

# Review of agricultural trade models: an assessment of models with EU policy relevance

Frank van Tongeren<sup>1</sup>, Hans van Meijl, Paul Veenendaal (LEI, The Netherlands); Søren Frandsen, Chantal Pohl Nielsen, Michael Stæhr (SJFI, Denmark); Martina Brockmeier, Dirk Manegold (FAL, Germany); Joseph Francois, Machiel Rambout (Erasmus University Rotterdam/Tinbergen Institute, The Netherlands); Yves Surry (INRA/Rennes, France); Risto Vaittinen, Leena Kerkela (Higher School of Economics and Business Administration, Finland); Thomas Ratering (VUZE, Czech Republic); Kenneth Thomson (University of Aberdeen, U.K.); Bruno Henry de Frahan, Akka Ait El Mekki (Université Catholique de Louvain, Belgium); Luca Salvatici (Universita degli studi di Roma La Sapienza, Italy)

## Abstract

This paper provides an assessment of the present state of applied modelling in the area of international trade in agriculture and related resource and environmental modelling. This review has a deliberate bias on current European policy issues. The outcomes of negotiation rounds such as WTO trade negotiations and the Kyoto environmental summit, and the prospect of EU enlargement bear implications for European farmers, related supplying and processing industries and European consumers. The assessment of likely policy impact is bound to be complex and should be supported by quantitative modeling analyses that explicit the trade relations of European countries with third countries. We provide in this paper a comparative assessment of alternative modeling approaches. This includes theoretical modeling foundations, datasets employed and institutional aspects, such as model maintenance and dissemination of results. A typology of models is provided by structuring the assessment along a clear set of evaluation criteria.

## 1 Introduction

The prospect of a new round of trade negotiations under auspices of the World Trade Organisation, the perspective of enlargement of the European Union and international negotiations on transboundary environmental questions are some of the important policy issues that the European Union is currently facing. The assessment of likely impacts of policies in these areas is bound to be complex and is often supported by quantitative modeling analysis. This paper provides an assessment of the present state of applied modelling in the area of international trade in agriculture and related resource and environmental modelling. It attempts to support users of models and users of model results in finding the most suited modelling tool for the problem at hand.

The general ‘filter’ for inclusion of models has been that the model should be relevant for current EU policy issues, be multi-commodity and multi-region in nature, has relevance for agriculture and natural resource based activities and be an applied equilibrium model (i.e.

---

<sup>1</sup> Corresponding author. Paper prepared for the Third Annual Conference on Global Economic Analysis, Melbourne, June 27-30, 2000. We acknowledge comments on earlier versions of this paper from participants of the 65<sup>th</sup> EAAE meeting, Bonn, March 2000 and from participants of the GTAP-EU workshop, Copenhagen, February 2000. The paper has been written in the context of a larger concerted action project that is financially supported by the European Commission (FAIR6 CT 98-4148) and which assesses the usefulness of the Global Trade Analysis Project (GTAP) framework from a European perspective. The content of this report is the sole responsibility of the authors and does not in any way represent the views of the European Commission or its services. For inquiries concerning the concerted action: F.W. van Tongeren, Agricultural Economics Research Institute (LEI), P.O. Box 29703, 2502 LS The Hague, The Netherlands. E-mail: f.w.vantongeren@lei.wag-ur.nl

not a technical or time series projection model). The models should also be of a relatively recent vintage. This has resulted in the following list of 18 models:

### **World models:**

*Partial models:* AGLINK (OECD), ESIM (USDA, Stanford University USA, University Göttingen), FAO World model (FAO), FAPRI (Iowa State University), GAPsi (FAL Germany), MISS (INRA Rennes), SWOPSIM (USDA/ERS), WATSIM (University Bonn, European Commission, Federal Ministry of Agriculture Germany)

*Economy wide models:* G-cubed (McKibbin and Wilcoxon, U.S. EPA), GTAP (Purdue University, GTAP consortium), GREEN (OECD), INFORUM (University of Maryland), MEGABARE/GTEM (ABARE Australia), Michigan BDS (University of Michigan), RUNS (OECD), WTO house model (WTO secretariat).

### **EU agricultural sector models**

- SPEL/EU (EUROSTAT, University Bonn), CAPMAT/ECAM (SOW, CPB, LEI)

The requirement that the model should be relatively recent and likely to be used in the 1990s has led us to exclude important precursors such as the IIASA Basic Linked System (Parikh et al. 1984), The GOL model developed by USFA-ERS (Roningen and Liu, 1983), OECD's MTM model (Huff and Moreddu, 1990) and the Tyers-Anderson model (Tyers and Anderson, 1992). We have also excluded single-commodity trade models and linear (or non-linear) programming models that attempt to describe input-output relationships for a certain production process in great detail.

A large part of these models are still operational and are currently used for policy- and outlook analysis. Consequently, they are in a continuous state of flux and are evolving through successive updates and changes. This situation led us to conduct the model review at a point of time (early 1999) and provide a snapshot of all these models as they functioned at the beginning of 1999. Changes that could have occurred to the operational models since this date are not considered in this paper.

Information on the individual models has been gathered by the team of contributors using published papers and journal articles, unpublished working documents, electronic www documents and personal contacts.

## **2 Model features**

A summary description of model features is provided in tables 1 to 3. This section highlights the various dimensions along which the models are described. A deeper discussion of the evaluation criteria and an elaborate description of each individual model is provided in Van Tongeren and Van Meijl (1999).

### **2.1 Conceptual framework: Definition and scope**

*Representation of national economies: partial versus economy-wide models*

*Partial models* treat international markets for a selected set of traded goods, e.g. agricultural goods. They consider the agricultural system as a closed system without linkages with the rest of the economy. The main area of application of partial equilibrium models is detailed trade policy analysis to specific products.

On the other hand, *economy-wide models* provide a complete representation of national economies, next to a specification of trade relations between economies. There are three broad classes of economy-wide models: macro-econometric models, input-output models and

Applied General Equilibrium models (AGE). A full economy-wide specification is obtained when the model is closed with respect to the generation of factor income and expenditures, which requires the explicit specification of factor markets for land, labour and capital.

### *Regional scope*

Multi-region models differ with respect to their regional coverage.<sup>2</sup> Global trade models attempt a closed accounting of the selected commodity trade flows for the entire world. If the model is economy-wide, the global model also includes a globally closed income accounting system. At the other end of the scale, a model might focus on trade between a selected set of trading partners, without attempting a globally closed accounting. Or it might even single out one group of countries, such as the EU-15, and describe its trade on world markets. A globally closed database does not imply that all regions or countries distinguished are treated with the same amount of detail.

### *Linked individual country models or parametric differences between regions*

There are two broad approaches with respect to the modelling of individual economies within the global economic system. One approach starts by giving a detailed representation of individual economies, taking into account much of the institutional and economic details of the individual countries, and subsequently linking individual country models through trade flows, capital flows and possibly factor mobility between countries. The other route to global modelling starts by assuming the same modelling structure for all individual economies, and representing differences between economies in terms of data and parameters only. This ‘one model fits all’ approach yields a more transparent model structure, at the cost of losing country detail.

## **2.2 Specification and modeling issues**

### *Dynamic versus comparative static specifications*

Dynamic models allow the analysis of lagged transmissions and adjustment processes over time. Alternatively, the comparative static approach studies the differences between equilibria resulting from different assumptions on exogenous data or policy variables without analysing the time path between equilibria. Dynamic models can be used to trace the accumulation of stock variables, whereas static models are unable to do this.

Dynamic features can be incorporated in equilibrium models in several ways. The most frequently used approach is to specify a recursive sequence of temporary equilibria. Recursive dynamics do not guarantee time-consistent behaviour, which contrasts with intertemporal equilibrium models.

### *Modelling of international trade*

In classical trade models assume that the goods of one producer perfectly substitute for those of another, i.e. goods are *homogeneous*. If the number of suppliers is sufficiently large, the market will approach the perfect competitive outcome and prices across suppliers will be equalised. Homogeneity and competitiveness also imply that each actor in the market is either an exporter or an importer of the good, but never both, and models that include this assumption describe only inter-industry trade. Since prices are equalised and there is no other distinguishing characteristic of the goods, it makes no difference from which supplier a

---

<sup>2</sup> In accordance with the international trade literature, ‘regional’ has a supra-national meaning in this paper, and not an intra-national (provinces etc.) one. A ‘country’ corresponds to the notion of a nation state. Whenever this report refers to regions, we mean an aggregate of individual countries. Regional aggregations of countries therefore do not necessarily represent a coherent geographical space, for example, a ‘Rest of the World’ region.

particular purchase is made. The homogeneity assumption is therefore associated with a 'pooled' market approach to trade modelling, where we see only what each actor brings to the market (supply) and what that actor takes from the market (demand). For obvious reasons, the pooled market approach is also known as 'non-spatial' modelling.

When product differentiation is possible, goods are called *heterogeneous* (and imperfect substitutes), and different buyers are willing to pay different prices to obtain the same quantity of the good. Hence, independent price movements among suppliers are possible. Another implication of heterogeneity is that each actor in the market may be both a buyer and a seller at the same time if goods are differentiated, and intra-industry trade can be captured.

The most popular way to introduce product differentiation follows Armington (1969) by assuming that imports and domestic goods are imperfect substitutes in demand. An alternative approach is to introduce product differentiation endogenously at the firm level on the supply side (Krugman 1979, 1980, Ethier 1979, 1982). In this approach fixed costs such as R&D or marketing costs are necessary to produce differentiated goods, and profits generated under imperfect competition are necessary to cover fixed costs. The heterogeneity assumption is associated with a bilateral (intra-industry) specification of trade, which keeps track of who trades with whom and allows for modelling of bilateral trade policy instruments.

### *Representation of policies*

An adequate representation of policy instruments is essential in applied trade models. Tariffs and quantitative restrictions such as quotas are two important types of trade policy instruments. Tariffs can be introduced in a straightforward manner and are most of the time expressed as ad valorem tariff rates. Also specific (per unit) tariffs are then translated into ad valorem rates.

Quotas and other non-tariff measures are more difficult to implement, and there are basically two alternative ways to quantify these for use in applied models (Laird, 1997): the first is a tariff equivalent representation, while the second method specifies quantity restrictions directly as bounds on trade flows. In many situations this latter method is preferable. For example, if a quota is not binding in the benchmark, its tariff equivalent will be equal to zero, while the quota may become binding as the result of a policy simulation. This effect will not be captured when the quota is approximated by a tariff equivalent. Another case is the endogenous generation of quota rents and their distribution.

Next to border protection instruments, other relevant policies frequently need to be represented in models. For example, in relation to the EU's GATT/WTO commitments ceilings on the volume of subsidised exports as well as bounds on the value of export subsidies may be relevant. In relation to the CAP, land set-aside and headage premiums are clearly examples of agricultural policies that do not directly affect border protection, but nevertheless have an impact on trade flows. In the area of (transboundary) environmental policy, tradable emission permits and tradable production quotas have emerged and should be captured appropriately.

### *Theoretical consistency*

Judging the theoretical consistency of models has many facets, and the discussion here is far from exhaustive.<sup>3</sup> At its most basic level, a model's numerical results should be qualitatively in accordance with the theoretical foundations on which the model has been erected. At the

---

<sup>3</sup> It is not a straightforward task to develop a sound set of criteria to judge the theoretical consistency of models. This theme is also closely related to the issue of model validation, which we have not taken up in this paper. There exists a sizable, and rather inconclusive, literature on model validation, see e.g. Van Tongeren (1995) for an overview. In addition the evaluation of theoretical and numerical validity would require much more information on the individual models than is available.

level of numerical implementation of the model, theoretical consistency places requirements on the parameters used in functional forms, especially parameters used in demand systems and supply equations. These should satisfy essential regularity conditions.

#### *Data and parameters*

Data requirements are very demanding for multi-regional models of international trade. The amount of data is determined by the level of disaggregation (countries/regions, activities/commodities) and the theoretical structure (homogeneous/heterogeneous goods, bilateral/pooled markets).

The data need to be mutually consistent. Substantial adjustments to the published data are necessary, especially if trade is related to domestic inter-industry structures. While trade data with broad coverage are now widely available on a comparable basis, this is certainly not true for input-output data and for trade protection information.<sup>4</sup> A coherent and consistent description of national economies in the form of a Social Accounting Matrix (SAM) usually underlies economy-wide models, although the SAM is sometimes only implicitly present in the database.

It is obvious that regular updating of datasets will improve the timeliness and relevance of results. The choice of base year for a modelling dataset has consequences, both for comparative static and dynamic models. The economic conditions that prevail at the point of reference determine the conclusions that can be drawn from alternative simulations.

The parameters used in behavioural equations determine the response to policy changes, and are therefore a very crucial element in each modelling exercise.<sup>5</sup>

Two approaches to estimating model parameters can be distinguished: econometric estimation and calibration. Econometric estimation of parameters should ideally be done by simultaneous equation estimation methods that take into account the overall model structure. However given the size of applied trade models, identification problems, lack of data etc., this is not feasible, and one has to resort to single-equation estimation methods, using either time-series or cross-section data. Most applied trade modelers resort to calibration methods -also called the 'synthetic approach'- to generate a set of parameters that is consistent with both the benchmark data and the model's theory. The calibration approach takes initial estimates of elasticities etc. from outside sources and adjusts certain other parameters in the given functional forms to the initial equilibrium dataset. Calibration therefore exploits theoretical restrictions, equilibrium assumptions and assumptions on functional forms to arrive at a point estimate.

### **3 Model overview**

In this section we describe the features of the selected partial-, economy-wide- and EU-agricultural models. We first describe the design choices of prototypical standard multi-region partial models and standard economy-wide models. These standards serve as a point of reference for the individual models described in tables 1 to 3. In this section we give a very brief overview.

---

<sup>4</sup> A recent joint initiative by USDA/ERS, Agriculture and Agrifood Canada, the European Commission, UNCTAD, FAO and OECD develops a new Agricultural Market Access Database (AMAD). Upon completion this will contain tariff-line level data on market access commitment- and implementation of about 50 WTO members. AMAD is expected to become publicly available in 2000. See Wainio et al. (1999).

<sup>5</sup> Key parameters usually are: price- and income elasticities and budget shares in demand systems; substitution elasticities and input cost shares in supply systems; Armington (substitution) elasticities in import demand; if economies of scale are included, parameters that capture the degree of exhaustion of returns to scale (cost-disadvantage ratio).

A standard partial equilibrium (PE) model has the following characteristics: global coverage, parametric differences between countries, comparative static, homogeneous goods, pooled markets, ad valorem price wedges (trade: tariff equivalents), theoretical consistency not implied by theoretical structure, and factor markets and non-agricultural sectors are exogenous. In general, all the selected models are pretty close to the standard model. They differ from the standard model because they are recursive dynamic (AGLINK, FAO World Model, FAPRI, GAPsi), endogenise land allocation (AGLINK, FAO World Model, WATSIM), model explicitly quantitative policies (AGLINK, ESIM, GAPsi, MISS and WATSIM) or include bilateral trade by using the Armington assumption (SWOPSIM, one application). Besides the design choices the models differ in their product and country coverage, which leads to a rather large differences in focus.

The standard approach economy-wide modeling is a multi-region applied general equilibrium (AGE) model with the following characteristics: global coverage, parametric differences between countries/regions, comparative static, Armington, bilateral trade relations, ad valorem price wedges (trade: tariff equivalents), theoretical consistency implied by model structure, endogenous volumes and prices on all markets, including factor markets. This standard multi-regional AGE model is a firmly established workhorse in international trade analysis. While retaining most of the standard assumptions, certain special features are introduced into some models to capture specific issues, such as developing country agriculture (RUNS) or aspects of the Common Agricultural Policy (some GTAP applications). Recursive dynamic variations of the standard model are now commonplace in global climate change research (GREEN, MEGABARE). Imperfect competition versions have gained ground in trade liberalisation of manufactures, and are likely to be used in the assessment trade liberalisation in services (WTO, BDS, GTAP). The most recent development is the intertemporal modelling of macroeconomic interactions between financial markets and real sectors (G-cubed). The size of the data collection effort for global models has in the past forced modellers to be rather economical as regards the regional and sectoral disaggregation. Two collaborative efforts to reduce this entry barrier exist to date: INFORUM and GTAP. The GTAP database is specifically tailored to the needs of general equilibrium modellers, and this has certainly contributed to its wider usage, also by non-GTAP modelling teams.

With regard to EU agricultural models we studied a partial equilibrium (SPEL) and a general equilibrium model (CAPMAT) which are both recursive dynamic.

#### **4 Assessment of models**

Nine out of the 18 surveyed models are partial models, according to Table 4. Partial models are in principle able to provide much product detail, and their main area of application is detailed trade policy analysis to specific products, which represent only a small portion of the economy. If agricultural trade policies do not lead to noticeable price shifts in other sectors, PE results will not differ significantly from AGE results. In industrial countries, with small agricultural GDP shares, the direct linkages of agriculture with other sectors is typically not very strong at the level of aggregation that AGE models tend to employ. An exception may be indirect linkages that run through markets for natural resources, especially land. In contrast, in Central and East European Countries (CEECs) with their relatively high share of agriculture in GDP, significant second-round effects are to be expected from policies that pave the ground towards the EU enlargement process, and AGE models provide the only coherent way to analyse these.

In industrialised countries and the European Union, there do exist strong linkages, however, with sectors that are closely related to agriculture, either because they deliver key inputs such as fertilisers, herbicides, agricultural machinery, or because they process primary agricultural products, such as beef processing and dairy industries. Highlighting such

interdependencies within the agricultural complex is one area where partial equilibrium models can potentially be very successfully used, and some of the recent partial models have taken up this challenge (WATSIM, ESIM). This aspect is also gaining importance in the presence of dramatically increasing trade shares of processed food products. Most of the partial equilibrium models surveyed here do not fully exploit this potential advantage because they have a focus on trade in primary agricultural commodities. As a result, there has been a tendency to use AGE models to highlight the forward and backward linkages within food supply chains, as well as to incorporate trade in differentiated food products.

The majority of the models has a global coverage, only three of them treat a regional subset of economies. One of those is a partial agricultural models (SPEL), one is economy-wide (INFORUM) and one is an EU-agricultural model with an economy-wide closure (CAPMAT/ECAM). Within the group of models that closes their accounting with respect to world trade, there are differences in regional emphasis. FAPRI focuses on the US, ESIM on Eastern Europe, MISS focuses on US-EU interactions, GAPsi emphasises the EU. A clear regional bias is less obvious in the economy-wide models with a global coverage. All of them include at least the major trading regions (US, EU, Asia Pacific).

The commodity coverage of partial models puts more emphasis and detail on agricultural commodities. Most AGE models include only 1-3 agricultural sectors, with the exception of RUNS and GTAP. The recent version of the GTAP database has an amount of agricultural detail that is comparable to partial agricultural models.

Only one of the models, INFORUM, features linked individual country models, while all others favour representation of differences between economies via differences in parameters. While in principle, individual country models can capture more regional economic and institutional detail, there are clear difficulties with this approach in terms of consistency and maintenance. Indeed, the linked country models approach seems to be less sustainable, and their contribution to global trade analysis has been rather limited. (The IIASA Basic Linked System, Parikh et. al 1988; The project LINK, Klein and Su, 1979)

**Table 4: Basic modelling design choices**

	Partial Models	Economy wide models	EU-Agricultural models	Total
Scope of representation				
National economies:				
- Partial	8	0	1	9
- General	0	8	1	9
Regional scope:				
- Global coverage	8	7	0	15
- Non-global coverage	0	1	2	3
Regional unit of analysis:				
- Linked country models	0	1	0	1
- Parametric differences	8	7	2	17
Dynamics:				
- Static	4	3	0	7
- Recursive dynamic	4	4	2	10
- Forward looking	0	1	0	1
Modelling of trade:				
- Homogeneous	8	0	2	10
- Armington	0	5	0	5
- Monopolistic competit.	0	2	0	2
- Other	0	1	0	1
Treatment of policies:				
- Tariff/price equivalents	3	5	0	8
- Explicit treatment of quantity restrictions	5	3	2	10
Data:				
Public data availability?				
- Yes	3	5	1	9
- No	5	3	1	9
Parameters:				
- Estimated	2	0	2	4
- Calibrated	6	8	0	14

Note: The table refers only to standard versions of models.

Comparative static modelling has certainly not gone out of fashion, although ten models favour a recursive dynamic approach which permits them to generate time paths of variables and lagged adjustment patterns. Forward looking time consistent behaviour is only introduced into one model, G-cubed, which does not have a specific agricultural focus, but concentrates more on macroeconomic phenomena. Explicit introduction of time is certainly appealing to policy users of models, since this relates the model outcomes to concrete time periods. Comparative static models have reacted to this demand by generating projections without explicit modelling of the dynamics. While this procedure has some appeal, it is also not free of criticism, and some caution should be exercised. Partial models have to make assumptions on the development of a large number exogenous variables to produce a projected future dataset. In fact, the largest part of the projected future does not derive from the model, but from outside assumptions. Since the partial model itself does not provide a consistency check, it is questionable whether these assumptions are always consistent among each other. Projections with static general equilibrium models provide a consistency check, but these



models rely on an extremely small number of assumptions for their projections. This implies that a large part of the step between two time periods is 'explained' by residual factors such as TFP growth rates which accumulate much of deviations not included in the original model. Finally, the features of the 'baseline' in all dynamic models as well as in projections are critical for the interpretation of policy results which are obtained relative to the constructed baseline scenario.

It is striking to note that all partial equilibrium models and the EU-agricultural models treat international trade in homogeneous products, while AGE models deal with trade in differentiated products by default. As already mentioned above, the volume of trade in processed food products is increasing relative to trade volumes in primary commodities. Since processed food can be considered to be of a more differentiated nature than primary products, it is highly relevant to come to grips with trade in differentiated products. By excluding intra-industry trade, and limiting the analysis to net trade, partial models capture the degree to which countries are interwoven only imperfectly. These models also run the risk of predicting the empirically contestable phenomenon of extreme specialisation. Net trade in homogeneous goods also makes it impossible to incorporate bilateral trade policies. While the standard treatment of trade in differentiated products follows the Armington specification, two AGE models (BDS, WTO) incorporate firm-level product differentiation and economies of scale by default, and the standard GTAP model has been amended in that direction. These models focus on manufacturing and services, where these phenomena are perhaps more relevant than in agriculture. However, in food processing industries economies of scale and imperfect competition aspects are certainly relevant as well. A related issue is Foreign Direct Investment (FDI) by internationally operating processing and retailing firms. This is as yet untreated in the applied models surveyed, but requires the recognition of economies of scale at the plant level as well as at the firm level (Markusen, 1984, Markusen and Venables, 1998). It must be recognised, though, that hitherto the empirical basis for these industrial organisation issues is rather weak.

Ten models attempt to capture explicitly quantitative trade restrictions and CAP-type policies, while eight of the models resort to a tariff-equivalent representation. Policies are typically formulated at the commodity level or tariff-line level. It is at this level that policy makers need information, and partial models are in principle able to get down to the required level of detail, including specific institutional arrangements. Partial models, with their focus on selected sectors, are in principle able to give a more precise representation of policies, such as quantitative restrictions. However, our survey of partial model reveals that some partial models under-utilise that potential and resort to a tariff-equivalent representation of policies. Specialised models of the EU agricultural sector (CAPMAT/ECAM and SPEL-EU) are a notable exception as regards the representation of EU agricultural policies, and the treatment of budgetary implications. However their treatment of international trade is rather limited.

The inventory of models shows that some datasets are used by different models. Usually, modellers adjust the raw data to suit their specific needs, and consequently some duplication of efforts occurs. Nine modelling teams choose to make their dataset publicly available, either free of charge or at cost. This practice, which is increasingly observed within the modelling community, is considered a very useful step as it allows others to build on existing (and time consuming) work and it increases the transparency of modelling results. Sharing of databases has in the past been hampered by well known public good problems, which provide insufficient incentives for individual teams to contribute to database development. The INFORUM network provides an early example of an institutional set-up that facilitates sharing of data. INFORUM contributors submit (input-output) data in a form that matches their particular country model, and does therefore not require major adjustments to a common standard. In contrast, the GTAP framework enforces uniform standards on

regional data and trade data. In addition, GTAP is supported by a strong group of institutional stakeholders which puts high requirements on the quality, timeliness and documentation of the data.

It turns out that 15 of the models surveyed here rely on calibration methods, and take their initial parameter estimates from the same published sources that sometimes date back a considerable time. Current models are dominated by ‘theory’ over ‘observations’. Econometric estimation of key behavioural parameters in applied models is certainly an underdeveloped area, although there are some initiatives to estimate partial models in consistence with micro-economic theory (ESIM, FAPRI, CAPMAT/ECAM). Recent developments in entropy estimation methods may help to alleviate some of the technical problems that one encounters in estimating large scale AGE models with limited data (see Golan et al., 1996).

Although not apparent from our earlier discussions, documentation of models is generally weak and scattered, with some notable exceptions (BDS, G-cubed, GTAP). Especially agency based models do not stand out by clarity of documentation. Modellers that are rooted in academia face stronger incentives to submit their work to peer reviews, which increases transparency. An important related aspect is the accessibility of models and data to outside users, who do not belong to the organisations or bodies which have (initially) financed or sponsored the development of these models. While nine models offer the possibility to obtain their datasets, the models themselves are often proprietary. However, some of the models which are presented in this report can be considered as ‘public goods’ (conditional on certain costs and guarantees) which can be used by or made available to interested organisations or persons. Thus, the SWOPSIM model developed by the Economic Research Service (ERS) of USDA has been made available to numerous academics who worked on the impact of agricultural trade liberalisation. The OECD AGLINK model is presently used by government services of OECD member countries. A part of the INFORUM models and modelling tools are in the public domain. At the present time, GTAP represents the most far reaching attempt to public availability, and has now several hundred users in the academic community as well as in research agencies all over the world.

Building an applied trade model is costly exercise, which tends to require several man-years of dedicated work on database construction, theory formulation, parameter estimation and computer implementation. In addition, the size of the investment implies that the basic design choices are to a large extent irreversible. Once a particular route has been chosen, the switching cost may become prohibitive. Some developments point towards a further reduction in entry costs to this type of work: (a) convergence towards standards in model building, where new models can build on established blueprints. (b) A major, and seldom fully appreciated, part of model building is devoted to database construction. GTAP has pioneered institutional innovations that lower the costs associated with database construction and database maintenance considerably. (c) The availability of powerful general purpose software packages renders it obsolete to develop own software to solve large scale models numerically. Additional advantages of using packages like GAMS, GEMPACK or GAUSS is the transferability, reproducibility (and therefore cross-checking) of models and ease of maintenance. Early partial equilibrium models have been implemented in spreadsheets, which was top technology at the time. Except for small scale models, and models for pedagogic purposes, spreadsheet models do not have much to commend them. They are inherently difficult to maintain and are very error-prone.

The degree to which models will contribute to new policy questions depends critically on their degree of adaptability. How capable are existing applied models to respond to newly arising policy questions? At a first glance, there are several issues on the current agricultural trade policy agenda that do not seem to fit well within existing trade modelling frameworks:

- 'consumer concerns' which are put forward as arguments to restrict imports of allegedly unsafe food products (e.g. hormone treated beef, genetically modified organisms).
- conservation of landscape as an argument to restrict imports from low-cost producers
- environmental concerns, which lead to production restrictions and 'green trade' issues.

Unfortunately, we do not have the benefit of hindsight. It is conceivable, however, that existing models will be adapted for use in the above policy areas. This encompasses at least two issues. First, how existing models can be adapted in terms of policy representations, and second, how the outcome variables that they provide can be translated into variables that arise on the policy agenda. With some creativity, the policy issues can be translated into preference and technology shifts, which interact with conventional import restrictions and production restrictions. A main contribution from existing models is likely to be a structuring of the discussion and initial quantification, rather than detailed numerical assessment.

## 5 Concluding remarks

There is, obviously, no model that suits all purposes. Each model has its own merits, given the goals addressed by it and the issues treated with the model. This paper, and the longer Van Tongeren and Van Meijl (1999) report, try to guide potential users in making their choice for an appropriate tool. For this purpose we have identified relevant design choices and a set of dimensions to classify and assess applied trade models.

Ten years ago, the OECD and the World Bank convened a symposium that assessed the 'state-of-the-art' in agricultural trade modelling at that time, see Goldin and Knudsen (1990). The field has changed over the past decade, but to some extent the comments made at this symposium can be echoed today. Probably the most important innovations have not been theoretical, nor have they been technological. The most significant changes have been of an institutional nature, albeit supported by recent computer and communications technologies. Ten years ago, models, data and software were almost exclusively proprietary. Today, it has become more common to exchange computer code and to share databases. This tendency can be expected to be continued in the future. The 'open source' concept that spurred rapid innovations in some parts of the software industry may very well be the direction towards which the global trade modelling community is heading.

## 6 References

- ABARE (1996), *The MEGABARE model: interim documentation*, Canberra: Australian Bureau of Agriculture and Resource Economics.
- ALMON, C. (1991), The INFORUM Approach to Interindustry Modeling, *Economic Systems Research*. 3(1): 1-7.
- ARMINGTON, P.A. (1969), "A theory of demand for products distinguished by place of production", *IMF staff papers* 16:159-178.
- BROWN D. K., A. V. DEARDORFF, and R. M. STERN (1992b), North American Economic Integration, *Economic Journal* 102:1507-18.
- BURNIAUX, J.-M. and D. van der MENSBRUGGHE, (1990), "A Rural/Urban-North/South General Equilibrium Model for Agricultural Policy Analysis". OECD Economics Department Technical Papers No. 33. Paris.
- DEVADOSS S. D., P.C. WESTHOFF, M.D. HELMAR, E. GRUNDMEIER, K. SKOLD, W.H. MEYERS and S.R. JOHNSON (1993), "The FAPRI Modeling System: A Documentation Summary" in: C. R. Taylor, K.H. Reichelderfer and S.R. Johnson (eds), *Agricultural Sector Models for United States: Descriptions and Selected Policy Applications*. Ames: Iowa State University Press.
- ETHIER, W. (1979), Internationally Decreasing Costs and World Trade, *Journal of International Economics*, Vol. 9, pp. 1-24.
- ETHIER, W. (1982), Decreasing Costs in International Trade and Frank Graham's Argument for Protection, *Econometrica*, Vol. 50, pp. 1243-1268.
- FAO (1993). "The World Food Model - Model Specification". FAO Mimeograph, ESC/M/93/1, Rome.
- FAO (1998). "World Food Model" Technical Documentation. Commodity and Trade Division, FAO, Rome, May 1998.

- FOLMER, C., M.A. KEYZER, M.D. MERBIS, H.J.J. STOLWIJK and P.J.J. VEENENDAAL (1995), *The Common Agricultural Policy beyond MacSharry Reform*. Amsterdam: North-Holland.
- FRANCOIS, J. F. and K.A. REINERT (1997), *Applied methods for trade policy analysis. A handbook*, Cambridge etc.: Cambridge University Press.
- FRENZ K. and D. MANEGOLD (1988), "Lineares Modell zur Bestimmung von Preis- und Mengenwirkungen einer restriktiven Agrarpreispolitik in der EG", Arbeitsbericht des Instituts für landwirtschaftliche Marktforschung 88/1. Braunschweig.
- GOLAN, A., G. JUDGE and D. MILLER (1996), *Maximum entropy econometrics: Robust estimation with limited data*, Chichester: Wiley.
- GOLDIN, I. and O. KNUDSEN (eds.) (1990), "Agricultural trade liberalisation. Implications for developing countries". Paris: Organisation for Economic Co-operation and Development.
- GUYOMARD H. & L. MAHÉ (1994), EC-US Trade Relations in The Context of the Gatt Negotiations and of the Reform of the Common Agricultural Policy. In *The Economics of the Common Agricultural Policy (CAP)*. *European Economy*, Reports and Studies, no 5.
- HENRICHSMEYER, W. (1995), "Das Konzept des SPEL-Systems: Stand und Perspektiven", Luxembourg: Eurostat.
- HENRICHSMEYER, W., VON LAMPE, M. and MÖLLMANN, C. (1998), "Weiterentwicklung und Anwendung des Welt-Agrarhandelsmodells WATSIM für Langfristsimulationen der Weltagrarmärkte sowie der Auswirkungen für die Landwirtschaft der EU und der Bundesrepublik Deutschland unter Einbeziehung des Modellsystems RAUMIS", Interim Report for the Federal Ministry for Food, Agriculture and Forestry, Bonn.
- HERTEL, T.W. (ed) (1997) *Global Trade Analysis: Modelling and Applications*, Cambridge University Press.
- HUFF H.B. and C. MOREDDU (1990), The Ministerial Mandate Trade model (MTM), *OECD Economic Review*. Vol 13. Special issue on Modeling the effects of Agricultural policies.
- KLEIN, L.W. and V. SU (1979), Protectionism: An analysis from Project LINK, *Journal of Policy Modeling* 1(1): 5- 35.
- KRUGMAN, P.R., 1979, Increasing Returns, Monopolistic Competition, and International Trade, *Journal of International Economics*, Vol. 9, pp. 469-479.
- KRUGMAN, P.R., 1980, Scale Economies, Product Differentiation and the Pattern of Trade, *American Economic Review*, Vol. 70, pp. 950-959.
- LAIRD S. (1997), Quantifying commercial policies, in: J. F. Francois and K.A. Reinert, *Applied methods for trade policy analysis. A handbook*, Cambridge: Cambridge University Press.
- LAMPE, M. von, (1998) *The World Agricultural Trade Simulation System WATSIM. An overview.*, University Bonn, Agricultural and Resource Economics, discussion paper 98-05.
- MARKUSEN, J.R. (1984), Multinationals, multi-plant economies, and the gains from trade" *Journal of International Economics*, 16:205-226.
- MARKUSEN, J.R. and A.J. VENABLES (1998), Multinational firms and the new trade theory, *Journal of International Economics*.
- MCKIBBIN, W. and WILCOXEN, P. (1999), The theoretical and empirical structure of the G-cubed model., *Economic Modelling*. Vol 16: 123-148.
- PARIKH, K.S., G. FISCHER, K. FROHBERG and O. GULDBRANDSEN (1988), *Towards free trade in agriculture*, Dordrecht: Martinus Nijhoff.
- RONINGEN V. and K. LIU (1983). "The World Grain, Oilseeds and Livestock (GOL) Model - Background and Standard Components", ERS Staff Report No AGES830317, Econ. Res. Serv. U.S. Department fo Agriculture.
- RONINGEN, V.O. (1986), "A Static World Policy Simulation (SWOPSIM) Modeling Framework", Staff Report, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.
- TYERS, R. and K. ANDERSON (1992) *Disarray in World Food Markets: A quantitative assessment*, Cambridge etc.: Cambridge University Press.
- TONGEREN, F.W. van (1995), *Microsimulation of the corporate firm: exploring Micro-Macro economic relations*, Berlin etc.: Springer Verlag. (Series Lecture Notes in Economics and Mathematical Systems, No. 427.)
- TONGEREN, F.W. and H. VAN MEIJL (ed.), (1999), Review of applied models of international trade in agricultural and related resource and environmental modeling, Agricultural Economics Research Institute, Report 5.99.11 (EU-Fair VI-CT 98-4148, Interim report 1).
- WOLF, W. (1995): SPEL System: Methodological Documentation (Rev. 1), Vol. 1: Basics, BS, SFSS. Theme 5 Series E, Luxembourg: Eurostat.
- ZINTL, A., GREUEL, H.-J. (1995), "SPEL System: Technical Documentation (Rev. 1), Vol. 1 an Vol 2. Theme 5 Series E, Luxembourg: Eurostat.

WAINIO, J., P. GIBSON and D.B. WHITLEY (1999) Implementation of Uruguay Round tariff reductions, ERS/USDA, Agricultural Outlook, November 1999.

**Table 1: Model summary of partial equilibrium models of trade in agricultural products**

	<b>Description</b>	<b>modelling of trade</b>	<b>Goals</b>	<b>key applications</b>
<b>Standard model</b>	<i>Static partial equilibrium model, global coverage, no factor markets included</i>	<i>Homogeneous good + pooled markets</i>		
AGLINK OECD	Recursive dynamic model Includes land allocation	Standard	To assist the OECD Secretariat in its annual medium term outlook. Conduct quantitative analysis agricultural policies on principal agricultural markets	Annual OECD medium term agricultural outlook.
ESIM USDA, Stanford, Goettingen	Standard model, land market included, special emphasis to Eastern Europe	Standard	Enlargement studies	EU enlargement
FAO World Model FAO	Recursive dynamic model Includes land allocation	Standard	Medium- and/or long- term projection model. Simulating impacts of policy changes.	To contribute to the outlook of FAO on agricultural commodity markets, Uruguay Round
FAPRI Iowa State University	Econometric recursive dynamic model, with a special emphasis on the US	Standard	Compound modelling system for: Policy analysis; Short-, medium and long term projections (1-10 years), annual baseline	Quantitative evaluations of (inter) national agricultural policies that affect US and world agriculture, Farm legislation reform through Uruguay Round negotiations
GAPsi FAL`	Recursive dynamic model	Standard	EU agricultural policy analysis	CAP reform, Agenda 2000; planned: EU enlargement, WTO
MISS INRA	Standard model, four regions	Standard	Analysis of agricultural policy changes in EU and US	Trade liberalisation in GATT framework and CAP reform in game theoretic setting, focussing on EU-US relations
SWOPSIM USDA/ERS	Standard model	Standard: base model Armington: one application	Simulation of effects of changes in agricultural support policies on production, consumption and trade	multilateral trade liberalisation (GATT Uruguay round), agricultural policy reforms in US and EU
WATSIM University of Bonn	Standard model	Standard	Three target periods with different aims: Short-term shock analysis (not yet available), Medium-term projections and policy analysis, Long-term projections and analysis of various shift factors.	1) Baseline for years 2005, 2010, 2015 and 2020 2) Analysis of different shift factors including income in Asia, productivity in Transition Countries, 3) Trade liberalisation

**Table 1: continued**

	<b>Policy Representation</b>	<b>Number of regions (r) or countries (c)</b>	<b>global coverage? (y/n)</b>	<b>Number of sectors/ products</b>	<b>number of farm (f) or processed (p) products</b>	<b>Software</b>	<b>data availability</b>
<b>Standard model</b>	Price wedges						
AGLINK	Quantity restrictions modelled explicitly	11 (c) + 2 (r) EU: 1 (r)	Y	19	6 (f) + 13 (p)	SIMPC	y
ESIM	Quantity restrictions modelled explicitly	7 (c) + 2 (r) EU: 1(r)	Y	27	17 (f) + 10 (p)	Spreadsheet (Supercalc 5.5 or Excel)	no
FAO World Model	Standard	147(c) + 1 (r) EU: 15 (c)	Y	13	6 (f) + 7 (p)	FORTTRAN	n
FAPRI	Standard	29 (c+r) EU: 1	Y	24	24 (f)	SAS-AREMOS, LOTUS 123	n
GAPsi	Quantity restrictions modelled explicitly	13 (c) + 4 (r) EU: 13 (c)+ 1 (r)	Y	13	13 (f)	GAMS, Excel (output)	n
MISS	Quantity restrictions modelled explicitly	1 (c) + 3 (r) EU: 1(r)	N	10 (final) + 10 (inputs)	10 ( f) + 4 (non agri-inputs)	Home made software (Language C)	y
SWOPSIM	Standard	36 (r) EU: 2 (c) + 2 (r)	Y	22	22 (f)	Spreadsheet (Supercalc 3 or 5)	yes
WATSIM	Quantity restrictions modelled explicitly	4 (c) + 10 (r) EU: 1(r)	Y	29	14 (f) + 15 (p)	FORTTRAN, GAMS	y

**Table 2: Summary of economy-wide models**

	<b>Description</b>	<b>Modelling of trade</b>	<b>Goals</b>	<b>Key applications</b>
<b>Standard model</b>	Applied General Equilibrium model, multi-sector, comparative static, constant returns to scale in production, perfect competition on all markets, global coverage	Armington, bilateral flows		
<b>G-cubed McKibbin and Wilcoxon</b>	Intertemporal applied general equilibrium and macroeconomic model.	Standard	Contribute to the policy debate on environmental policy and international trade, with a focus on global warming policies.	Economy-wide impacts of greenhouse policies, financial crisis in Asia, global predictions and outlook of the world economy, Uruguay Round
<b>GTAP GTAP consortium/ Purdue University</b>	Standard (default version) Recursive dynamic and imperfect competition versions available.	Standard Monopolistic competition versions available	Trade policy analysis, especially multilateral liberalisation. Agricultural policies.	GATT Uruguay Round, technological changes, environmental policies; EU enlargement, CAP reform
<b>GREEN OECD</b>	recursive dynamic	Standard, except crude oil (homogeneous)	Asses the economic impact of imposing limits on carbon emissions	Kyoto protocol assessment
<b>INFORUM INFORUM project/University of Maryland</b>	Linked system of dynamic national macroeconomic models with inter-industry Input-Output linkages.	Price and income sensitive econometrically estimated import and export equations	Annual forecasts and policy analysis at national and internationally linked levels.	Early work on NAFTA, national US studies (LIFT), Austrian integration in EU
<b>MEGABARE and GTEM, ABARE</b>	recursive dynamic endogenous population growth, technology bundles in electricity and iron&steel	Standard	Policy scenario analysis primarily in climate change but also in global agricultural trade reform and trade in strategic commodities (e.g. coal).	Climate change policy and the economic impact of the Kyoto Protocol, WTO and the agricultural trade liberalisation
<b>Michigan BDS Model University of Michigan</b>	scale economies and monopolistic competition in manufacturing industries,	Monopolistic competition	To analyse microeconomic effects of trade liberalisation policies	Regional trade agreements (NAFTA, extension of EU with Eastern European countries), Uruguay round, liberalisation in services
<b>RUNS OECD</b>	recursive dynamic	Agriculture: homogeneous goods & pooled markets Manufactures: standard	Analysis of Agricultural policies	GATT Uruguay round, agricultural trade liberalisation
<b>The WTO housemodel</b>	Standard and imperfect competition versions	Standard and firm level product differentiation	To analyse global trade analysis issues such as the upcoming WTO Round	Multi-region CGE analysis of the results of the Uruguay Round

1



Table 2: continued

	<b>Policy representation</b>	<b>Number of regions ( r ) or countries ( c )</b>	<b>Global coverage (y/n)</b>	<b>Number of sectors</b>	<b>Number of farm (f) or processed (p) products</b>	<b>Software</b>	<b>Public data availability</b>
<b>Standard model</b>	Ad valorem Price wedges		Global			General purpose package	Yes
<b>G-cubed</b>	Standard and tradeable emission permits	4 (c) + 4 (r) EU: part of 'other OECD'	Y	12	1 (f) + 1 (p)	Gauss	N
<b>GTAP</b>	Standard in default version Volume and value restrictions (quota etc) available	27 (c) + 12(r) + RoW EU: 5 (c) + 1(r)	Y	50	12 (f) + 8 (p)	GEMPACK and GAMS versions available	Y, at cost
<b>GREEN</b>	Standard quota, tradable emission permits	5 (c) + 7 (r) EU: 1 (r)	Y	9	1 (f)	C	N
<b>INFORUM</b>	Standard macro-economic policy instruments, taxes and transfers	13 (c)	N	Varies by country: min. 33, max. 100	Varies by country	G	Y partly, free
<b>MEGABARE/ GTEM</b>	Standard Tradable emission permits	27 (c) + 12(r) + RoW EU: 3 (c) + 1(r)	Y	50	12 (f) + 8 (p)	GEMPACK	Partly, Y, See GTAP Energy parts: N
<b>Michigan BDS model</b>	Standard	34 (c) +RoW EU: 12 (c)	Y	29	2 (f)	GEMPACK	Y
<b>RUNS</b>	Standard	13 (c) + 9 (r) EU: 1 (r)	Y	20	11 (f) + 4 (p)	Fortran	N
<b>WTO housemodel</b>	Standard And import quota	5 (c) + 7 (r) + ROW EU: 1 (r)	Y	19	3 (f) + 1 (p)	GAMS/MPSGE	Y

**Table 3: Summary EU-agricultural models**

	<b>Description</b>	<b>modelling of trade</b>		<b>Goals</b>	<b>key applications</b>		
SPEL-EU University of Bonn	Recursive dynamic partial applied equilibrium model of agricultural production in EU-15	Homogenous goods + pooled markets		Short and medium-term forecasts and policy simulations of the effects of agricultural policy decisions	Particularly, CAP/Agenda 2000		
CAPMAT/ECAM SOW-VU, CPB, LEI	Recursive dynamic applied general equilibrium model and a simulation and accounting tool of agricultural production in EU-15	Homogenous goods + pooled markets		EU agriculture policy analyses	CAP reform (partial liberalisation), agricultural proposals in "Agenda 2000"		
	<b>Policy Representation</b>	<b>number of regions (r) or countries (c)</b>	<b>global coverage? (y/n)</b>	<b>Number of sectors/ products</b>	<b>number of farm (f) or processed (p) products</b>	<b>Software</b>	<b>data availability</b>
SPELL/EU	Price wedges and quota	13 (c) + 1 (r) EU: 13 (c) + 1 (r)	n	5-6 DIGIT/NACE	114 (f)	Home made software	Y, cost
CAPMAT/ECAM	Price wedges and quota, explicit bounds on volumes and values	13 (c) + 1 (r) EU: 13 (c) + 1 (r)	n	30	20 (f), 7 (p)	SAT in GAMS, ECAM home made software (FORTRAN)	n