LEI

Brief review of the CAPRI modelling system

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This review has been written at the request of the coordinator of the CAP-STRAT project. The goal of this review is an independent assessment of the CAPRI modelling system, based on general evaluation criteria. The reviewer has used CAPRI documentation that has been made available by the project coordinator. This review does not include a detailed assessment of the mathematical structure, the mathematical properties or even a validation of the computer implementation of CAPRI. The reviewer has not had the benefit of 'hands-on' experience with the model. The set of documents used included technical model documentation (Heckelei and Britz (1999), Britz et al (2003), LEI (2003)), as well as a sample of papers on appications (Britz et al. (2002), Wieck et al. (2003), Perez and Britz (2003)).

1. General

Institutions and individuals involved

The CAPRI[1] model development was started in 1997 as a FAIR3 (4th framework) funded project. It built on the RAUMIS, SPEL/EU and WATSIM models that had been developed earlier by German institutions. The coordinator and main driving force behind the endeavor is the Institute for Agricultural Policy Analysis of University of Bonn. The project had four core partners and sub-partners in almost all member states and lasted until 1999. A new initiative was launched under a 5th framework project in 2002. This CAP-STRAT project is again led by the same coordinator. The main source for disseminating project related information is a well organised website:
www.agp.uni-bonn.de/agpo/rsrch/capri/

Goal of the model

The CAPRI modelling system is designed as a projection and simulation tool for the EU's (primary) agricultural sector. 'Projection' here means the generation of a future situation, based on unchanged policies, while 'simulation' refers to the numerical evolution of alternative policies. The original model was developed in the late 1990s and was specifically designed for the assessment of CAP policy reforms (Agenda 2000). Since then the scope has been broadened to encompass also trade policies and environmental policies.

Regional scope

CAPRI covers all EU15 member states, disaggregated to some 200 sub-national regions at the NUTS-II level. Through linkages with the WATSIM model of international trade, the model has a global coverage as far as trade in agricultural products is concerned.

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[1] Common Agricultural Policy Regional Impact analysis

The regional disaggregation of agricultural production in the EU 15 allows the model to capture some of the regional variability in soil and climatic conditions. It yields a rather detailed, region- and activity-specific, response to policy changes that is not captured by aggregative models.

Commodity / sectoral scope

The CAPRI model is a partial equilibrium model, focusing on the agricultural sector in the EU. The emphasis is on primary production (crops and livestock) and first stage processing commodities. The coverage of crops and livestock is very comprehensive, as the system covers basically all activities in the Economic Accounts for Agriculture (even vegetables and flowers). Chain linkages are covered through processing margins, but there is no explicit modelling of the supply chain linkages. With two important exceptions: technical relations in the feed-livestock complex (feed composition) and in the milk-dairy complex (fat, protein contents) are modelled in detail.

Key applications

The CAPRI modelling system has been applied to a variety of policy questions related to the EU CAP:

- Agenda 2000 ex ante assessment (1999)
- Dairy reforms (2002)
- Mid-Term review proposal of the CAP (2002)
- Kyoto protocol type arrangements of tradeable emission permits (2003)
- Assessment of trade negotiation proposals under the WTO Doha round (2003)
- Assessment of environmental effects of CAP reforms (2003, DG-ENV project)

Documentation and availability

The model has been developed under a series of EU funded projects, which involved a (varying) number of collaborating institutions. The data and the model appear to be 'club goods' among the group of collaborators. It is unclear if and how access to third parties might be arranged.

The series of CAPRI projects has produced a great number of working papers (can be accessed through internet). The working papers typically cover certain partial aspects of the modelling system, and tend to focus on technical aspects. There exists one integrative document (CAPRI model description, Britz, Wieck, Perez, Janssson, 2003) which undertakes the tasks to describe the whole suite of models, techniques and databases. This is a daunting task given the complexity of the modelling system, and the paper only partially succeeds in this.

Generally speaking, there exists a lot of partial documentation of the modelling system, various policy applications are documented well in accessible papers, but a comprehensive monograph would be very welcome.

2. Theory

Theoretical underpinnings

The core of CAPRI is a linear programming model of production activities. There are 200 representative farms at the regional NUTS-II level that maximize their profit function by choosing the composition of inputs and outputs, at given prices for the final product and given prices for key inputs.

A major theoretical innovation of the project is a consistent aggregation procedure that aggregates sub-national farms to the member state level using techniques from the maximum entropy and positive mathematical programming literature. Implicit in the estimated parameters of the synthetic model is the underlying regional variation of behaviour.

Trade occurs between member states and market clearing at the EU15 level yields prices for inputs and outputs. Through an iterative procedure supply is again optimized for each NUTS-II representative farm, and new market prices are calculated until the whole system is in equilibrium.

The programming method allows the inclusion of physical and technical relationships that govern agricultural production. This is a major advantage over an aggregative production function approach because it preserves physical relationships and complementarities, which would typically not be covered in with a production function approach. The programming approach also allows the inclusion of environmental indicators and constraints imposed by environmental policies.

For perennial crops, vegetables and some special crops, the model contains econometric sub-models rather than the programming approach. A clever method has been employed that estimates these econometric sub-models with taking technical relations into account.

The model does not include factor markets for land and labour, nor does it contain markets for intermediates inputs other than feed and young livestock. Land prices at the NUTS-II level (and quota rents where applicable) are obtained as shadow prices of the programming problem.

A recent addition to the CAPRI modelling system is the WATSIM trade model. This is a partial equilibrium model of world trade in agriculture, employing the Armington assumption to model bilateral trade. The linkage with WATSIM allows the analysis of interactions between EU and world markets. Specifically, changes in border prices will influence the determination of internal EU prices (and vice versa).

Theoretical consistency

Partial equilibrium models for projections and policy evaluation are often not theoretically consistent. That is, the parameters and functional forms sometimes do not fulfill consistency requirements stemming from micro-economic theory. The four essential properties of demand functions are: 1) adding up: at the given level of prices and income, demand equals total expenditure, 2) homogeneity: compensated (Hicksian) demand is homogeneous of degree zero in prices and uncompensated

(Marshallian) demand is homogeneous of degree zero in income and prices together, 3) symmetry: cross-price effects are symmetric, 4) negativity: the matrix of own- and cross price derivatives of compensated demand functions is negative semi-definite. In particular this implies that a) compensated demand function slope downward, and b) own price effects dominate cross-price effects. Similar observations hold for equation systems used to model the supply side.

The CAPRI modelling team has put great emphasis on theoretical consistency issues, and the available documentation stresses that the system conforms to these requirements, i.e. it is theoretically consistent. (It must be, because otherwise the model solution would most likely not converge to equilibrium). The documentation is, however, too scattered to permit a thorough assessment of this claim given the scope of this review.

Estimation

CAPRI is a large-scale application of maximum-entropy (ME) methods and positive mathematical programming (PMP) methods. The large scale and the combined application of these techniques is to be considered a major innovation of the project. Specifically, the PMP method is used to calibrate a non-linear objective function to a given base equilibrium. The non-linear objective function avoids the extreme specialization (corner) solutions that haunt LP models. The ME approach is employed because the PMP calibration problem does not place enough restrictions on the parameters to allow for estimation (too many degrees of freedom). The developed method for CAPRI is certainly very clever, and it appears to deliver the desired results. A well-known critique of the ME approach is its sensitivity to the a-priori chosen 'support points'. The CAPRI team is very well aware of this feature.

Dynamics

The model does not contain explicit dynamic behaviour, such as lagged adjustments. Projections through time are driven by the time paths of exogenous variables, obtained from other sources than the CAPRI model. This means that there are no true dynamic linkages between periods (such as lagged prices affecting today's decisions). This has the advantage of making the projection path independent from feedback mechanisms –hence avoiding oscillating behaviour and such like. One class of time dependent stock variable is present, however, and that is intervention stocks.

Representation of policies

A big advantage of the programming approach is the ability directly model activity related policy instruments. The model does not have to resort to indirect policy representation such as ad valorem price wedges, but it directly incorporates the first pillar instruments, such as compensation payments, set-aside obligations, output quota etc. Because the model has 200 representative farms, it captures some of the regional variation for eligibility and size of payments. Of course, the shift of the CAP towards farm-specific payments can only imperfectly be covered. Nevertheless, the representation of CAP policy instruments is very comprehensive and the programming approach allows the analysis of the response of producers to changing incentives implied by the MTR.

As regards trade policies, the model does include TRQs, but these are modelled in a quite peculiar and not very transparent way. It is unclear why the team has chosen for this option, given that the programming model would allow for direct modelling of TRQs as a complementarity problem.

3. Data

Compilation and maintenance of the database for this modelling system is a huge task, and will easily absorb the bulk of research time in the project. Harmonisation of data across various sources appears to be daunting. The project has been handicapped by the abolition of the SPEL/EU database, which provided fairly detailed information at the member state level. especially on input allocation. The project was therefore forced to seek for alternatives and has in fact developed practical solutions.

Level of aggregation

The model covers 200 NUTS-II regions with the EU15, which are aggregated up to member state level. Outside the EU, the trade model divides the world into 11 regional groupings, with a view of their relevance in trade negotiations. The new eastern European member states (CEECs) are included as one region.

The product coverage is wide and detailed within the EU15. It covers 35 cropping activities (including vegetables and fruits), 16 livestock activities, and 3 'land' activities to capture set-aside and fallow land. On the input side 30 inputs are distinguished. For example 4 types of fertilizers are distinguished and seed and plant protection inputs are included. The database includes 10 different feeding stuffs and 8 different young animal inputs into livestock production. Intermediate inputs, such as machinery and energy are also present.

Base year and sources

It is a bit unclear what is the base year for projections into the future. The national data is updated from the old SPEL/EU database that had as its latest year 1997, but has since been abandoned. The team has introduced (another) innovation wit the design of an estimation and simulation technique to fill gaps in the database – specifically relevant for the allocation of intermediate inputs to activities. (COCO).

Sub-national (NUTS-II) data come from REGIO database and is supplemented with FADN information for input allocations.

Non-EU regions are covered in the WATSIM database, and projections are based on exogenous data from the FAO @2030 publication.

Representation of policies in the data

The policy representation is rich. EU CAP (first pillar) policies are directly represented, e.g. area payments etc. Trade policies come from either WTO notifications or from a variety of sources, including OECD PSE data (price wedges) and the GTAP database (price wedges).

Drivers for projections

For projections the supply model ate the sub-national level is driven by a) assumptions on development of yields. This is trend estimated and tallied to DG AGRI outlooks), b) input saving technical progress. Assumed exogenously, c) availability of land (Utilisable Agricultural Area). This is based on exogenous assumptions.

The non-EU countries require further assumptions on world price developments and macro variables (GDP?). These are from FAO and World Bank.

Software requirements

The core of the model is implemented in GAMS (using CONOPT). Graphical interface and interface to a GIS system are modelled in F77, C and JAVA.

4. Assessment

The CAPRI model team must be complimented with their achievements. They have constructed the most comprehensive and most detailed model of EU agriculture that is available to date. The model has already proven its usefulness in a number of highly relevant policy applications. The main thrust of the modelling system is the regional disaggregated analysis of CAP policies and related environmental policies. The analysis is potentially detailed in its indicators, ranging from production to (regional) farm income and environmental indicators, and therefore suits the current needs of policy makers very well.

The series of CAPRI projects has resulted in a number of significant technical and methodological innovations in applied modelling. Although the list is probably not exhaustive, the following stand out:

- The consistent EU-wide modelling of about 200 representative farms at the NUTS-II level
- Large-scale application of the combined PMP-ME approach, leading to a method to consistently aggregate regional results to a calibrated synthetic model at the aggregate national level.
- The incorporation of numerous physical/technical relationships and constraints in the agricultural supply models
- The construction and maintenance of a large and consistent database (comprising regional, national and global data)
- The linking of agricultural activities to environmental impact indicators
- Development of specialised algorithms to solve the model and to estimate a consistent database

In addition to these technical aspects, the project coordinators should also be complimented for keeping the spirit in the team and for achieving the objectives of this highly ambitious project.

The crucial question for any model is the following: Does the model yield insights that would otherwise not be attained? In the case of CAPRI, the answer is ‘yes’. The regionally disaggregated analysis, based on the regionally differentiated response to policy shocks and with a strong rooting in agricultural production modelling, is clearly very valuable and could not be done with other means. As regards the more aggregate conclusions, e.g. impact of MTR on EU-wide supply and prices, the answer is less straightforward. Aggregate models seem to yield very comparable results, at least in the qualitative sense (direction and order of magnitude).

Of course there are also some areas for improvement. High on this reviewer's list stands a comprehensive and streamlined documentation of the modelling system. This documentation –perhaps in the form of a book- should be very specific in separating the discussion of economic theory from implementation matters relating to algorithms and computing issues. The current pieces of documentation, with some exceptions, appear to mix the two issues too much. It is also striking to note that the list of references in the various documents is typically very short and contains little references to other published work in the field. For the long-term sustainability of the project, importance of recognition and scrutiny by academic peers should not be underestimated.

A second point of reflection concerns the scope of the model. While the initial aims where already ambitious –regional supply models plus market interaction at the EU-wide level, the scope has been widened gradually. It now also encompasses a model of world trade and attempts are underway to map production activities to farm types. The latter would potentially allow a better modelling of farm-specific policies. At some point the extension of the scope of the model may be too wide, so that the model, the data (and the people) become unmanageable.

5. Future directions

The CAPRI modelling effort has been responsive to the needs of policy makers. The question is in which direction the model can and should be developed to keep up with this challenge.

The single most important challenge at this time is the extension of the model to the new Eastern European member states of the European Union. This, however, will not be an easy task as data for Eastern Europe are less readily available. In addition, it might be worth considering to extend the model in CEECS beyond primary agriculture and to include non-agricultural activities as well. Given the large share in employment and GDP, many of the pressing policy issues in relation to enlargement relate to rural development and rural-urban interactions. Resource shifts between agriculture and non-agriculture can only be assessed in a framework that includes factor markets, especially labour markets.

Another set of challenges relates to broadening and sustaining a group of active users of the CAPRI model. The modelling system is large and complex, which renders it difficult to distribute it to others without proper training and support. Yet, the development of a large system like CAPRI can benefit enormously from the active participation of a network of users and co-developers. It will be interesting to see in which direction the institutional setup of CAPRI is developing in the future.

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