for improvements of PE models, regarding the empirical estimates, novel solutions to model policy instruments, or of extending product and regional coverage. In some cases, the paper will refer to such examples if they appear especially interesting in the light of the challenges arising from policy and market changes discussed in the following. However, the authors admit that the selection of topics and examples discussed remains subjective, to a certain extent also rooting in limited access to up-to-date models documentations or reports from research projects. A further decisive factor relates to the language used to document models and to report scientific findings. We regret that concentrating on papers published in English may lead to a bias in geographic coverage.

The following table lists some recent research projects funded under the EU framework program which comprise developments or applications of quantitative tools aiming at the impact assessment of the CAP or CAP reform options. The majority are so-called Specific Targeted Research Projects (STREP) with a limited number of partners, where the topics were defined by policy makers. SEAMLESS and SENSOR are so called integrated projects with larger participation of up to 30 partners and corresponding extended budgets compared to the STREPs. Beyond these research projects, it should be mentioned that quantitative models are regularly applied in the context of project tenders directly launched from different DGs in order to support specific policy questions mainly using already available tools.

The paper is structured as follows. The first part looks at how primary factor use and markets are modeled in European PE models and evaluates their ability to contribute information to current policy questions regarding regional labour markets and impacts of different single farm payment implementations on land prices and use in marginal areas. The second chapter is devoted to quantitative analysis of product markets, the classical domain of PE models, again with a focus on the recent changes in the CAP. The third chapter looks at modeling of agri-environmental interactions.

Table 1: Projects under Framework Program VI supporting CAP policies with quantitative tools

Project acronym	Work program	Models applied for agricultural markets / land use
EDIM	Policy support for re-orientation of dairy markets	EDIM
EU-MedAgpol	Policy supports for trade negotiations EU-Mediterranean	CAPRI, TASM, CGE for Tunesia
EU-Mercopol	Policy supports for trade negotiations EU-Mercosur	CAPRI
CAPRI-Dynaspat	Policy support for CAP reform	CAPRI, CAPRI-Dynaspat
Genedec	Impact assessment of decoupled payments	Aropaj, FARMIS, Teagasc model, PMP based farm models, PROMAPA.G, DREAD, ESIM
MEA-SCOPE	Micro-economic instruments for impact assessment of multifunctional agriculture	MODAM, Agripolis
TRADAG	Support to WTO negotiations	GTAP

INSEA	Development of tools to assess economic and environmental effects of enhancing carbon sink and greenhouse gas abatement measures on agricultural and forest lands	EU-FASOM, AROPAj
IDEMA	Development of tools and models for to provide a comprehensive socio-economic assessment of the impact of decoupling on the EU farm sector	ESIM, AgriPolis
SEAMLESS	Development of Sustainability Impact Assessment Tool for EU agricultural systems across disciplines and scales	GTAP, CAPRI, farm models
SENSOR	Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions	NEMESIS, CAPRI, GLUE-S
WEMAC	Development of a partial equilibrium model that will provide simulations of the global effect of agriculture policy, trade reform and macroeconomic factors on arable crop and oilseed markets	WEMAC
AGMEMOD 2020	Agricultural Member States Modelling for the EU and Eastern European Countries	AgMemod

2. Product markets

The so-called health check of the Commission (European Commission 2007a) requires an analysis to what extent the combined impact of the reform process and the recent developments in product markets allow a removal of the remaining elements of supply control (set-aside, dairy quotas and the special Common Market Organizations) while at the same time identifying such regions and sectors where more targeted policies are needed.

2.1. Bio-fuels

Bio-fuels have become a hot topic. According to the EU biofuels directive (EU 2003) EU Member States should ensure that biofuels and other renewable fuels attain a minimum share of their total consumption of transport fuel. This share should lie, measured in terms of energy content, at 5.75% by the end of 2010. The so-called “Renewable energy road map” from January 2007 (European Commission 2006a) acknowledges, however, that targets set for intermediate years had not been met and that the one for 2010 will be most probably also not reached, and therefore proposes a bundle of measures to promote bio-fuels further on. However, there are also growing concerns about negative impacts of producing bio-fuels (see e.g. UN 2007), both from an environmental point of view as from a social one.

Integration of demand for bio-fuel processing in PE models has and will hence be on top of the agenda in many modeling teams. There are four major challenges to tackle when modeling bio-fuels. The first challenge consists in developing a behavioral model for bio-fuel processing industry in order to describe the demand for the different agricultural bio-fuel feed stocks as a function of energy prices, agricultural raw product prices, further input prices and the different policy instruments as blending, tax reductions or subsidies used in bio-fuels markets. The solution may require linkage between specialized energy or forestry models and PE model for agriculture. The second challenge relates to the question of import substitution, which may refer to the bio-fuels themselves, the feed stocks used in their production or to indirect ones, such as rapeseed oil in the food industry being substituted by palm oil and used for bio-fuel processing instead. The import substitution analysis can draw on the experience in application of PE models in trade analysis, may however ask for expansion of product and regional coverage of the models. Thirdly, the fate of the by-products as cakes, bran or gluten must be taken into account. And a fourth challenge relates to possible differences in farming practices between producing bio-fuel feed stocks or targeting food or feed markets.

The methodologies adapted so far to model bio-fuels in PE models are rather different. Schmidhuber (2006) introduced exogenous shocks in the AT2030 modeling system of the FAO to analyze world wide effects of bio-fuel production. The supply functions for ethanol and bio-diesel in the AGLINK model (von Lampe 2006) follow a double-log form depending on time, the cost ratio between bio fuel and fossil fuels and an exogenous adjustment factor to take into account politically determined growth. AGLINK also considers several by-products of bio fuel production. In some of the AGLINK country models, substitution between feed stocks for bio-ethanol production is modelled based on a CES function. The implementation in ESIM (Banse et al. 2005) is rather interesting for at least three reasons. Firstly, ESIM explicitly differentiates between products grown for energy production on set-aside areas, and products grown elsewhere. Secondly, it takes explicitly the prices of fossil fuels into account when determining the processing level to bio-fuels, applying a linear-log functional form. And thirdly, it integrates by-products from bio-fuel processing. The so revised ESIM model was used in the context of the SCENAR 2020 study (Nowicki et al. 2007) and by DG-AGRI (European Commission 2007b). AGMEMOD is currently in the process of integrating bio-fuel demand, and von Ledebur and Chantreuil (2007) propose to derive the demand for cereals for bio-fuel production exogenous from Member State specific targets for bio-ethanol production, and to model rapeseed oil as the sole source for bio-diesel. A logistic function is then used to derive from the target in the final simulation year values for intermediate year. The CAPRI team has expanded the product list in the global market model by palm oil and gluten feed and improved the handling of by-products form the milling industry and sugar-beet processing, and explicitly links by-products to bio-fuel processing. So far, bio-fuel demand per product is treated as exogenous, derived from targets for bio-ethanol and bio-diesel and exogenously determined shares for the feed stock.

For all approaches discussed, the parameterization of the chosen behavioral function remains a challenge as very few observations are available. Furthermore, this issue becomes complicated, as a robust integration of markets with considerable production potentials outside of the EU, for example in South America, is required for more meaningful modeling exercises.

2.2. Market integration in the enlarged EU and trade liberalization

The recent proposal by the EU commission to remove any intervention measures from feed grains markets reflects the increased differences in production costs and market structures in the enlarged union. In the past, world market prices below administrative ones in combination with well developed transport and market infrastructure in the EU10, EU12 and later EU15 more or less leveled out price differences inside the EU and stabilized the prices everywhere at or above intervention price levels.

After the east expansion, high price differentials between surplus and deficit regions inside the EU can be observed, partly due to transport costs. On top, the combination of high world market prices and reduced administrative ones has changed the picture. Analyzing policy impacts at EU level must thus take the fairly ***different market situations in the Member States*** into account, as they will impact on farm income, but also on the relevance of payment schemes or supply control measures.

PE models have used different methodologies to describe ***price transmission*** between markets, including intra-European ones. There are basically three different approaches in use. The first one is based on estimated or assumed price transmission functions between each Member States and an anchor price. AGMEMOD uses generally a formulation which takes last year prices, the prices in the anchor region and the self-sufficiency in the domestic market as well in the anchor market into account. In the case of the anchor market, the world market prices, a possible intervention price and the EU degree of self-sufficiency is taken into account (Chantreuil et al. 2005). ESIM (Banse et al. 2005) applies a logit function to describe price transmission between world and EU markets, depending on EU's net trade position. The lower bounds of the logit function is the maximum of the intervention price and the world market price, whereas the upper limit is defined by the maximum of world market price and the EU threshold price which is at 155% of the administrative price. The Aglink model of the OECD (OECD 2007) uses linear price linkage equation including a margin representing transport costs and, when not explicitly modeled in the supply and demand equations, border measures as tariffs. Models using price linkage function face a problem in case of the new Member States, where very few observations are available to estimate parameters or validate the model. Takayama-Judge type models as the second approach use explicit minimization of bi-lateral transport costs to define price differentials, as e.g. in the EU-FASOM model (Adler et al. 2006) or EDIM (Bouamra-Mechemache and Reqillart 2005a). And finally, the Armington assumption may be applied as in CAPRI (Britz et al. 2007) where EU15, the new EU10 und Bulgaria & Romania and further world regions or countries are treated as trade blocks, and price transmissions between the blocks is based on the Armington assumption in combination with bi-lateral transport costs. Inside the blocks however, a linear price transmission functions from Member States to an EU anchor price is used. The Armington assumption is also applied in DREMFIA (Lehtonen et al. 2005), a Finnish sector model with fixed Rest-of-the-world prices. As generally with the Armington assumption, it allows an easy calibration to an observed vector of trade flows and prices, but in almost no case are the underlying parameters estimated from observations. All those approaches face data and/or parameterization problems and may need a review in the light of recent market and policy developments. In that context, it should also be mentioned that most teams working at EU level have or are extending their models to cover all EU accession candidates.

Another challenge for agricultural PE models is the increasing number of ***bilateral trade agreements*** which often introduce new Tariff Rate Quotas at least during intermediate but often lengthy implementation periods. Price pressures from abroad into EU markets is – for the majority of the cases – not based on the WTO bound tariffs, but linked to preferential trade agreements. The highly differentiated nature especially in bilateral trade agreements of the EU firstly poses serious data problems, as often time series data on trade flows in quantities and values are hard or even impossible to obtain in the product definition of the agreements. In the CGE world, simulation models working on single tariff lines are partly used to capture the bi-lateral tariff framework which are then used in a premodel step to arrive at the regional and product aggregation of the CGE (see e.g. TRADAG project). Access to those single tariff line data bases or the development of an equivalent instrument concentrating on agricultural EU imports could benefit the different market models currently in use for European policy impact assessment.

The second challenge relates to the structure of the PE models themselves, regarding product and country differentiation and the integration of trade policy instruments. In the context of the EU-MedAgPol project, the entry price system for fruits & vegetables along with bi-lateral TRQs was explicitly introduced in the model equations of the CAPRI trade model (Britz et al. 2007). In parallel, the non-EU part of the CAPRI trade model was further dis-aggregated to distinguish between several Mediterranean countries (Morocco, Tunesia, Turkey, Israel, Algeria, Egypt). The sister project EU-MEDFROL used the newly developed AGRISIM model (Kavallari and Schmitz 2006) to analyze effect of bilateral trade liberalization between the EU and Mediterranean countries. AGRISIM is a standard synthetic Multi-Commodity model using double-log behavioral functions. Nominal protection rate and price transmission elasticities link domestic to world market prices. Production quotas, minimum producer prices and subsidies are taken into account. Both in CAPRI and AGRISIM, olive oil, tobacco and tomatoes are modeled explicitly. A far more detailed description regarding Mediterranean products offers the TURKSIM model (Grethe 2002) which comprises 15 fruits and vegetables. It was used in several studies on Turkey's integration in the EU, but – as DREMFIA for Finland – worked with fixed import and export prices. CAPRI is applied as well in the EU-MercoPol project to analyzing effects of bi-lateral trade liberalization between the EU and Mercosur. The trade model is dis-aggregated to individual Mercorsur countries. Specific work packages aim at the estimation of supply and demand elasticities for major products.

2.3. Market risks

With the CAP moving out of market management, and reducing administrative prices to a basic safety net, price ***volatility*** in EU markets may be increasing. Most PE models are non-stochastic and not able to deliver higher moments of their result vectors, and do not take into account risk in their behavioral equations. For a few years, FAPRI provides a stochastic baseline (Westhoff et al. 2005) which is derived by a simplified version of FAPRI. Drawing from the errors terms around a 22 year time series for major variables as crop yields or error terms of key demand equations, 500 sets of exogenous variables are drawn and then simulated with that model version. It is somewhat astonishing that the paper does not discuss the necessity to modify the stock change equation.

A somewhat similar exercise was conducted a few years back with CAPRI, drawing yield shocks from the co-variance matrix of the error terms of the de-trended crop yields for cereals (Baeckstrand and Britz 2005), which required the introduction of short time stock changes in the market part of CAPRI.

Generally, it can be expected that analyzing market risks will be important in the years to come, and be also discussed in the context of the health check and the further reform process of the CAP. Both the FAPRI and the CAPRI exercise may hint at necessary structural adjustments in existing PE models. Firstly, processing time and storage demands for bootstrapping exercises are enormous and may require slimmer versions of the models. The necessary simplifications could, for example, be based on a statistical response surfaces of the non-EU part of the models. Care should be given to not oversimplify reduced forms by removing the effects of TRQs. Secondly, introducing stochastic shocks may require a revision of behavioral equations. This may include a short-run stock agent to avoid overestimation of price volatility, but also revisions of supply equations driven by price expectations. And last not least, it may be necessary to take the risk attitude of the agents into account.

2.4. Further CAP reform steps

Clearly on the agenda for the next decade is the liberalization of *dairy markets* as indicated already during the health check (EU Commission 2007). Several attempts have been made to estimate marginal production costs of raw milk and shadow prices of milk quotas in the last years. FADN data were used by Schokai (2005) and Cathagne et al. (2006). to estimate marginal costs curve at EU15 Member state level for different time horizons, and again by Wieck and Heckelei (2007) to estimate short-run production costs of milk for major European production regions. There is hence ample room to base dairy supply and quota rents in PE models on econometrically estimated parameters. An example is the EDIM project which updated the EDIM model, and used the revised model to analyze effects of a WTO agreement and WTO plus increase in dairy quotas at Pan-European scale (Bouamra-Mechemache and Reqillart 2005a). The analysis was complemented by applying the EU-FARMIS modeling system. EDIM also estimated own demand elasticities for dairy products in the EU.

Supply of raw milk, production and demand of dairy products are covered in all major PE models, equation structures and parameterization however differ substantially. Most models allocate milk protein and fat explicitly to dairy products. The methodology chosen however differs. In AGMEMOD (Chantreuil and Haranhan 2007), milk protein with the exemption of butter and a residual product is allocated according to own and cross-prices of the dairy products (fluid milk, butter, skimmed milk, cheese, whole milk powder, other dairy products). A residual product closes the protein balance. Milk fat allocated to butter is again price dependent. The milk fat allocated to the products driven by the protein allocation is based on fixed coefficients. The remaining milk fat, hence the one not allocated to milk and other products, is then allocated to the residual category. The teams involved in AGMEMOD at least try to estimate the elasticities used in those behavioral equations from time series. AGLINK (OECD 2007) again uses balances for milk fat and non-fat solid, where butter and skim milk powder close the balance. Supply of dairy products is driven by product prices in relation to the value of milk fat and not-fat solids in the products, for the latter, butter and skim milk powder prices are used as proxies. CAPRI (Britz et al. 2007) employs a normalized quadratic profit function at dairy level assuming fixed protein and milk fat content of the dairy products (butter, skimmed milk powder, whole milk powder, cheese, cream, concentrated milk, fresh milk products) to derive production per dairy product and demand for raw milk, under explicit constraints for protein and milk fat linked to milk fat and protein prices. The output quantities depend on own and cross processing margins, i.e. the difference between the dairy product prices and the value of milk fat and protein. In EDIM, as in CAPRI, the market price of the dairy products (butter, skim milk powder, whole milk powder, condensed milk, casein, liquid milk, cream, fresh products and five categories of cheese: fresh, semi hard, hard, processed, blue and soft cheese) is equal to the value of the fat and protein content plus a margin. That margin is defined by the derivative of cost function depending on the production level of the respective dairy product. Both CAPRI and ESIM derive their behavioral models from assumed elasticities, whereas the sources in AGLINK and EDIM could not be located. ESIM (Banse et al. 2005) covers butter, skimmed milk powder, cheese and other dairy products, but does not cover separated fat and protein balances, but uses raw milk equivalents. Processing output depends on own and cross prices for dairy products, the price for raw milk and the prices for all remaining products.

Generally, there seem to be a good basis for policy support regarding changes in the CMO for milk and dairy, based on different econometric exercises to capture production costs and well developed structures in the models. The *abolishment of obligatory set-aside* is another option proposed in the context of the health check, but a discussion on set-aside is covered above in chapter on primary factors.

2.5. Possible conclusion for the research agenda

Generally, we may observe that there is still a notable tendency to prefer clearly structured equations in combination with synthetic parameters over econometric work (see also van Tongeren et al. 2001). The synthetic models either employ flexible functional forms for behavioral equations and calibrate parameters accordingly as in CAPRI, or apply constant elasticity equations as in ESIM and AGRISIM. In two trade liberalization projects based on CAPRI, work packages either dealt with estimating parameters (EU-Mercopol) or with integration of parameters of existing country specific models (EU-MedAgpol).

There are only a few projects were behavioral parameters are estimated (AGMEMOD, EDIM, EU-Mercopol). Generally, we can observe that there are two schools when estimating parameters for PE models. Where estimations are based on single farm observations, often using FADN, system estimations rooting in micro-economic theory are used. Milk output is certainly especially appealing as the analysis may then only distinguish raw milk and other agricultural outputs. In some cases, as in EDIM, supply response from the micro-economic models is aggregated to national level and implemented in PE models. Far less popular seems a stringent application of micro-economic theory when estimating behavioral parameters at national or regional level for a larger range of products. The large-scale projects developing the econometrically based AGMEMOD country modules all applied single equation models. An exemption is the work of Jansson (2007), who estimated parameters of a cost function for all EU15 regions in CAPRI simultaneously for all annual crops under an explicit land constraint with a Bayesian estimator.

3. Agri-Environmental interaction

3.1. Policy context

The CAP reorients itself towards the three pillars of sustainability, and that will require new tools to assess the impact of existing and new policy instruments not only by economic, but as well by environmental indicators. Under pillar I, the relevant policy is cross-compliance (CC), applied since 2005 to 19 EU legal acts and the so-called Good Agricultural and Environmental Conditions (GAEC). Under Pillar II, the so-called Axis 2 (Improving the environment and the countryside) aims at ensuring the delivery of environmental services by agri-environmental measures in rural areas, and preserving agricultural land use in areas with physical and natural handicaps. So far, there are only a limited number of studies employing quantitative economic models to assess the effects of CC on farming decisions. This equally applies to analyzing the impact of agri-environmental measures at a larger scale.

Pillar II, accounting for 9% of the EU budget 2007-2013 compared to 34% for pillar I comprises a rather diverse mix of programs. There are three EU priority areas in axis 2 for the programming period 2007-2013: (1) bio-diversity and preservation of high nature value farming and forestry systems, (2) water quality and scarcity and (3) climate change. Funds under Axis 2 allow payments to farmers in disadvantaged areas (LFA), Natura 2000 payments, agri-environment measures, animal welfare payments and support for forestry. A minimum of 25% of co-funded expenditure under pillar II has to be spent on Axis 2 with a maximum EU co-financing rate of 55%. A specifically challenging field for quantitative analysis is the agri-environmental measures, programmed by the Member States and approved by the Commission, due to their diverse nature, the limited availability of data, and empirical difficulties to estimate costs related to program participation. Further policy fields of interest regarding environmental impacts of agriculture relate to Green House Gas emission or other gaseous emission, especially ammonia.

3.2. Modeling aspects

Quantitative analysis of the measures under CC including GAEC and axis 2 faces three challenges. The first relates to data availability. Contrary to other elements in the CAP which are rather consistently implemented across the EU, environmental concerns require to take the regional and local situation into account. EU legislation therefore only defines a framework, laying out the targets of the legislation and some rather general rules, whereas actual implementation is done by national or even sub-national legislation. That renders it already rather tedious to gain an overview on the measures and even more so regarding the actual implementation. Secondly, given their often specialized nature, a clear mapping in the “language” of quantitative models, in categories such as higher costs, upper limits on certain decision variables or incentives for others is often impossible. The third challenge relates to structural properties of the quantitative models themselves:

Classical PE models with supply and demand functions and some representation of international trade are by definition less suitable for environmental impact assessment (see e.g. Mittenzwei et al. 2007) as their interface to policies is linked to a triple defined by region, product and item of the market balance (supply, demand, trade). The obvious advantage of the structure is the fact that the elements modelled are typically available as time series so that statistical estimation or validation of model behaviour is rather straightforward. This set-up proved highly suitable for market related policy instruments as price support, tariffs or subsidies paid for processing, a policy setting classical PE had originally been defined for in the eighties. Their spatial resolution is at the level of countries or above. Given those features, it is not surprising that – to the authors’ knowledge – none of the well known PE models as FAPRI, AgLink or ESIM comprises environmental indicators, albeit the models by now often run crop supply by separate behavioural functions for yields and areas. An exemption is the FAPRI-Ireland model (Behan & McQuinn 2002) which uses land allocation, fertilizer application rates per crops and animal herds in combination with fixed coefficients to estimate GHG emissions. Several teams from the AgMemod partnership are now linking IPCC coefficients to the results of the national models (Simola 2006). The integration of measures relating to CC and GAEC or measures from axis 2 is hardly possible in PE models, as any measure must be mapped into change of prices.

Besides the one mentioned above, the DREMFIA model for Finland (Lehtonen et al., 2006) provides an example comprising nutrient balances, a Shannon index to measure crop diversity and pesticide applications. DREMFIA is however a regionalized Programming model where price endogeneity is achieved by integrating the sum of consumer rents under linear demand in the objective function, a model type which seems not too popular. The only similar layout found by the authors in Europe is the newly developed EU-FASOM (Schneider and Schwab 2006) model, which comprises detailed GHG balancing and forestry. In EU-FASOM, the demand functions are linearized to get a fully linear model. The model documentations suggest that both systems are only covering own price effects in demand.

Already the two examples above belong to the class which employs aggregate programming models. Most of those are based on production activities, which are characterized by input and output coefficients, and their spatial resolution is typical at administrative regions or farm types inside administrative regions below country level. They offer hence interfaces related to input and outputs, and to activities, as e.g. payment per ha or hectares. Many of the models also model substitution between mineral and organic fertilizers, and between own produced fodder and concentrates. The activity based structure rendered them quite successful in evaluating the reform process of the CAP since 1992 with its switch from market support to payments linked to production activities, and the introduction of supply control measures as quotas and set-aside. Their success over the last decade was further promoted by the introduction of PMP (Howitt 1995) which solved the over-specialization problem of a pure LP models and allowed for perfect calibration to a base year. The extensions of PMP led finally to a class of hybrid supply models combining a Leontief technology for certain inputs with econometrically estimated dual costs function (Heckelei and Britz 2000, Jansson 2007). The structure of programming models allows as well the definition of passive environmental indicators based on emission factors linked to the input/output coefficients or the activity levels, and those indicators are able to measure the side effects of the reform process on the state of the environment, as, for example, in RAUMIS (Gömann et al. 2005), Aropaj (De Cara et al. 2004) or PASMA (Schmid & Sinabell 2007). But already the introduction of the so-called “accompanying measures” in 1992 clearly proved the limits of the approach. In order to allow for price feedback, aggregate programming models need however either be linked to a market model or integrate the integral under demand curves as in DREMFIA or EU-FASOM.

But in the majority of cases, as for CGEs, aggregate programming models feature a one to one relation between activities/sectors and major outputs, which renders them less useful for policy measures related to decisions at process level as e.g. the type of soil cultivation used. Unfortunately, agri-environmental measures and CC including GAEC typically do not target production activities per se, but specific processes as e.g. storage and application of organic manure, plant protection and soil preparation. Aggregate programming models are therefore subject to over-estimating the costs related to environmental restrictions as the decision space is restricted to changes in activity levels. But at current state, the large scale programming models are at least for a certain period still useful to accompany the on-going reform process, but may need structural adjustments in the medium term to continue their usefulness in supporting policies and analysing agri-environmental interactions.

Some models have already started necessary structural adjustments. At least for a test region, Aropaj (Godard et al. 2005) introduced yield functions depending on N-Input, determining the curvature of the yield function from a crop-growth model, and assuming that the N-P-K composition is kept fixed, whereas other intermediate inputs are kept unchanged per ha. A similar approach was used for RAUMIS already in 1995 (Weingarten 1995), using observation from crop growth experiments, where, however, also other input coefficients besides fertilizers depend on yield.

Only some types of farm models comprise individual processes as soil preparation, fertilization, feeding practise etc. as decision variables and thus offer interfaces suitable to model in detail environmental standards and incentives (e.g. Flichman et al. 2006). A rather interesting example in the context is EU-FASOM (Adler et al. 2006) as it does not work at the level of single farms but at Member State level. It takes different soils and different technologies into account, sourced in parts by EPIC, but the authors admit that the model is not yet fully functional.

Should cross-compliance legislation at national level and/or control be enforced and the spending for agriculture under axis 2 increase, the demand for models explicitly modelling technological choice can be expected to increase. Those models struggle however with the fact that observations on those processes are generally not available from statistics, rendering already the definition of a probable status quo difficult and even more so the validation of the behavioural response. That clearly hints at two major challenges. Firstly, generation of appropriate data bases to define plausible definition of processes available to farmers including their costs, and secondly, access to time series or cross-sectional data on to what extent they are currently used. The latter requires co-operation with statistical offices and data sampling.

In order to overcome the fundamental shortcomings of PE-models in environmental analysis, modeling teams have therefore linked market models with regional or farm type models. A typical example is CAPRI of which the supply models comprise inter alia nutrient balances and GHG inventories (see e.g. Mittenzwei et al. 2007). A similar tactic is found in the SEAMLESS project where a model chain comprising bio-physical models, farm type models and CAPRI is set-up (Flichman et al. 2006). There are other projects where PE and programming models are combined, e.g. IDEMA, but projects reports are often not very clear about the details of model linkage. Currently, it seems not yet clear if highly specialized farm models sourced from regionalized data sources and coupled with an extrapolation algorithm to upscale results to regional level will be superior to template models implemented at regional or farm type level across Europe.

Finally, there are many instruments already in the current agri-environmental policy which even go beyond the typical process definition in specialized farm models, and some elements of both cross-compliance and agri-environmental measures are falling in that category. An example is the prohibition to remove landscape elements as hedges or trees. And in the some cases, even fundamental knowledge necessary to define policy targets and appropriate indicators is missing, for example when it comes to assessing landscapes.

3.3. Topics addressed

Agricultural sector models in Europe seem to concentrate in the field of agri-environmental interaction currently mostly on *water quality* issues, often linked to phosphate and nitrate emissions from agriculture. In some models ,explicit constraints capture elements from the Nitrates Directives and thus elements of Cross Compliance (e.g. Helming and Peerlings 2005). Nitrogen and/or phosphate balances seem to be implemented in almost all programming models. Little attention seems to be given to questions of *water scarcity and irrigation* in Pan-European System, contrary to other modeling teams, e.g. in the US (Atwood et al. 2000). Albeit there are specialized models for single regions (e.g. Iglesias et al. 2004, Judez et al. 2001, Riesgo & Gomez 2005), there seems to be no Pan-European model covering irrigation water as a constraint. CAPRI covers irrigation water requirements as an indicator in the 1x1 km grid result set (Britz 2007).

GHG emissions and abatement are covered by several models and respond to the third priority area mentioned above (climate change). Aropaj (Adler et al. 2006) models abatements of GHG gas emission in agriculture for EU15 in combination with Carbon sequestration based on farm models derived from FADN derive abatement costs, however at exogenous prices. The parameterization of Aropaj in that study as part of the INSEA project is in parts based on the results from EPIC. INSEA also developed the large scale EU-FASOM model including forestry and modeling GHG abatement under endogenous prices in a LP with linearized demand functions. Perez (2005) has implemented GHG inventories in CAPRI and estimated abatement costs of CO_2 with endogenous prices for agricultural products. As mentioned above, several national models of the AgMEMOD system also are linked to GHG emissions coefficients. Leihtonen et al. (2006) analysed changes in land use in Finland based on DREMFIA with a focus on peat lands. Peat land emit – due to their high soil organic carbon content – considerably more N_2O compared to other soils and are therefore deemed a major source of agricultural GHG emission in Finland. The study analyzed a possible climate change policy allowing no or only grassland or fallow on peat-lands, but also the effect of the MTR compared to Agenda 2000.

A recent project for DG-ENV (Oenema et al. 2007) linked emission coefficients from RAINS (Amann 2004) into CAPRI to analyse abatement options for *Ammonia*. Both Ammonia and GHG emissions are also addressed in the model chain comprising the PE ESMERALDA model for Denmark (Wier et al. 2000), comprised in the FAPRI-Irland model (Behan & McQuinn 2002) and as a further example in RAUMIS (Gömann et al. 2005).

A recent review of economic models dealing with *bio-diversity* (Eppinka & Berga 2007) clearly shows that the topic is typically not addressed in agricultural sector models. Mattison & Noris 2007 argue that economic models for agriculture are able to provide the necessary data as changes in land cover and farming intensity to analyze impacts on bio-diversity, and cite a wide range of studies analyzing relations between bio-diversity loss and changes in agriculture or effects of conservation programs as, for example, the agri-environmental measures under pillar II. The examples underline, however, that the analysis requires in-depth knowledge about the factors impacting on the distribution of species, rendering large-scale analysis difficult. That view is also shared by the EU Commission (EU Commission 2007) who states in the “biodiversity action plan for agriculture” that a “site-specific approach is necessary in order to offer an accurate picture of the interrelations between local farming activities and specific biodiversity assets.” An example for a large-scale application is the EURURALIS study (Verburg et al. 2006) where a bio-diversity index is defined composed of a species index, nitrogen level and level of disturbance to the ecosystem. A bio-diversity index is also included in the RAUMIS model since middle of the nineties (e.g. Goemann et al. 2005). The European Environmental Agency (EEA 2007) has proposed a set of agri-environmental indicators, which specifically for agriculture comprises the nitrogen balance and area under management practices potentially supporting biodiversity which is linked to High Nature Value Farmland. But many other indicators discussed in the EEA document are indirectly linked to agriculture as well. Examples are nitrogen deposition linked to ammonia emissions or freshwater water quality. But generally, bio-diversity can only be analyzed based on spatially explicit data and is therefore linked to down-scaling approaches discussed below.

3.4. Downscaling approaches

There seems to be growing recognition of the fact that infra-regional analysis of environmental effects below NUTS 0-III level is necessary as farming practice and its environmental impacts depend inter alia on soil, slope and surrounding land cover. There are basically two “schools” in that field.

The first one generates from local information possible technologies, often integrating bio-physical models, and uses traditional LP or PMP models to derive the optimal farm practice at local scale, as, for example applied in SEAMLESS. That approach has a long-standing history dating back to the late eighties (Gassman et al. 2005). The major research question is here in fact how to validate and calibrate the farm/regional model layer, and how to link it with market models for large-scale analysis. A recent example is the model chain in SEAMLESS (Flichman et al. 2006) which comprises as a novel aspect an extrapolation procedure mapping the supply behavior of farm type models into the regional programming models from CAPRI. Equally, in INSEA (Adler et al. 2006) in total 1,084 HRUs (Homogenous Response Units) for EU25 were delineated as the unique combinations of elevation, slope, soil texture, soil depth and volume-of-stones which are then masked with land cover, irrigation and NUTS II region to define individual simulation units (ISU) for EPIC. Simulation results for different tillage systems were then analyzed regarding carbon sequestration in the farm type models Aropaj, a specialized model for a NUTS I region in Germany, and in EU-FASOM. LUMOCAP (www.riks.nl/projects/LUMOCAP) uses a constrained cellular automaton to downscale land use from national results of an agriculture PE model, and then applies local agricultural models to analyze effects on the environment.

The second approach dis-aggregates model results at national or regional scale to small geographical referenced response units. I/O coefficients, crop hectares and stock densities for larger regional units are taken as given from expost-data or scenarios, downscaled and then mapped in the language of bio-physical models and indicator calculators. The major challenge for those top-down-approaches consists in ensuring compatibility between the way the I/O coefficients are generated in the top level

PE model and in the down-scaled layer, for example regarding the relation between nutrient loads and yields.

FATE (Grizzetti et al. 2007) uses a Pan-European 10x10 km grid for simulations with EPIC, and downscales to 1 ha resolution for river basin modeling in some instances. Results published so far refer to the base year situation, applications linked to scenarios results with CAPRI are currently undertaken. CAPRI-Dynaspat developed an approach (Leip et al. 2007) where model results at NUTS II level for EU27 are consistently downscaled to about 200.000 so-called Homogenous Soil Mapping Units, clusters of 1x1 km pixel cells uniform in soil type, slope class, land cover and administrative unit. The result sets comprised crop shares, stocking densities as well as input and output coefficients for around fifty agricultural activities, and drives the bio-physical crop growth model DNDC to analyze the Nitrogen, Water and Carbon cycle. The approach is further developed to allow the spatial allocation of farms in SEAMLESS (Elbersen et al. 2006). In GENEDEC, a down-scaling of crop shares was implemented for a French region based on Aropaj results (Chakir 2007). SENSOR down-scales at least the land cover based on the GLUE-S (Jansson et al. 2007).

3.5. Possible conclusions for the research agenda

Given the growing need for environmental indicators, the linkages between farm or regional models and market models need probably to be enforced, as well between bio-physical models or indicator calculators and agricultural sector models. That requires on the one hand a clear strategy how either the price feedback from the market model can be integrated in regional or farm scale modeling, or how the supply response from those lower layers can be employed by the market model to achieve mutual consistency in results between interlinked models. The same holds for the environmental accounting part, i.e. if bio-physical models or indicator calculators are used, care must be given to the fact that core results are compatible.

In many of the model and their applications, environmental impacts of agriculture were so far modeled as passive indicators, i.e. they are part of the results reported but do not impact on the decision space captured by the models. Using the indicators as restrictions in the model most often will require major structural adjustments. In many of the models the decision variables are single production activities per main output (one activity producing wheat, a second for barley etc.) with a fixed vector of input and output coefficients. Farmers however react to environmental legislation by adjusting the special intensity as well. In opposite to crop areas and herd sizes where different data sets allow for cross-regional and time series analysis in order to estimate supply behavior, observations on input/output coefficients are scarce. That challenges perhaps less the parameterization of the technology choices open to farmers which can be derived via a combination expert knowledge and bio-physical modeling (van Ittersum et al. 2008). It is however certainly a challenge for the behavioral part of the model regarding how the switch between technologies is modeled as it is linked inter alia to investment decisions, risk attitude and imperfect information. This problem of unobserved behavior in any case cannot be satisfactorily solved by using an extension of the standard PMP approach on different technologies (Roehm and Dabbert 2003).

From the topic side, it is rather obvious that the question *water scarcity* in the Mediterranean requires more attention in modeling activities. The same clearly holds for bio-diversity issues and the analysis of High Nature Value Farmland.

4. Primary factors

The analysis of primary factor use and prices, especially for labour and capital, has traditionally not been the stronghold of PE models, which focused more on agricultural commodity markets and relevant policy measures. However, recent developments on Agent Based Models, econometric exercises to allocate labour use to production activities and envisaged future model links shall be mentioned as current and potential advances towards improving the understanding and the projection of the use of land, labour and capital in the agricultural sector.

4.1. Land markets

The introduction of decoupled payments introduces a novel element in European land markets. In the absence of cross-compliance and entitlements, and neglecting transaction costs and market imperfection, introduction of decoupled payments paid per ha of agricultural land should increase as a direct effect rental prices by the premium amount compared to the absence of premium payments. Indirect effects such as changes in income uncertainty and risk aversion improve financing possibilities or affect the labor-leisure allocation, but are generally considered to be of minor importance, at least at the aggregate level. An addition to the well known complexities of analyzing agricultural land markets due to quality differences and spatial dependencies, the on-going CAP reform process adds at least four additional complications compared to the text book case of a decoupled payment. A first one is the semi-decoupled nature of the premium scheme resulting not only from partial decoupling, but also from cross-compliance, both incurring costs which may vary between member states, farms and plots. Estimation of these costs is difficult in itself, but in turn their impact on market outcomes, for example due to the uncertain degree of compliance, implies further challenges for quantitative analysis. Secondly, possible path-dependencies may exist from past policy and market developments such as the coupled payment schemes and other elements of the CAP implemented in the nineties. A third distinct issue is the specific implementation of the entitlements at Member State, or even sub-Member State level as in the U.K., in combination with the complex rules governing the transfer of entitlements. Fourthly, the simultaneous introduction of decoupled payments and changes in supply control and market intervention measures requires the representation of complex interactions.

Traditional PE models are certainly not well suited to analyze effects on land markets, as they typically do not break down regional entities into groups of agents competing for land. Outside the PE world, different types of statistical estimators may be used in time-series and/or cross-sectional analysis to shed light on the question if there are significant changes in land prices due to the reform process. Agent based models combined with modules allowing for market feedback may help to understand how the specific implementation of the decoupled payments in the CAP may impact on land markets and structural change. Basically, only model chains comprising programming models and/or ABM's with a land market are able to provide deeper insights in the development of land markets after the latest CAP reform (Happe et al. 2006). The contribution of programming models is however limited as they are only able to estimate changes in shadow prices of land. Interpretation of the results is far from straightforward. In classical LP models as Aropaj (De Cara et al. 2004), land is often the sole primary factor modeled as a constraint, so that the shadow price of land and its changes are most probably overestimated, capturing returns to family labour and capital in addition. In models applying Positive Mathematical Programming (PMP) or extensions, an increase in market revenues and premiums at the new optimum compared to the starting situation will be distributed both to the duals and the cost function, and even a decrease in the land rent cannot be excluded a priori. The major challenge for ABM's is the validation of these complex modeling systems for the use as projection tools.

Interlinked with the question of land markets is the development of land use in marginal areas, often linked to the provision of social and environmental benefits. There are at least three interesting questions regarding marginal land use linked to recent policy developments. The first question asks if the decoupling of animal premiums will threaten the economic viability of extensive grassland production systems and lead to land abandonment. The second one relates to the costs of cross-compliance and the question if land drawing relatively small decoupled premiums per ha could be abandoned as cross-compliance is enforced by a combination of increased controls, higher penalties and inclusion of further legal acts. That could, for example, lead to losses of stationary set-aside often considered important for bio-diversity. And the third question refers to the potentially countervailing effect of the high price level of agricultural products and the increasing demand for bio-fuels specifically on marginal farm land.

4.2. Primary factor modelling and rural development indicators

The current rural development policy of the EU (programming period 2007-2013) includes the so called Common Monitoring and Evaluation Framework (CMEF) which applies a set of common indicators (European Council, 2005) used to describe inputs and outputs, the baseline situation, the immediate results and the wider impact of the rural development programs. The "impact indicators" are the most relevant for modelling purposes as they shall evaluate the net effect of the implemented measures, i.e. subtracting changes caused by other developments and including indirect effects (European Commission 2006). With "employment creation" and "labour productivity", two out of the seven common impact indicators relate to primary factors specifically. In addition, baseline indicators differentiated by sector are listed defining the benchmark against which the success of the programs shall be measured. For agriculture, also the Gross Fixed Capital Formation (GFCF) in Agriculture is mentioned in addition to the labour related indicators Gross Value Added per Annual Working Unit (GVA/AWU, total and per sector) and "employment".

Modelling labour and capital use in agriculture is not at the core of traditional PE models and this is unlikely to change in the future for several reasons. (1) The evaluation of market oriented policy instruments and projection of market developments with respect to product prices and the elements of the market balances are the main objectives of PE models. (2) The income distribution over different primary factors is generally an interesting indicator for policy assessment, but the availability of the necessary data on factor prices and quantities is very limited with respect to coverage and quality. (3) The aggregate use of primary factors in agriculture strongly depends on the interaction with other sectors of the economy and the factor market conditions are highly differentiated by regional policy and economic conditions.

Given the small potential benefit with respect to the main objective, the high cost of developing and maintaining primary factor modules, and the conceptual limitations of PE models in this respect explain the small role of primary factors, often not treated explicitly at all (for example in the AGLINK model, OECD 2007). The role of primary factor in the ESIM model (Banse et al. 2005) is restricted to labour and capital price indices influencing product supply quantities. Implied factor quantity changes could conceptually be derived from the maintained assumption of profit maximisation, but this is apparently not used, likely acknowledging that profit maximisation is a strong simplification in the context of labour and capital allocation. Recent econometric exercises in the context of the CAPRI modelling system try to estimate labour input coefficients of agricultural production activities using single farm FADN data for the EU (Garvey and Kempen 2008). This approach gives some insight into labour demand effects resulting from a change in production structure by a post-model analysis. However, feedback from regional primary factor markets is not implemented. Finally, even the value of the base year information suffers from the limited quality of the FADN labour data, especially in the southern regions of Europe.

A promising direction for improving the ability of PE models to contribute to a meaningful analysis of labour use is the incorporation of farm structural change, as labour use differs significantly by farm specialisation. Here, models with differentiated farm types allow for a change of their weight in projections. This could either be done based on forecasts using models allowing for the impact of exogenous drivers or, in addition, in an endogenous fashion, where agricultural product market outcomes affect structural change. In the EU context, such an approach first requires the completion of a demanding econometric exercise. First approaches in this direction are implemented for an Austrian regionalised sector model (Weiss et al. 2003) and conceptualised for the EU within the SEAMLESS project (Zimmermann et al. 2007).

Despite some of these advances, the partial nature of PE models will always limit the scope of agricultural labour and capital modelling as important feedback with the general economy is left out. The last two years, however, sequential calibration methods have been suggested and implemented to link more detailed PE with CGE models (e.g. Banse and Grethe 2008). This allows for a flexible joint application of models depending on the question of analysis without creating inflexible "super models" with the negative consequences for maintenance. The link between regional CGEs and agricultural PEs could certainly provide an excellent tool for rural development analysis spanning agri-environmental interactions and general economy developments, thereby explicitly representing primary factor dependencies between the regional sectors.

5. Summary and conclusions

The paper reviewed current policy questions regarding European agriculture and analysed available tools and methodologies to answer those, with a focus on Partial Equilibrium models. Generally, the review hints at an active and well developed research community which continues to improve their tools and methodologies in order to support, but as well to question policy making in the EU. Both the number of PE models continues to increase and existing models are gaining in coverage and complexity. This is also due to the political instruments which increase in number as well as complexity and corresponding quantitative information for grows as well. Examples are the implementation of the (semi)-decoupled payments and the list of indicators proposed by the EU Commission for impact assessment. Consequently, quantitative modelling activities for agricultural policy analysis will stay important and likely even grow in the mid-term future.

New challenges in modelling agricultural commodity markets are faced due to increased price volatility following further opening of EU borders, the EU enlargement, and the policy driven bio-energy boom. Further development of stochastic PE models, explicit representation of spatial interdependencies, and inclusion of new processing activities as well as links to energy market models are current responses of the modelling community. Adaptation to and mitigation of climate change in addition to more and more transparent environmental problems related to bio-mass production for energy use are good reasons why the modelling of agri-environmental interactions will stay important. Significant progress has been made lately in this area by linking economic and biophysical models. The key challenge here is the modelling of intensity adjustments to changing economic conditions as many environmental impacts directly depend on the input use in agricultural production. Monitoring and evaluation of rural development programmes as well as land market impacts of decoupled premium payments require quantitative information on employment and return to primary factors in agriculture. The performance of PE models in this area is weakest due to limited spatial differentiation, the traditional commodity market orientation, and the sectoral focus of the tools. Agent Based Models made significant advances in recent years with a more realistic representation of primary factor use in agriculture, specifically land markets. Promising avenues to improve the generated information on policy impacts labour and capital quantities comprise the incorporation of structural change modules and the formal links to CGE models.

Generally, the linking of models across disciplines and scales is one of the more prominent responses of the scientific community to increased complexity and integration of policy impact assessment activities. In order to do this successfully, i.e. at low cost, development of conceptual links need to go hand in hand with flexible and transparent software design helping to document the models and facilitate the actual linking. This issue has been left out of this overview, but will be important for the dynamics of future large-scale modelling activities.

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