Review of applied models of international trade in agriculture and related resource and environmental modelling

Frank van Tongeren
Hans van Meijl (editors)

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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 issues are some 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 report 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 report has been written in the context of a larger concerted action project that is supported by the European Commison (FAIR6 CT 98-4148) and which assesses the usefulness of the Global Trade Analysis Project (GTAP) framework from a European perspective. This report is a joint effort by the 18 members of the project team, Frank van Tongeren and Hans van Meijl were in charge of editing the individual contributions.

Orders:
Phone: 31.70.3358330
Fax: 31.70.3615624
E-mail: publicatie@lei.wag-ur.nl

Information:
Phone: 31.70.3358330
Fax: 31.70.3615624
E-mail: informatie@lei.wag-ur.nl

Contributors

Frank van Tongeren & Hans van Meijl (eds.), Agricultural Economics Research Institute (LEI), The Netherlands

Paul Veenendaal, Agricultural Economics Research Institute (LEI), The Netherlands

Søren Frandsen, Chantal Pohl Nielsen & Michael Stæhr, Danish Institute of Agricultural and Fisheries Economics, (SJFI) Denmark

Martina Brockmeier & Dirk Manegold, Federal Agricultural Research Centre (FAL), Institute for Market Analysis and Agricultural Trade Policy, Germany

Joseph Francois & Machiel Rambout, Tinbergen Institute Rotterdam, The Netherlands

Yves Surry, Institut National de la Recherche Agronomique (INRA), Station de Rennes, France

Risto Vaittinen & Leena Kerkela, Helsinki School of Economics and Business Administration, Department of Economics and Management Science, Finland

Thomas Ratinger, Research Institute for Agricultural Economics, Prague, Czech Republic

Kenneth Thomson, Department of Agriculture University of Aberdeen, U.K.

Bruno Henry de Frahan & Akka Ait El Mekki, Unité d'économie rurale, Université Catholique de Louvain, Belgium

Luca Salvatici, Universita degli studi di Roma La Sapienza, Dipartimento di Economia Pubblica, Rome, Italy

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1. Introduction

This report provides an assessment of the present state of applied modelling in the area of international trade in agriculture and related resource and environmental modelling. The scope of this review is further limited by a deliberate bias towards current European policy issues. The prospect of a new round of trade negotiations and the perspective of enlargement increase the need to deepen the reforms of the Union's agricultural policies, as set out in Agenda 2000. The outcomes of negotiation rounds such as WTO trade negotiations and the Kyoto environmental summit 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 analysis that explicit the relations of European countries with third countries.

At the present time such a modeling framework is provided by the Global Trade Analysis Project (GTAP), which is supported by a consortium of international and national agencies. GTAP maintains and develops a global database on the basis of which multi-region, multi-sector general equilibrium models are built. This survey of models is part of a larger project that sets out to investigate the usefulness of this type of modeling -and the associated database- for imminent policy issues in the European context. As a first step, we provide in this report 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.

There is no ideal model that can serve all the above stated purposes. The choice of theoretical framework, the extent of regional and sectoral disaggregation and the choice of datasets and estimation methods determine the domain of applicability of the model. Model users often change their requirements from a given model, and develop their demands in response to new policy problems. Potential users of applied models should be aware of strengths and weaknesses of alternative approaches. This review primarily presents factual information about relevant models, and presents this information in a structured format so as to highlight common features, differences and areas of applicability of modelling approaches. In this way we hope to assist the users of models in making their own assessment.

The general 'filter' for inclusion of models in the current review has been that the model should:

- have relevance for current EU policy issues;
- be multi-region in nature;
- have relevance for agriculture and natural resource based activities;
- be multi-commodity;
- have a medium term time frame (around 5 years);
- be an equilibrium model (i.e. not models that project demand-supply gaps using primarily technical relations);
- be of recent vintage, and likely to be used in some form in the 1990s;

- be an applied model, i.e. uses a combination of theory and empirical data;
- be documented in a accessible way.

This has resulted in the following list of 18 models, which we distinguish according to the following two criteria: 1) models that cover world trade and those that focus on the European Union, 2) partial equilibrium models focussing on agriculture and economy-wide 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 Wilcoxen, 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/VU, CPB, LEI-DLO The Netherlands

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., 1988), the GOL model developed by USDA-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, see Labys (1975).

Chapter 2 discusses general demarcation criteria for applied models of international trade in agriculture and related resource and environmental modelling. An attempt is made to identify design choices and scope of applicability. The resulting set of criteria is used for a description and classification of models in chapter 3, culminating in a summary presen-

tation in tabular form. Chapter 4 provides a comparative assessment of modelling approaches, by comparing models across the criteria introduced earlier.

A word on method: information on these models has been gathered by the team of contributors using published papers and journal articles, unpublished working documents, electronic www documents and personal contacts. An annex to this document provides a detailed description of each of the models reviewed in this report.

2. Evaluation criteria

This chapter introduces our set of evaluation criteria, which are subsequently used to describe and compare alternative modelling approaches. The set of criteria is based on the recognition that applied modelling forms a combination of theory and empirical data, both of which deserve due attention in policy relevant modelling.

2.1 Conceptual framework: Definition and scope

2.1.1 Market equilibrium models versus time series projection models

Although time series projection models have been excluded from the list, it is useful to distinguish this approach from equilibrium models. *Time series projection models* attempt to forecast the future on the basis of extrapolation of historical data. These models typically put more emphasis on the statistical behaviour of time series data than on the economic theoretical underpinnings of behavioural equations. A projection model may, for example, project commodity supply based on agronomic data on acreage and yield, without taking into account farmers' responses to changing market prices. For a discussion of this method and a large scale application, see Alexandratos (1995).

On the other hand, *market equilibrium models* contain the response (behaviour) of economic agents to changes in prices (costs), and prices adjust so as to clear markets. The objective of these models is the determination of equilibrium prices and quantities on (interrelated) sets of markets.[1] In a fully fledged global equilibrium model, there will typically be endogenous prices attached to world markets as well as domestic markets. This class of models is firmly established within mainstream economics where the behavioural response of suppliers and buyers is typically derived from optimising assumptions: given a description of the production technology, the supplier chooses a combination of inputs such that costs are minimised for a given level of output. Given a description of consumer preferences, the buyer determines his preferred consumption bundle such that his utility is maximised for a given level of his budget. Standard assumptions include constant returns technology, homothetic preferences, and markets characterised by perfect competition. While these basic theoretical assumptions underlie equilibrium modelling, the optimisation process is usually not modelled explicitly. Rather, a reduced form approach is common, where demand and supply are specified as functions of income, prices and elasticities.

Depending on assumptions made about the flexibility of production factors, equilibrium models can be classified as short term, medium term or long term. Short term (in the

[1] This does not deny the existence and relevance of disequilibrium situations. Temporary shortages and excess supply situations (which may for example arise as a consequence of price- or quantity regulations) can very well be captured in equilibrium models, for example by allowing for stockpiling and -depletion. The key point is that these models catch market interactions in a coherent and theorectically sound way.

Marshallian sense) means that some production factors are fixed, and are not allowed to reallocate between alternative uses. The fixed factors will typically be capital, agricultural land, and perhaps agricultural labour. Medium term models allow for reallocation of all production factors as response to some exogenous events. Finally, long term models would also model endogenous capital formation.

Within the group of market equilibrium models, we can identify partial and economy-wide models.

2.1.2 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. Effects of the rest of the domestic and world economy on the agricultural system may be included in a tops-down fashion by altering parameters and exogenous variables. Partial models are in principle able to provide much product detail. See also Meilke et al. (1996) who give a summary of global partial equilibrium models adapted to agricultural trade.

Partial models may be single- or multi-product. Multi-product models are able to capture supply and demand interrelationships among agricultural products. Most partial models include linear or log-linear behavioural equations, which allows the representation of supply and demand relationships (responses) prevailing in the markets under study. They also incorporate into their supply and demand relationships exogenous variables such as technical change, world population and household income.

Partial models of international trade in agriculture generally focus on trade in primary commodities. That is, they capture agricultural supply, demand and trade for unprocessed or first-stage processed agricultural products without taking into account trade in processed food products, despite the fact that the latter commodities represent an increasing share of world trade.

The main area of application of partial equilibrium models is detailed trade policy analysis to specific products, which represent only a small portion of the activities of the economy in question. This 'small sector' condition implies that policy-induced economy-wide changes are so small that they can safely be ignored.

On the other hand, e*conomy-wide models* provide a complete representation of national economies, next to a specification of trade relations between economies. A first step in moving from partial equilibrium to economy-wide modelling is to introduce supply and demand equations for an aggregate residual commodity. By imposing regularity restrictions on the supply and demand elasticities of the amended model, one obtains a model that includes demand and supply interactions between agricultural commodities and other commodities in a consistent way. A fuller 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. In other words, the essential general equilibrium features are captured by including factor movements between sectors, next to allowing for demand interactions. Economy-wide models capture implications of international trade for the economy as a whole, covering the circular flow of income and expenditure and taking care of interindustry relations.

There are three broad classes of economy-wide models: macro-econometric models, input-output models and Applied General Equilibrium models (AGE). Macro-econometric models do not concern us here, since they will not zoom in on agriculture, but rather are concerned with macro-economic phenomena such as inflation and exchange rates. Input-output models provide a comprehensive description of interindustry linkages and a full accounting of primary incomes earned in production activities.

AGE models do also usually contain full Input-Output detail, but on top of that they contain equations that describe the behavioural response of producers, consumers, importers and exporters and possibly other agents in the economy.[1] AGE models are specifically concerned with resource allocation issues, that is, where the allocation of production factors over alternative uses is affected by certain policies or exogenous developments. International trade is typically an area where such induced effects are important consequences of policy choices. Needless to say, such induced effects are not visible in partial models. In the face of changing international prices, resources will move between alternative uses within the domestic economy, or even between economies if production factors are internationally mobile. Only if a complete description of the multi-sectoral nature of the economy is provided, can such developmental issues be analysed.

2.1.3 Regional scope

Multi-region models differ with respect to their regional coverage.[2] 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. An intermediate position is frequently adopted, wherein the model's database is closed with respect to the world, but only selected regions are treated with a great amount of detail, and confining the description of other regions to a smaller range of variables that are of crucial importance.

2.1.4 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

[1] Well known limitations of open Leontief input-output models include the absence of behavioural relationships, fixed prices, exogenous final demand, perfectly elastic factor supplies, and an inability to demonstrate welfare effects.

[2] In accordance with the international trade literature, 'regional' has a supra-national meaning in this report, 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.

of the individual countries, and subsequently linking individual country models through trade flows, capital flows and possibly factor mobility between countries.[1]

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. The approach yields a relatively transparent model structure, since there is only one economic model. This in turn greatly facilitates both the data handling aspects as well as the interpretation of results. In the linked country models approach, the individual country models may be based on different theoretical assumptions, which may make it difficult to disentangle model results into the effects of exogenous events on the one hand and differences in theories on the other hand. A disadvantage of the 'one model fits all' approach is clearly its limited capability to handle structural differences between economies.[2]

2.2 Specification and modelling issues

2.2.1 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. The time path between equilibria is not the subject of analysis in comparative static models.

Dynamic models can be used to trace the accumulation of stock variables, whereas static models are unable to do this. In comparative static models, policy changes have no effect on the accumulation of stocks -e.g. capital stock- and the associated changes in production possibilities. For short-run agricultural analysis the implications of accumulating commodity stocks may be relevant as well.

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. That is, in each time period the model is solved for an equilibrium, given the exogenous conditions prevailing for that particular period. In between periods, stock variables are updated, either exogenously (e.g. population) or as a result of the equilibrium outcomes of the preceding period (e.g. investment demand leading to a changed capital stock in the next period). Recursive dynamics do not guarantee time-consistent behaviour. In contrast, in intertemporal equilibrium models agents display optimal behaviour over time as well as within periods. Intertemporal models are usually tantamount to using rational expectations assumptions.[3] Such forward-looking behaviour leads to equilibrium time paths that move towards a long-run steady state (if it exists). A main reason to incorporate such intertempo-

[1] The United Nations Project LINK (Klein and Su, 1979) is a well known example of this approach to global modelling.

[2] An intermediate approach has been followed by the GLOBUS model (Bremer, 1987), which included three prototypical model structures for respectively developed market economies, centrally planned economies and developing economies.

[3] Furthermore, by modelling the intertemporal equilibrium behaviour of economic agents, as well as equilibria within periods, such models are able to counteract the Lucas (1976) critique on economic models.

ral features into general equilibrium models is the desire to model savings rates endogenously, and hence to allow the model to generate alternative (endogenous) growth rates. In such models, a policy change can have a lasting effect on the economy's growth rate through changes in the accumulation of capital stocks. A feature which is impossible with a fixed savings rate assumption.[1]

Comparative static models are sometimes used to generate projections of policy impacts at some future point in time. Such projections are not to be confused with econometric forecasts, but are achieved by constructing an artificial future dataset that is consistent with the model's assumptions -a so called baseline-, and subsequently conducting a policy experiment on the basis of this projected dataset. The artificial future dataset is constructed by making assumptions on the growth of exogenous variables and parameters and subsequently letting the model solve for an equilibrium that is consistent with these assumptions. Typical projections with AGE models rely on exogenous forecasts of GDP, factor endowments and factor productivity.

2.2.2 Modelling of international trade

Assumptions concerning the nature of traded goods: homogeneous versus heterogeneous goods

In classical trade models, goods are assumed to be similar in the eyes of buyers. In such a market, the goods of one producer perfectly substitute for those of another and are called *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 a buyer or a seller of the good, but never both, since each actor is either able to produce the good with non-negative profits at the prevailing market price or not. This implies that a country can only be an exporter or an importer of a certain good, and models that include this assumption describe only inter-industry trade.

Homogeneity therefore simplifies the task of trade modelling considerably in two respects. First, the model does not need to track who trades with whom. Since prices are equalised and there is no other distinguishing characteristic of the goods, it makes no difference from which supplier a particular purchase is made. Second, the model needs only to track a single trade flow for each actor, either imports or exports.

However, these simplifications in modelling have severe limitations for applied trade research, as these models explain only inter-industry trade and not intra-industry trade. The latter turns out to be an important phenomenon in trade, since even at high levels of disaggregation, countries report both exports and imports in any sector. If intra-industry trade is netted out, one ignores an important phenomenon of the real world and underplays the importance of trade to each region. Furthermore, these trade models can be hypersensitive to changes in transportation costs and trade policy wedges, and run the risk of extreme specialisation when sector-specific factors of production are not present in the model, see also Francois and Reinert (1997).

[1] If knowledge is included as a production factor that can be accumulated, growth rates become endogenous, even with a fixed savings rate (see the endogenous growth literature, for example, Grossman and Helpman (1991).

One way to introduce intra-industry trade in a model is to assume that goods are distinguished by other factors than price alone, and hence are viewed as imperfect substitutes from the perspective of the buyer. When product differentiation is possible, goods are called *heterogeneous* and the task of trade modelling is considerably more complex. First, there is no need for prices to equalise across suppliers. If goods are heterogeneous, then different buyers are willing to pay different prices to obtain the same quantity of the good. Hence, independent price movements among suppliers are possible. Second, each actor in the market may be both a buyer and a seller at the same time if goods are differentiated. This implies that the trade model has to trace twice as many activities than under the homogeneity assumption.

There are two ways to incorporate product differentiation into applied trade models. On the one hand, product differentiation can be introduced exogenously by assuming that products are differentiated by country of origin. This method introduced by Armington (1969) simply assumes that imports and domestic goods are imperfect substitutes in demand. The often used Armington formulation in applied trade models invokes the assumption that products are differentiated by country of origin. In combination with a preference function that is separable in domestic products and combined foreign products, this yields empirically manageable import functions. Most often a CES functional form for preferences assumed. This assumption has received much criticism because the source of product differentiation is exogenously introduced on the demand side. Another disadvantage of this assumption is that terms of trade effects turn out to be quite large empirically. The Armington assumption implies that each importer, however small the region may be, has some degree of market power, and is therefore able to influence world prices.[1]

An alternative approach is to introduce product differentiation endogenously at the firm level on the supply side. This approach assumes that consumers prefer differentiated goods either to obtain a better match between their preferred variety and those extant in the market place (Lancaster, 1980) or to obtain increased variety in consumption (Spence 1976, Dixit and Stiglitz 1977). Krugman (1979, 1980) and Ethier (1979, 1982) introduced the concept of monopolistic competition into international trade theory. In this approach fixed costs such as R&D or marketing costs are necessary to produce differentiated goods. The inclusion of fixed costs has some implications for trade policies. Next to the traditional gains from trade we get 'noncomparative advantage' gains from trade in the presence of scale economies and imperfect competition. First, shocks that increase output at firm level result in positive scale effects. Second, there are gains from trade in the form of increased variety (thereby incurring fixed costs and reducing the sales of existing firms). Thirdly, scale economies imply that the market can only support a limited number of firms, which are consequently imperfectly competitive. Trade creates a larger market that can support a larger number of firms and hence a greater level of competition. The reduction in market

[1] The terms of trade effects following an import enhancing trade liberalization will be larger, the larger the elasticity of substitution between domestic and combined foreign goods. The import demand equation becomes flatter, which in turn implies larger effects on the volume of imports of the liberalizing country, which translates into larger upward price effects on world markets. If goods are also distinguished by country of origin, a higher elasticity of substitution between imports from different regions will dampen terms of trade effects, because in this case the burden of adjustment is spread out over more exporting regions (Brown, 1987). One consequence of the Armington assumption is that trade diversion effects from regional trade integration are dampened.

power is called the procompetitive effect. The advantage of this approach is that it locates product differentiation on the supply side and it minimises terms of trade effects. A disadvantage is that the absence of firm level data makes econometric estimation of elasticities problematic (Winters, 1990).

Characterisation of the global market: Bilateral relations versus pooled markets
The global market can be thought of as a network of buyers and sellers. One way to represent this network is a bilateral specification, that is the complete set of interactions between each buyer and seller for each commodity. Alternatively, one may view the market as a 'black box' or pool in which we see only what each actor brings to the market (supply) and what that actor takes from the market (demand).[1] The pooled approach aggregates supply and demand for a certain good into one figure, and the bookkeeping and computational requirements are reduced to: 1) a mechanism to equilibrate demand and supply on a market-wide basis, 2) a mechanism to allocate trade shares to each supplier, and 3) a mechanism to allocate trade shares to each buyer. The pooled approach provides no information regarding who trades with whom, only the connection between the individual actor and the aggregate market pool is visible. For obvious reasons, the pooled market approach is also known as 'non-spatial' modelling.

Clearly, the bilateral specification provides a richer and more detailed picture of the market, but requires much more data, parameters, bookkeeping and computational effort. Whether the additional effort is justified by additional relevant information is dependent on the kind of problems a model has to tackle. Many policy disputes and policy instruments are bilateral in nature, and international economic relations should be modelled at the same level.

2.2.3 Representation of policies

Tariffs and quantitative restrictions such as quotas and voluntary export restraints (VERs) are two types of trade policy instruments examined in applied trade models. Tariffs can be introduced in a straightforward manner and are most of the time expressed as the percentage by which the domestic price exceeds the world price; i.e. an ad valorem tariff rate. Quotas are more difficult to implement. First, one has to investigate whether a quota is binding or not. Second, it is difficult to assess what would be the level of imports without the quota. Third, one has to model who appropriates the rents that accrue from the quota: domestic importers or foreign exporters. With regard to the second element researchers focus on the price distortions caused by the quota. There are several methods to quantify quotas and other non-tariff measures (Laird, 1997), which basically amount to two alternative ways to implement them in applied models: the first is a tariff equivalent representation, while the second method specifies quantity restrictions directly.

[1] In a network with n actors (nodes), there are a maximum of $n(n\text{-}1)$ bilateral links. In the pooled market specification, a maximum of only $2n$ flows needs to be tracked.

Tariff Equivalents or Price Wedges

The tariff equivalent or price wedge of a non-tariff measure is the difference between the free world price of a good and the price on the domestic market. These measures can relatively easily be observed when goods are homogenous and free world prices can be obtained from transaction values. For manufactured goods, the former is a problem and for many (agricultural) commodities the latter is a problem. A popular method to arrive at estimates of tariff equivalents is use of Producer Support Estimates (PSE).[1] These include the transfer from price distortions (i.e. price wedges), and the transfers from government to producers. The transfer from price distortions or market price support is again the transfer from consumers to producers in the form of price gaps between domestic and world prices. The transfer from government expenditures includes both direct government payments and indirect transfers (e.g. input subsidies, tax concessions). The Consumer Subsidy Equivalent (CSE) measures the implicit tax or subsidy imposed on consumers. See Cahill and Legg (1990) for a comprehensive description. Both PSEs and CSEs are regularly published by OECD and USDA. A disadvantage of these subsidy equivalents is that they vary considerably from year to year, not only through changes in policies but especially through changes in world prices, exchange rates and the value of domestic production.

The representation of quantity restrictions as price wedges is not always an adequate approach. If a quota is not binding in the benchmark, its tariff equivalent will be equal to zero. However, the quota may become binding as the result of a policy change. This effect will not be captured when the quota is approximated by a tariff equivalent because the tariff equivalent remains zero. Additional complications arise in the case of multi-tier protective schemes like Tariff-Rate Quotas (TRQs). These schemes specify different tariff rates for different import quota levels, and it has to be determined whether each quota is really binding and/or the tariff is prohibitive. Also, the implementation of a quota implies the generation of quota rents, which accrues as income to the holder of the right to import or export under the quota. The endogenous determination of quota rents and their distribution over holders of quota rights can only properly be captured by an explicit representation of these policy measures. See for example de Melo and Tarr (1992) for a discussion of trade quota instruments. In the area of transboundary environmental policy (Kyoto protocol), tradable emission permits and tradable production quotas have emerged and should be captured in an appropriate way in policy models.

Other policy instruments

Next to border protection instruments strictu sensu, 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 polices that do not directly affect border protection, but nevertheless do have an impact on trade flows.

[1] Formerly known as 'Producer Subsidy Equivalents'.

2.2.4 Theoretical consistency

Judging the theoretical consistency of models has many facets, and the discussion here is far from exhaustive.[1] 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 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. The parameters used in the demand system and the supply equations should satisfy essential regularity conditions.[2]

The economic structure of general equilibrium models forces the model builder to exercises a strict discipline with regard to the restrictions on parameters. In particular, a necessary condition for the existence and uniqueness of an equilibrium solution is that all excess demand functions are homogeneous of degree zero in prices. This condition is met when the regularity conditions on demand and supply equations are satisfied. In a properly designed general equilibrium model, equality between incomes and expenditures will always be satisfied for the economy as a whole. This feature does not always hold for partial equilibrium models because they lack the restrictions imposed by an economy-wide national accounting framework.

2.2.5 Model closures

'Closing' the model is the process of classifying the variables as either endogenous, i.e. values are determined (solved for) by the model, or exogenous, i.e. predetermined outside the model. Model experiments are conducted by introducing alternative assumptions on exogenous variables.

Alternative model closures can also be employed to construct different models from the same basic modelling framework. Multi-region models with a global coverage can sometimes be transformed into single region models by singling out one specific region and declaring 'the rest of world' as exogenous. Similarly, economy-wide models can be transformed into partial models of selected sectors, by specifying a closure which holds 'the rest of the economy' as exogenous. The latter possibility is especially useful if one wants to compare partial equilibrium outcomes against general equilibrium outcomes, thereby checking for the presence of significant economy-wide induced effects following a certain policy change targeted at the agricultural sector.

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[1] 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 report. 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.

[2] 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.

There are certain general closure rules that have to be fulfilled by both partial and general equilibrium models. Both in a partial and a general equilibrium setting, a valid closure has to assure that the number of endogenous variables is equal to the number of equations. In addition to this necessary technical condition, the closure must specify a valid economic environment. For example, if the equilibrium model demands that all buyers exhaust their budget, the closure must be such that all buyers are on their budget constraint, and that there are no 'leakages' with respect to incomes and expenditures.

Since partial models describe only a subsystem of the economy, they do not have to be concerned about the so-called 'macroeconomic closure', i.e. the treatment of the link between investment and savings. In models without intertemporal decision making with respect to investments, the identity between macroeconomic investment and savings is guaranteed by fixing either one at some pre-specified level, and requiring the other variable to accommodate. For example, a so-called 'Keynesian closure' specifies an exogenous investment level and lets savings adjust endogenously. On the other hand, in 'neo-classical closures', investment is adjusting to savings levels. Since the source of savings may be both domestic and foreign, the closure rule also has implications for the treatment of the current account balance. If the trade balance is fixed exogenously, one essentially also fixes the difference between domestic savings and domestic investments. In addition, in multi-region economy-wide models, the approach of fixing trade balances at the regional level is a simplifying way to avoid modelling the allocation of global savings to individual regions. A disadvantage of this approach is the inability to model endogenous changes in the volume of regional trade balances. It is obvious that the specification of the macroeconomic closure can have profound impacts on model outcomes.

2.3 Data and parameters

Data

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).

Not only is the amount of data usually quite large, but the data need to be mutually consistent. Especially if trade is related to domestic inter-industry structures, substantial adjustments to the published data are necessary, because the procedures for collecting and classifying trade statistics differ from those employed for domestic input-output tables. 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[1]. A Social Accounting Matrix (SAM) usually underlies economy-wide models. Although the SAM is sometimes only implicitly present in the database of AGE models, it forms the basis for a coherent and consistent description of national economies. See Laird (1997) for a descrip-

[1] A recent joint initiative by USDA/ERS, Agriculture and Agrifood Canada, the European Commission, UNCTAD and FAO 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 and Gibson 1999.

tion of widely used data sources for international trade analysis. The Annex to this report lists the datasources of individual models in some detail.

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 additional 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.

Parameters

The parameters used in behavioural equations determine the response to policy changes, and are therefore a very crucial element in each modelling exercise. 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). As already mentioned above in section 2.2.4 the values of these parameters must be determined in consistency with data and theory.

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 generally not feasible, and one has to resort to single-equation estimation methods, using either time-series or cross-section data. See Jorgenson (1984) for econometric estimation of AGE models.

Most applied trade modellers 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

3.1 Partial models

In this section we describe the features of the selected partial equilibrium models. We first describe the design choices of a prototypical standard multi-region partial equilibrium model. This standard model will serve as a point of reference for the individual partial equilibrium models. Secondly, we describe the individual models in alphabetical order and identify their non-standard features.

A standard partial equilibrium model:
A standard partial equilibrium model has the following characteristics:
- regional scope: Global coverage;
- regional unit of analysis: Parametric differences between countries;
- dynamics: comparative static;
- modelling of trade: Homogeneous goods;
- characterisation of global markets: Pooled markets;
- representation of policies: Ad valorem price wedges (trade: tariff equivalents);
- theoretical consistency: Not implied by theoretical structure;
- model closures: Factor markets and non-agricultural sectors are exogenous.

The standard multi-region applied partial equilibrium model framework consists of an economic structure that includes for each region constant elasticity supply and demand equations which determine domestic prices. The standard model is multiproduct by nature to capture supply and demand interrelationships among agricultural products. Therefore, supply and demand equations are functions of own and cross product prices. The interactions between the agricultural product groups are taken into account while influences of factor markets and the rest of the economy are treated as exogenous. Supply and demand relationships incorporate therefore exogenous variables such as population, household income and technical change. Each sector produces one homogeneous good that is perfectly substitutable both domestically and internationally. A region's international trade is viewed as the difference between the regions' supply and demand and brought to the world market (pooled approach, no bilateral trade). For each product, world market clearing price balances global trade. World prices for each product feed back into domestic prices through a set of equations which specify wedges between world price and domestic price. All policies are inserted as ad valorem price wedges. Finally, the standard model is comparative static in nature. In this paper the standard SWOPSIM model is an example of a typical standard partial equilibrium model.

The standard partial equilibrium model can be modified to capture the following elements:

- possibility that policy instruments can be represented explicitly and in a detailed fashion;
- inclusion of autonomous shifters into behavioural (supply and demand) relationships to generate projections.

Standard or modified standard partial equilibrium models included in this paper are ESIM, MISS, SWOPSIM and WATSIM. Another type of partial equilibrium models differs with respect to dynamics in the sense that they are recursive dynamic in nature. Examples of this type of models included in this paper are AGLINK, FAO World Model, FAPRI and GAPsi.

3.1.1 AGLINK

The AGLINK model is a recursive dynamic supply and demand model of world agriculture, which uses (Nerlovian) partial adjustment relationships. AGLINK is developed by OECD in co-operation with its Member countries, and is presently used by government services of OECD member countries. The model is used for analysis of the impacts of agricultural policies and for forecasting the medium term development in supply, demand and prices for the principal agricultural commodities produced, consumed and traded in member countries (e.g. used in medium term outlook of OECD). In contrast to the standard model land allocation is captured by endogenising planted area and yield. Furthermore, dynamics are introduced by including lags in both endogenous and exogenous variables. The AGLINK model is built around complete modules for 10 main OECD Member countries or regions (including EU, Hungary and Poland), and 3 non-OECD Member countries/regions, while the countries left over are treated as exogenous to the model. This implies that these 'main' countries/regions are represented in most of the commodity markets modelled, while a few other countries are included if they are 'important' in a certain commodity market. The markets modelled are 19 agricultural commodity markets and mainly the principal ones for the OECD countries. In terms of theoretical consistency and perhaps except for its feed demand equations, price elasticities in AGLINK are not necessarily theoretically consistent.

3.1.2 ESIM

The ESIM[1] model was initially developed in a co-operation between the USDA/ERS and teams of Prof. T. Josling of Stanford University and of Prof. S. Tangermann of Göttingen University. This SWOPSIM-style model is designed to evaluate accession of Central and Eastern European countries to the EU, see Tangerman and Josling (1994). Besides EU enlargement ESIM is used to analyse the effects of CAP (e.g. Agenda 2000) and WTO policies on agricultural markets and budgetary expenditure. It covers 27 commodities representing the major part of agricultural production value and it covers the world with special emphasis on European countries (EU-15, Bulgaria, Czech Republic, Estonia, Hungary, Poland, Slovakia and Slovenia, ROW). In contrast to the standard model land

[1] European Simulation Model.

allocation among different crops is addressed and CAP instruments such as compensation payments, land set aside, quota restrictions, and export refunds are treated explicitly. Projections can be generated in an ad hoc manner by including income, population and technology shifters.

3.1.3 FAO world model

The FAO world model is developed by the Commodities and Trade Division of the Food Agriculture Organisation (FAO). The model is designed to obtain medium- and/or long-term projections (e.g. used in outlook of FAO on agricultural commodity markets) and to simulate impacts of policy changes on prices, production, consumption and trade of the most important agricultural products (FAO, 1993, 1994, 1998). The model is quite active and is routinely used by FAO's Commodities and Trade Division. The model covers 13 agricultural commodities which belong to the grain/livestock/fats and oil complex, and 147 individual countries (115 developing and 32 developed countries). The European Community relates to the 15 member States including the new German Länder. In contrast to the standard model, area planted in cereals and oilseeds is an endogenous variable, which implies that the land allocation problem is to some extent captured in the World Food Model. Dynamics are introduced by adoption of a (Nerlovian) partial adjustment model specification for the supply equation and for some regions (e.g. EU15) which use lagged prices to capture the dynamic decision process of crop and livestock production. The baseline is generated by using time trends and constant growth rates for exogenous variables such as technical change, population and gross domestic product.

3.1.4 FAPRI

FAPRI models are developed at the Food and Agricultural Policy Research Institute (FAPRI) at Iowa State University (Devadoss et al., 1989). It is basically an integrated set of models used to 'provide quantitative evaluations of national and international agricultural policies and other exogenous factors that affect US and world agriculture' (Devadoss et al., 1993, p130). FAPRI has been used for several years in conducting US policy evaluations. The set of models involves domestic livestock models, domestic crop models, government cost and farm income models for the US linked to some world trade models. Currently, the system covers 24 agricultural commodities in 29 countries and/or regions. FAPRI belongs to econometric, dynamic and partial equilibrium based models. It is an estimated and synthetic system of structural econometric models where each component presents specific theory structure and can be solved individually. While demand is always treated as endogenous, supply can either be endogenous or exogenous. In most cases, it is exogenously modelled in countries with little domestic production. Dynamics have been introduced by lagged variables for supply and demand functions in a naive adjustment model for most of them. A projection function is included to generate projections of the exogenous variables for the next ten years.

3.1.5 GAPsi

GAPsi[1] is developed and used at the Institute of Market Analysis and Agricultural Trade Policy (MA) of the Federal Agricultural Research Centre (Frenz and Manegold, 1988, Kleinhanss et al., 1998, Salamon, 1998). This model is designed to evaluate EU agricultural policies (e.g. CAP reform, Agenda 2000). It describes supply and demand interactions between 13 agricultural commodities for 17 countries/regions (14 EU member countries). In contrast to the standard model GAPsi is recursive dynamic covering a period of 10-15 years. The gap between the base year (1995) and the target year (2005) is made up by annual model runs with the calculation for year t based upon model results for year t-1 and exogenous variables for year t. This method is used for providing both, a baseline projection (including a few years available for calibration) and the calculation of alternative policy scenarios. A second, deviation from the standard model is that quantity instruments (quota, budget restriction) are modelled explicitly.

3.1.6 MISS

MISS[2], a Simplified World Trade Model, is developed by the Institut National de Recherche Agronomique (INRA) in France (Mahé and Moreddu, 1987). It's main aim is to analyse the effects of agricultural policy changes in EU and US (e.g. Guyomard et al., 1988, Mahé and Tavéra, 1989). MISS is a standard partial equilibrium model that covers 10 agricultural commodities and four regions (EU, US, Centrally Planned Economies, and Rest of World). MISS is perhaps the only (or one the few) partial equilibrium models which satisfies all the theoretical regularity conditions pertaining to supply equations. On the demand side, this is not true. Another important aspect of the MISS model is that policy instruments are explicitly represented. A third aspect which is deemed important in the MISS model concerns the fact that it includes exogenous shifters in it's supply and demand relationships to capture the effects of for, example, technical change and population growth. MISS was perhaps the first synthetic partial equilibrium model where systematic simulation exercises and sensitivity analyses were conducted to test the impacts of these exogenous shifts. Therefore, beside its use in many policy-oriented analyses (trade policy games), MISS has also been used for projection simulations over a three year time horizon periods from 1988 to 2002 (Guyomard et al., 1991; Guyomard et Mahé, 1994). Finally, it has to be mentioned that MISS is currently not in use anymore.

3.1.7 SWOPSIM

The SWOPSIM[3] world trade modelling framework was originally developed by Roningen (1986) at the Economic Research Service, United States Department of Agriculture (USDA) to study the impact from the GATT Uruguay Round. 'SWOPSIM models are designed to simulate the effects of changes in producer and consumer support policies on production, consumption, and trade' (Roningen 1986 p.iii). SWOPSIM is a standard multi-

[1] The acronym stands for Gemeinsame AgrarPolitik - Simulation (Common Agricultural Policy simulation).
[2] MISS is the acronym in French for 'Modèle International Simplifié de Simulation'.
[3] Static World Policy Simulation Model.

commodity, multi-region partial equilibrium model, which describes the supply and demand interactions between 22 agricultural commodities for 36 regions (Sullivan, Wainio and Roningen 1989). Western Europe is largely covered by EC aggregation and Eastern Europe treated as a single block. Spain and Portugal may be treated separately but other smaller European countries were not specifically listed.

Generally, the framework has been employed to analyse the effect of policy changes on agricultural activity and trade. Applications of the SWOPSIM modelling framework have included: WTO trade liberalisation (e.g. the Uruguay round); effects on agriculture from EU enlargement and potential Eastern European EU membership; agricultural policy reform (e.g. CAP); free trade hypotheses versus supply control; trade prospects and the opening up of Asian markets; environmental change and global warming; crop disease; trade liberalisation impacts on production factor demand and the gains from trade (and comparative advantage); effects of protection and exchange rate policies on agricultural trade; and welfare analysis.

The SWOPSIM model has been made available to numerous academics who worked on the field of agricultural trade liberalisation (for a recent application on the Blair House agreement, see Ames et al., 1996). SWOPSIM data and parameters are frequently referenced as sources for other models. The standard SWOPSIM model has been extended to capture trade flows using an Armington-type specification (Dixit and Roningen, 1986), to include the permanent impact on derived demand for factors following policy shifts (Liapsis 1990) and to include medium and long term projections (e.g. Roningen et al., 1990).

3.1.8 WATSIM

The WATSIM[1] model is developed by the University of Bonn (Heinrichsmeyer et al., 1998, von Lampe, 1998). The model of world agriculture focuses on three target periods with different aims: Short-term shock analysis (in work, not yet available), medium-term projections and policy analysis, and long-term projections and analysis of various shift factors (e.g. income in Asia, productivity in transition countries). This SWOPSIM-type model covers 29 agricultural commodities and 15 regions (EU, rest of Western Europe, and Central and Eastern Europe). Most price and income elasticities are taken from the data base of the SWOPSIM modeling framework. In contrast to the standard partial equilibrium model policies such as compensation payments per ha or per head, set-aside obligations, productions quotas and export restrictions are treated explicitly.

3.1.9 Conclusion

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).

[1] World Agricultural Trade Simulation Model.

Besides the design choices the models differ in their product and country coverage, which leads to a rather large differences in focus.

Table 3.1 Model summary of partial equilibrium models of trade in agricultural products

	Description	**modelling of trade**	**Goals**	**key applications**
Standard model	*static partial equilibrium model, global coverage, no factor markets included*	*Homogeneous good + pooled markets*		
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 3.1 Continued

	Policy Representation	**Number of regions (r) or countries (c)**	**global coverage? (y/n)**	**Number of sectors/ products**	**number of farm (f) or processed (p) products**	**Software**	**data availability**
Standard model	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)	FORTRAN	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)	FORTRAN, GAMS	y

3.2 Economy-wide models

As we did in section 3.1 for partial equilibrium models, we first define a prototypical model as a point of reference against which the features of individual economy-wide models can be compared. We choose as our standard a multi-region AGE model, which has the following characteristics in terms of the criteria introduced in section 2:

- regional scope: global coverage;
- regional unit of analysis: parametric differences between countries/regions;
- dynamics: comparative static;
- modelling of trade: Armington;
- characterisation of global markets: bilateral trade relations;
- representation of policies: ad valorem price wedges (trade: tariff equivalents);
- theoretical consistency: implied by model structure;
- model closure: Endogenous volumes and prices on all markets, including factor markets. Exogenous: factor endowments, policy instruments. Macro closure: 'neoclassical', savings driven investment at global level. (endogenous trade balance).

The main features of the standard multi-region AGE model correspond closely to those attributed by Baldwin and Venables (1995) to 'first generation' models: comparative static, constant returns to scale in production, perfect competition on all markets, Armington assumptions for imports. In addition, our standard model has a database with global coverage, i.e. in principle global economic activity is covered. 'Standard models' included in this report are RUNS, GREEN, GTAP and MEGABARE. Within each regional economy of a standard multi-region AGE model, inter-industry linkages are captured by an input-output structure. Demand for factors of production is derived from cost minimisation, given a sectoral production function (nested CES) that allows for substitution between inputs. Typically, substitution is allowed only between primary factors -land, labour, capital- while intermediate inputs are used in fixed proportion with output (Leontief technology). Each sector produces one homogeneous good that is perfectly substitutable domestically but substitutes imperfectly with foreign goods (Armington assumption). Next to the binary distinction 'domestic versus foreign', the multi-region nature of the model enables a distinction of traded commodities according their region of origin. That is, bilateral trade flows are captured.[1] Factor markets for land, labour and capital are included, endowments for these primary factors are given and the factors are fully employed. Labour and capital are assumed to be fully mobile across domestic sectors, while land is imperfectly mobile and tied to agricultural production. Consumer demand is derived from utility maximisation under a budget constraint, and consumers allocate their expenditures over domestic and foreign goods. A government actor levies various types of indirect taxes and subsidies -including import tariffs en export subsidies. All policy instruments are specified as ad valorem price wedges. All factor markets and commodity markets are assumed to

[1] One strand of AGE models uses, in addition to Armington style imports, a CET transformation function that models the split of domestically produced goods into exported commodities and those destined for the domestic market. An advantage of this method is that it dampens the size of terms of trade effects that emerge in Armington models, see de Melo and Robinson (1989).

clear, which yields equilibrium solutions to factor- and commodity prices as well as the corresponding equilibrium quantities.

All regional economies are linked through bilateral commodity trade and through interregional investment flows. As discussed in section 2.2.5, there are different approaches to deal with this latter aspect. If one is willing to assume a constant current account balance in all regions, then the difference between regional savings and investments is essentially predetermined, and as a consequence the aggregate level of the savings - investment balance is also predetermined. If one wants to allow for endogenous determination of the current account balance, the standard model must include a mechanism to redistribute aggregate savings over regions.

We also classify under the heading 'standard model' those which include a recursive sequence of temporary equilibria[1]. Recursive models do generate time paths for endogenous variables, but there is in fact no behavioural linkage between periods. As a result, the equilibrium solution in each period can essentially be calculated without reference to earlier or later periods.

'Second generation' models add increasing returns and imperfect competition in some of the sectors, allowing for estimates of scale and variety effects, as discussed in section 2.2.6. These models are comparative static in nature. Examples included here are the Michigan BDS and WTO models. In contrast, 'third generation' models include time consistent forward looking behaviour and endogenous savings rates, hence allowing for the modelling of short run dynamics. The G-cubed model is an example of this brand. Below, we proceed to present an overview of economy-wide models in alphabetical order.

3.2.1 G-cubed

Initiated by Dr. McKibbin W., J. and J. Wilcoxen, the model was constructed with funding from the Brookings Institution, the US National Science Foundation and US Environmental Protection Agency. G-cubed[2] aims at contributing to the ongoing policy debate on environmental policy and international trade, with a focus on global warming policies. The model is a 'third generation' model that combines insights from modern macroeconomics with typical multi-sectoral resource allocation aspects. Key applications are economy-wide impacts of global warming policies, and impacts of global macroeconomic shocks (recent financial crisis in Asia).

G-cubed[3] (McKibbin and Wilcoxen,1999) has 8 regions including the United States, Japan, Australia, Other OECD (composite region), China, Less developing countries (composite region), oil exporting developing countries (composite region), Eastern Europe and the Former Soviet Union (composite region). Each region/country is made up of twelve sectors, with a separation into energy sectors (electric utilities, gas utilities, petroleum refining, coal mining, and crude oil and gas extraction) and non-energy sectors

[1] The Baldwin and Venables (1995) 'first generation models' are comparative static. However, single region recursive AGE models have a long tradition, starting from the work of Adelman and Robinson (1978) on Korea. While the standard recursive approach allows for accumulation of capital stocks, investment behaviour is not forward looking in these models.

[2] G-cubed stands for Global Computable General Equilibium Growth model.

[3] http://www.msgpl.com.au/msgpl/msghome.htm

(mining, agriculture, fishing and hunting, forestry and wood products, durable manufacturing, non-durable manufacturing, transportation, and services).

The data set has been constructed by developing a consistent set of several input/output tables and related investment and consumption data and international trade data. The dataset relies heavily on information for the US economy, with 1987 as the base period. Time series were constructed for the US economy to estimate econometrically the consumption and production parameters (elasticity of substitution and distribution parameters of the US economy. Then, the relevant parameters (e.g. elasticities of substitution) are assumed to be equal across regions and other parameters are calibrated using the base period.

G-cubed is an intertemporal general equilibrium and macroeconomic model. It combines a conventional AGE model representing the real sectors in a disaggregated way and a model representation of financial and capital assets and flows. Imposition of the intertemporal budget constraints ensures that agents and countries cannot forever borrow or lend without undertaking the required resource transfers necessary to service outstanding liabilities. The short run behaviour is a weighted average of neo-classical optimising behaviour and ad-hoc 'liquidity constrained' behaviour. This feature allows for analysis of the short-run dynamics and adjustment paths to a long run steady state. The model assumes that agents form rational expectations about key decision variables and other exogenous variables. The model adopts the Armington specification and specification of bilateral trade flows for eight tradable commodities.

Policies are represented by relevant policy instruments such as taxes, interest rates, money supply, investment tax credit, government debt and government transfers, and emission permits. The model employs full short run and long run macroeconomic closure with macro-dynamics at an annual frequency around a long run Solow/Swan neo-classical growth model.

Due to its intertemporal orientation, a 'business as usual' baseline scenario needs to be generated, which serves a the benchmark for policy simulations. This baseline requires that assumptions on the long run evolution of exogenous variables are made (population, non-energy and energy productivity, energy efficiency and monetary policy). For the construction of the baseline it is also necessary to match assumptions on exogenous variables and expectations held by agents in the real world. The baseline trajectory is then constructed by solving the model for each period after the initial period given any observed shocks to variables, shocks to information sets or changes in initial conditions.

3.2.2 GTAP

In 1990/91, collaborative work by Thomas W. Hertel at Purdue University in the United States with the IMPACT Project in Melbourne, Australia, catalysed an initiative known as the Global Trade Analysis Project (GTAP). Since its inception, the explicit aim of the GTAP project has been the lowering of entry barriers to global trade analysis. The project is now supported by a consortium of 18 national and international agencies which provides financial support as well as guidance to the Center of Global Trade Analysis at Purdue University. The consortium includes some of the major players in global trade analysis (World Bank, WTO, UNCTAD, European Commission, OECD).

The GTAP project goes beyond the construction of a model. Its tangible publicly available products are:

- provision of a global database;
- provision of a standard general equilibrium modelling framework;
- software and accompanying literature (Hertel, 1997) for manipulating the data and implementing the standard model;
- annual short courses and a WWW based distance learning course which expose new users to the database, the model and the accompanying software;
- a global network of researchers with a common interest of multi-region trade analysis and related issues;
- a World-Wide Web site for the dissemination of data, software and Project related information;[1]
- a technical paper series through which new developments and non-standard versions of the GTAP model are disseminated.

Much of the focus of GTAP is directed towards the analysis of agricultural policy and trade (Francois *et al.*, 1995; Hertel *et al.*, 1995), although there have been GTAP-related applications in non-agricultural trade-related issues (McDougall and Tyers, 1994) as well as environmental policy analysis (Perroni and Wigle, 1997). European interest in GTAP has also grown, with a steady increase in the literature examining the impacts of European enlargement to the East and CAP compatibility under the Uruguay Round commitments (Hertel et al., 1997, Jensen *et al.*, 1998), modelling applications based on the Agenda 2000 reform proposals (Blake *et al.*, 1999). More recently, database development and modelling have also expanded in the direction of energy usage and climate change.[2]

The roots of the GTAP database can be traced back to the SALTER database created by the Australian Industry Commission. The current version of the database (version 4) has a coverage of 45 regions, 50 commodity groupings and 5 primary factors (Land, Skilled and Unskilled Labour, Capital and Natural Resources), and is benchmarked to 1995 US dollar values. Europe is represented by country data for the UK, Germany, Denmark, Sweden, Finland next to an aggregate 'Rest of the EU' and EFTA. The main components of the database consist of bilateral trade, transport and protection matrices that link the country/regional input-output (IO) databases. The database is fully documented in McDougall et al. (1999). Although the commodity coverage has a deliberate agricultural bias with 12 primary agricultural sectors (8 food processing sectors, 1 forestry sector and 1 fishing sector), within the remaining 30 commodity groupings, there is significant disaggregation of manufacturing, service and fossil fuel sectors.

The default GTAP model (Hertel 1997) is a standard multi-region AGE model as defined above. A special feature is modelling of consumption expenditures through a non-homothetic Constant Differences of Elasticities of substitution (CDE) demand system (Hanoch, 1975, Surry 1989), which allows budget shares to vary with income. The standard GTAP model includes all quantitative restrictions as *ad valorem* price wedges. Although not apparent in the standard GTAP treatment, other policies may also be explicitly incorporated into the model framework, based on work by Bach and Pearson (1996). Thus, the

[1] http://www.agecon.purdue.edu/gtap/

[2] A related report forthcoming from this project surveys EU-relevant GTAP applications.

incorporation of budget restrictions (for example on headage payments), production quota (for example milk quota), tariff rate quota on imports and similar restrictions on volumes require the use of inequality constraints. GTAP parameters are determined through calibration. That is, key behavioural parameters are taken from extraneous sources and the remainder is calibrated to the benchmark dataset.

The default macro closure mechanism employed in the GTAP model is to have investment specified as being *savings-driven*.[1] Discrepancies between regional savings and investment are compensated by changes in the trade balance such that regional closure is satisfied. Alternative closures are readily implemented in GTAP. For example, the general equilibrium model can be transformed into a partial model of agricultural trade by declaring non-agricultural commodities as exogenous. Similarly, one region can be singled out for analysis by declaring the 'Rest of World' as exogenous.

The standard GTAP model is comparative static. Some GTAP studies (Bach *et al*., 1998, Frandsen *et al*., 1998) employ annual growth-rate projections for productivity, GDP and endowment variables to project the database into the future.

Although the standard GTAP can be characterised as a 'first generation' model in the Baldwin-Venables sense, it is flexible enough so it can be geared towards 'second'- and 'third generation' models. Deviations from perfect competition have been explored by Swaminathan and Hertel (1996), Francois (1998). Dynamic analysis has been pursued by McDougall and Ianchovichina (1996) International technology spillovers have been introduced by Van Meijl and Van Tongeren (1998, 1999a,b) (see GTAP website Technical Papers page).

3.2.3 GREEN

GREEN was developed at the OECD Secretariat in the period 1991-1992 and updated over the last years. Key developers are J.M. Burniaux, J.P. Martin, G. Nicoletti and J. Oliveira-Martins. The project was initiated at the OECD in 1990 at the request of the Economic Policy Committee. GREEN is routinely used by the OECD for the assessment of policies that affect carbon emissions. The model has recently extensively been used to assess implications of the Kyoto protocol on global climate change.

In GREEN the world is divided into 12 regions: OECD plus major energy producers and energy consumers. Europe is represented by the EEC. The industry aggregation covers nine sectors, six of them being energy sectors. Agricultural activities are aggregated into one sector.

GREEN is a relatively standard time-recursive AGE model with global coverage. Since it focuses on carbon emissions, It is data and modelling place much emphasis on energy demand and carbon emissions related to energy usage. The production structure is a nested CES with an explicit treatment of substitution among alternative energy sources in an energy nest. Except for crude oil, internationally traded commodities are differentiated according the Armington assumption. The model incorporates policy instruments such as ceilings (quotas) on emissions and tradable emission permits. No special attention is given to the agricultural sector and specific polices related to agriculture. GREEN is a recursive

[1] This depends on the choice of investment mechanism employed in the model framework.

dynamic model that considers the time period 1985 - 2050. The standard closure of the model is neo-classical with fixed trade balances.

The basic database and generation of parameters is very similar to the procedures employed in RUNS, see below section 3.2.7, with the exception of energy data. These have been compiled from International Energy Agency data.

3.2.4 INFORUM

The key institution is the economics department at the University of Maryland, and in particular the INFORUM center. INFORUM (INterindustry FORecasting at the University of Maryland) was founded by Professor Clopper Almon in 1967. In some ways, INFORUM is similar to the GTAP consortium. There is a network of researchers working on national models that feed into the overall scheme of linked macroeconomic models.[1] INFORUM publishes a great deal of data and public versions of its macroeconomic modelling software.

The system of linked INFORUM models has been used to produce annual forecasts and analyses of public policy since 1979. For example, it was one of three models used by the U.S. government in early policy research during NAFTA negotiations, though its role in the trade policy community has since been more limited. The current system of linked macroeconomic models contains models for the United States, Canada, Mexico, Japan, Korea, Germany, France, United Kingdom, Italy, Spain, Austria, and Belgium. A model of China has also been developed, but has not yet been made a part of the linked system.

The INFORUM system can be used to study the industrial and aggregate impacts of macroeconomic developments such as changes in exchange rates, trade policy, and government policy. Such experiments are qualitatively similar to those assessed with a standard AGE model. In addition, the system of models is used to provide the U.S. INFORUM model, LIFT, with forecasts of foreign prices and demands for U.S. exports by sector. Based on these forecasts, detailed macroeconomic forecasts are produced every six months. Applications to trade policy are relatively limited and tend to focus on North America. The Canadian, Mexican and USA models were used by the Canadian government (Department of External Affairs) in a study of the impacts of alternative free trade agreements between the U.S. and Canada on the Canadian economy and later a similar study was completed looking at the recently completed NAFTA accord, Almon et al. (1991). Richter (1994) has examined the consequences of the full participation of Austria in the European Union. Christou and Nyhus (1994) have examined broader aspects of European policy. They develop a number of assumptions representing EC directives on the Single Market, and introduce them in the INFORUM system of models.

The INFORUM models are internationally linked, dynamic macroeconomic models with inter-industry linkages, and are used to produce annual forecasts for a variety of industry indicators. At the heart of the individual country models lie national input-output models, where prices for each industry's product are determined by their input costs and a mark-up. Demand for each industry's product comes from other producers (i.e. intermediate demand) and from consumers, government and foreigners. These are ultimately

[1] See: http://www.inform.umd.edu/EdRes/Topic/Economics/EconData/Intpartn.html

combined through national accounting identities. The basic approach of INFORUM models is described by Almon (1991). In general, fully independent models are developed, which are then linked trough trade flows. The number of sectors may vary by country, and the base year from which projections are initially made may also vary.

Probably the best developed and most used INFORUM model is a model of the US economy known as LIFT. Being an econometrically driven macroeconomic forecast model, the LIFT model is a multi-sector model but not an equilibrium one. Rather, forecast models of individual sectors are linked through input-output relationships, and the general shifts in prices and incomes that result are linked to demand patterns. However, the sense of economywide constraints (i.e. capital and labour markets clearing) is not central to this class of models. Individual markets clear, but full adding-up conditions are not imposed. Neither is utility-maximisation based final expenditure patterns. The result is that the welfare implications of income changes can be difficult to interpret.

3.2.5 MEGABARE and GTEM

MEGABARE and its successor GTEM are dynamic models of the world economy, developed at the Australian Bureau of Agricultural and Resource Economics (ABARE)[1], with Kevin Hanslow as its principal developer. These models build on the GTAP model and database.[2] The focus for the development of MEGABARE was to create a dynamic general equilibrium model of the global economy suitable for analysis of international greenhouse policy, but its scope includes broader issues relating to international trade policy, especially agricultural trade reform.

As GTAP database has been the data source for the models, and consequently the regional and commodity coverage are the same as in GTAP. In MEGABARE the version 3 of the GTAP database with 30 regions and 37 industries was used, while GTEM utilises version 4. Additional data are included on sectoral usage of fossil fuels and the associated carbon dioxide emissions. Data on production, exports and prices of energy commodities (coal, oil and natural gas) rely on the United Nations Industrial Statistics Yearbook (United Nations 1994).

The key applications with MEGABARE and GTEM are related to the Kyoto Protocol and its implications on the economies of Australia, developing countries and EU. Another area of application is regional integration in the APEC and ASEAN context.

GTEM and MEGABARE are recursive dynamic AGE models, which share their basic structure with the GTAP model. The dynamics of the model enters through the capital stock evolution and the growth in population and labour force. Investments in physical capital follow a partial adjustment path influenced by the savings patterns of different age groups in each region and the international flow of capital. Additional dynamic features enter through the demographic module which simulates population growth (given births and deaths in each time period and net migration) and the growth in the labour force (given new entrants and retirements in each period). The dynamic process is of the recursive na-

[1] http://www.abare.gov.au

[2] The latest version of the model, GTEM, is under a development but the model documentation was not yet available at the time of writing. This description relies mainly on the interim documentation of MEGABARE (ABARE, 1996).

ture as in the Monash model[1]. The production structure of the GTEM and MEGABARE have been further developed from the GTAP model. In certain sectors (electricity, steel and iron) the technology bundle approach has been used, which assumes that different technologies are available for each industry. Each technology uses inputs in fixed proportion to output, and the choice of a particular technology depends on relative prices. The endogenous technology choice feature is considered important in the context of greenhouse policies, where alternative technologies are likely to become available in the future. Emission accounting equations for each sector have been added, and additional equations are included to impose various policies intended to curb the growth in emissions. GTEM includes also the emissions trading and the implementation of emission response functions for greenhouse gases other than carbon dioxide.

The endogenous population growth has implications on the savings behaviour and the growth in the labour force. These modelling extensions have put additional demands on the data and parameters. The birth and mortality rates are econometrically estimated functions of GNP. The savings behaviour in different age groups has been calibrated from the data with the life cycle model given initial savings.

3.2.6 MICHIGAN BDS MODEL

The Michigan Brown-Deardorff-Stern (BDS) model, is aptly described as a comparative static 'second generation' model, with monopolistic competition in manufacturing sectors modelled in the Dixit-Stiglitz fashion. It evolved from earlier work in the mid 1970s on the Tokyo Round of Multilateral Trade Liberalisation.

The BDS model has been used to analyse the economic effects of the Canada-U.S. Trade Agreement (CUSTA) and later to analyse NAFTA (Brown, Deardorff, Stern 1992a,b, 1996), the extension of the NAFTA to some major trading countries in South America, the formation of an East Asian trading bloc, the potential effects of integrating Czechoslovakia, Hungary, and Poland into the EU (Brown, Deardorff, Djankov, and Stern (1996)). Besides regional integration issues the model has been used to analyse liberalisation of trade in services by Brown, Deardorff, and Stern (1995) and by Brown, Deardorff, Fox and Stern (1996).

The complete database consists of 29 sectors and 34 countries. Europe is represented by 12 countries. The industry specific breakdown has a deliberate bias towards manufacturing and services, with one aggregate sector for agriculture, fisheries and forestry, one extraction sector, 21 manufacturing branches of which one is food processing, and six service sectors. The initial databases have been compiled from a variety of sources, but the Michigan team is recently using the GTAP version 4 database.

The input-output data as well as the model documentation are available on Internet[2]. The complete database and documentation should be available from the authors on request (Brown, Deardorff, Fox and Stern, 1996).

The model departs from the standard model by assuming imperfect competition that is based on increasing returns to scale technology. Imperfect competition is modelled in Dixit-Stiglitz fashion as monopolistic competition, where each firm produces its own vari-

[1] http://www.monash.edu.au/policy/monmod.htm
[2] http://www.spp.umich.edu/rsie/model

ety and free entry eliminates pure profits (Dixit and Stiglitz, 1977). This model displays the scale and variety effects that have been discussed above. Only manufacturing industries are modelled as imperfectly competitive ones. In the production of services perfect competition is assumed[1]. To make the regional expenditure meet the budget constraint trade balance is fixed. Fixed trade balance rules out international capital mobility, but since investment behaviour is not modelled, this is conventional 'long term' closure.

The BDS model incorporates nominal tariffs as well as import quota and other NTBs, represented by endogenous tariff equivalents. The actual tariff that applies is a composite of the nominal tariff and the tariff equivalent of the non-tariff barrier. The quota facility is invoked by specifying the fraction of the sector covered by non-tariff barriers and the desired change in the quota limit.

3.2.7 RUNS

Runs was developed at the Centre d'Economie Mathématique et d'Econométrie at the Free University of Brussels during the eighties by Burniaux (1987). RUNS[2] has subsequently been integrated into the OECD Development Centre's 1990 - 1992 programme on Developing Country Agriculture and International Economic Trends, under the direction of Ian Goldin (Burniaux and van der Mensbrugghe 1990). The model is not currently in use at OECD, but RUNS results are still likely to be referenced to date. The main goal of the model was agricultural policy analysis, especially analysis of the impact of the common agricultural policy (CAP) on developing countries and assessment of the Uruguay Round of multilateral trade liberalisation. The model includes 22 regions (OECD members plus major developing economies). Europe is represented by the three regions: EEC; EFTA and Eastern European Economies. RUNS distinguishes 20 commodities, among which 11 primary agricultural commodities and four processed food products.

RUNS is a relatively standard time-recursive AGE model which covers global economic activity. A special feature of the model is the Rural-Urban distinction, which is represented by imperfect domestic factor mobility between rural and urban sectors. Sticky wages allow for analysis of labour absorption and unemployment issues. Modelling of production of agricultural commodities allows for joint production, whereas non-agricultural commodities follow the standard approach via nested CES functions. Agricultural commodities are considered homogeneous on international markets, whereas trade in manufactures is modelled along the Armington assumption. All policy instruments are represented as price wedges. The model is recursive dynamic, covering the period 1985 - 2002. A temporary static equilibrium is calculated for every three years and updating of stocks occurs between temporary equilibria.

The standard closure of RUNS is neo-classical with fixed trade balances in each region. Alternatively an endogenous investment function has been specified which makes investment dependent on the price of future consumption. This version allows for endogenous trade balances.

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[1] In earlier application of the model services where modeled as non-tradable goods Brown, Deardorff, and Stern (1992a,b) but recently the collection of services trade data (see Brown, Deardorff, Fox and Stern, 1996) has made it possible to treat these commodities as tradables.

[2] RUNS stands for Rural Urban North South.

As far as the estimation of parameters is concerned, RUNS relies on estimates available in the literature in conjunction with calibration to the benchmark data. Agricultural demand and supply elasticities rely mainly on USDA's GOL model (Roningen and Liu, 1983) and the OECD MTM model (Huff and Moreddu, 1990). The representation of policies in the form of price wedges utilises the OECD Secretariat's estimates of PSEs and CSEs as well as FAO producer prices. Other data sources include SAMs compiled by the Development Centre, Supply Utilisation Account of the FAO (SUA), and the CHELEM data base for bilateral trade flows.

3.2.8 WTO housemodel

The WTO housemodel has been constructed to evaluate the results of the Uruguay Round of Multilateral trade liberalisation and to support the WTO Secretariat in its preparations for the next round of negotiations. Principal developers have been Joseph F. Francois, Bradley McDonald, and Håkan Nordström. The basic WTO model is a 'first generation' model, but various aspects of imperfect competition have been added to it.

The model has a global coverage with 13 regions and 19 sectors of production. Europe is represented by the EU, EFTA and Eastern Europe. Agriculture is aggregated into three primary sectors (plus forestry and fishing), and one food processing sector. The basic data as well as elasticity estimates are taken from the GTAP dataset. Additional trade protection information on MFN tariff rates are from GATT's Integrated Data Base, the values of tariff equivalents for industrial non-tariff barriers are from estimates in the literature, while anti dumping duties are from national sources and actions reported to the GATT secretariat.

The WTO housemodel exists in different versions, The basic version is the standard perfect competition, constant returns, comparative static model with Armington assumption for international trade. The amended version assumes monopolistic competition and scale economies internal to each firm, in the line of Dixit and Stiglitz.

Quotas (MFA and minimum market access) are modelled explicitly as inequality constraints. Two types of closure rules to capture steady-state 'accumulation effects': Either fixed regional saving rates or endogenous regional saving rates.

3.2.9 Conclusion

The standard, 'first generation' 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 research in the field of global climate change (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.

Table 3.2 Summary of economy-wide models

	Description	Modelling of trade	Goals	Key applications
Standard model	Applied General Equilibrium model, multi-sector, comparative static, constant returns to scale in production, perfect competition on all markets, global coverage	Armington, bilateral flows		
G-cubed McKibbin and Wilcoxen	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
GTAP GTAP consortium/ Purdue University	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
GREEN OECD	recursive dynamic	Standard, except crude oil (homogeneous)	Asses the economic impact of imposing limits on carbon emissions	Kyoto protocol assessment
INFORUM INFORUM project/University of Maryland	Linked system of dynamic national macroeconometric 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
MEGABARE and GTEM, ABARE	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
Michigan BDS Model University of Michigan	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
RUNS OECD	recursive dynamic	Agriculture: homogeneous goods & pooled markets Manufactures: standard	Analysis of Agricultural policies	GATT Uruguay round, agricultural trade liberalisation
The WTO housemodel	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

Table 3.2 Continued

	Policy representation	Number of regions (r) or countries (c)	Global coverage (y/n)	Number of sectors	Number of farm (f) or processed (p) products	Software	Public data avalilability
Standard model	Ad valorem Price wedges		Global			General purpose package	Yes
G-cubed	Standard	4 (c) + 4 (r) EU: part of 'other OECD'	Y	12	1 (f) + 1 (p)	Gauss	N
GTAP	Standard in default version Volume and value restrictions (quota etc) avaiulable	27 (c) + 12(r) + RoW EU: 5 (c) + 1(r)	Y	50	12 (f) + 8 (p)	GEMPACK and GAMS versions available	Y, at cost
GREEN	Standard quota, tradable emission permits	5 (c) + 7 (r) EU: 1 (r)	Y	9	1 (f)	C	N
INFORUM	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
MEGABARE/ GTEM	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
Michigan BDS model	Standard	34 (c) +RoW EU: 12 (c)	Y	29	2 (f)	GEMPACK	Y
RUNS	Standard	13 (c) + 9 (r) EU: 1 (r)	Y	20	11 (f) + 4 (p)	Fortran	N
WTO housemodel	Standard And import quota	5 (c) + 7 (r) + ROW EU: 1 (r)	Y	19	3 (f) + 1 (p)	GAMS/MPSGE	Y

3.3 EU Agricultural models

This section focuses on agricultural models with a European perspective in stead of the models treated in section 3.1 and 3.2 which have a global perspective. We study a partial equilibrium (SPEL) and a general equilibrium model (CAPMAT) which are both recursive dynamic.

3.3.1 SPEL

The Sectoral Production and Income Model for Agriculture (which in German yields the acronym SPEL) is developed and used by Prof. Dr. W. Henrichsmeyer at the University of Bonn, the European Center for Agricultural, Regional and Environmental Policy Research (EuroCARE) and the SPEL group at Eurostat of the European Commission (Heinrichsmeyer 1995, Wolf, 1995, Zintl and Greuel, 1995a en b). The goals of the model are monitoring and diagnosis of the current situation in the agricultural sectors of the EU-Member States and, short and medium-term forecasts and policy simulations of the effects of agricultural policy decisions. Furthermore, the model is used to check the consistency of Eurostat's agricultural statistics. SPEL is a partial equilibrium model that covers supply and demand for 114 primary agricultural commodities for the 15 EU-member countries.

SPEL is not designed as an academic model for the agricultural sector, but as a policy information system comprising both an integrated data storage system and various versions of policy related forecasting and simulation models (Heinrichsmeyer 1995). The main part of SPELL is the SPEL/EU Base System (BS), which provides detailed ex-post descriptions of the structure, intensity and use of agricultural production and of income generation in the EU member states. The Base System contains of a consistent accounting framework and input/output (supply and use) generation based on input-output coefficients and is therefore comparable with a conventional macroeconomic input-output model, but it has much more detailed breakdown.

The Short-term Forecast and Simulation System (SFSS) is used to generate forecasts (1-2 years) by combining econometric, trend-based forecasts and the systematic incorporation of expert know-how. The Base System (BS) and the SFSS are continuously applied at Eurostat and EuroCARE (2 times a year) in order to up-date the reference period (1973 up to the current year). The SPEL/EU-Data (results of the BS and the SFSS) are published by Eurostat and available for everybody on technical media.

The Medium-term Forecast and Simulation System (MFSS) performs policy simulations relative to a reference data set (up to 7 projection years, which are based on econometric trends and expert assessments). The MFSS system contains a supply model which links price expectations of farmers (based on past experience), the reaction of production intensity (input use and yield per hectare) to expected input and output prices, and the central activity model which shows the level of production activities as a function of changes in value-added per unit of the production activities. Food demand is based on econometric analysis and a forecasting system. A partial equilibrium model is used for balancing supply with forecasted demand. The foreign trade component contains net-trade functions between the EU and the rest of the world. Finally, the model is recursive dynamic and includes explicitly CAP policies, like quota, set-aside, premiums, etc. For more

detailed analysis of the effects of the EU agricultural policy on foreign trade, MFSS can be linked to WATSIM, see section 3.2.8. MFSS is in particular used for CAP/Agenda 2000 (Agenda 2000: Overview of the impact analysis of CAP reform proposals, Europe Agri No. 30, 1998).

Finally, the model is recursive dynamic and includes explicitly CAP policies, like quota, set-aside, premiums, etc.

3.3.2 CAPMAT and ECAM

CAPMAT[1] has been developed as a part of the FEA (Future of European Agriculture) project, a joint venture of three institutes: the Centre for World Food Studies (SOW) in Amsterdam in co-operation with the Central Planning Bureau (CPB) and the Agricultural Economics Research Institute (LEI). CAPMAT, which covers the EU-15, builds on the previously developed ECAM[2] model that covers only the EU-9 (Folmer et al., 1995). This model has been mainly used in order to carry out policy simulations, the main goal being the assessment of the impacts of agricultural policies, rather than the forecasting and/or the projection of variables. CAPMAT was used in 1996 for the EU Commission's preparation of 'Agenda 2000', and resulted in an unpublished FEA-Report. In 1997 the methodology and databases were subsequently updated for the analysis of the impact of the CAP reform proposals included in 'Agenda 2000'. Finally, a partial liberalisation scenario has been implemented in 1998.

CAPMAT consists of a dedicated database, an applied general equilibrium (AGE) model to simulate overall medium term effects and, a simulation and accounting tool (SAT) that applies selected growth factors from the AGE-model (or from explicit assumptions) to the information extracted from the database.

ECAM is used as the AGE component of CAPMAT (although in principle another model could be used). ECAM contains a detailed description of the agricultural sector, but is closed with respect to the domestic economy by incorporating the rest of the economy in a semi-exogenous manner. The ECAM model has the structure of a non-linear program, and consists of three main parts: a module for total demand, one for agricultural supply, and an exchange component, which balances demand and supply. ECAM mainly distinguishes itself from other models AGE models through its representation of agricultural supply, in particular its explicit treatment of pastures and other non-marketed green fodder, as well as the separate elaboration of yield and acreage relations (that is, crop yield per acre and acreage are both represented). As far as non-agriculture supply is concerned, the supply of the tradable good is treated as a given endowment which grows according to an exogenous trend; the non-tradable sector (mainly building and construction services) operates under a constant returns to scale technology with fixed mark-up rate over variable costs, and the level of production driven by demand. Consumer demand follows expenditure minimisation according to a two-level demand system: at the lower levels linear expenditure system (LES) with trends on commitments for food demand; at upper level an AIDS-system for food, beverages and tobacco and non-food.

[1] Common Agricultural Policy Simulation Tool.
[2] European Community Agricultural Model.

The model is consistent with micro-economic theory, since supply and demand responses are derived from assumed optimising behaviour of producers and consumers. Although non-agricultural sectors have a stylised representation in ECAM, the model is consistent with a general equilibrium framework, so that welfare theoretical conclusions can be drawn. On the other hand, the recursive dynamic simulation does not ensure agents behaviour to be time consistent and intertemporally efficient. As far as the functional specification is concerned, the model is 'statistically consistent', since all behavioural components have been estimated by econometric (maximum likelihood) methods. With regard to the data ECAM itself generates a SAM for every year in a simulation period, using the base year (1982) SAM and model outcomes.

The simulation and accounting tool (SAT) for the EU-15 uses growth factors from ECAM (EU-9). An AGE model like ECAM generates growth factors until 2005 for key variables. In each year considered, SAT calculates the input demand, the consumer demand and the net exports by member state (given an assumed change in stocks). Other outputs include for example supply and utilisation accounts by commodity and country, costs and revenue for every activity by country, farm revenue by country and EU budget. Because the number of commodities and regions of the AGE-components are different from those considered by SAT the factors of a 'sister'-country are applied for endogenous variables in countries not covered and for commodities a common growth factor is applied to all members of a subset. The models covers over forty agricultural commodities, the base year is 1995 and as ECAM, the model is recursive dynamic. Furthermore, CAP-policies are modelled explicitly (import levies, intervention prices, export subsidies, stock volumes, production/input quotas, producer/consumer subsidies/taxes, direct transfers).

Table 3.3 Summary EU-agricultural models

	Description	**modelling of trade**	**Goals**	**key applications**
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'

	Policy Representation	**number of regions (r) or countries (c)**	**global coverage? (y/n)**	**Number of sectors/ products**	**number of farm (f) or processed (p) products**	**Software**	**data availability**
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

4. Assessment

We started this survey with the claim that no model can serve all purposes. Following the criteria set out in section 2, Table 4.1 gives an overview of the design choices made in the surveyed models, and serves as an aid to get an overview of the current state of the field.

Table 4.1 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 quantitative policies:				
- Tariff/price equivalents	3	5	0	8
- Explicit treatment	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 are taken into consideration.

Nine out of the 18 surveyed models are partial models, according to table 4.1. Results obtained from a general equilibrium analysis will only differ significantly from partial equilibrium results if agricultural trade policies lead to noticeable price shifts in other sectors. However, in industrial countries agriculture accounts for only a small share of GNP. Therefore the strength of the 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 those linkages than run through markets for natural resources, especially land. In contrast, Central and East European Countries (CEECs) witness a relatively high share of agriculture in economic activity. There are, therefore, significant second-round effects to be expected from polices that pave the ground towards the EU enlargement process, and AGE models provide the only coherent way to analyse these. More generally, policy changes such as CAP reform and WTO agreements are associated with impacts that reach beyond the agricultural sector and involve effects on factor markets for land and labour, which can most fruitfully be studied in a general equilibrium framework.

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 in this report 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. RUNS and GTAP are exceptions in this regard. 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, see section 2.1.4. 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)

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, see section 2.2.1. 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 do 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. If net trade in a certain commodity turns out to be zero, two economies are unduly qualified as unlinked if in fact there exist intra-industry trade relations. 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 does require the recognition of economies of scale at the plant level as well as at the firm level (Markusen, 1984, Markusen and Venables, 1998). Scale and variety effects tend to yield 'large numbers' in trade liberalisation studies. It must be recognised, though, that hitherto the empirical basis for these

industrial organisation issues is rather weak. Cross country econometric evidence on key parameters that measure scale economies are not yet available.

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 there 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 there 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.

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.

5. References

Note: an extended bibliography to each model is provided in the Annex to this report

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Appendix 1 Partial models

A1.1 AGLINK

	The AGLINK Model
Institutions and individuals	OECD, Directorate for Food, Agriculture and Fisheries
Goal of the Model	To assists the OECD Secretariat in their yearly medium term outlook and to conduct quantitative analysis of the impacts of changes in agricultural policies on principal agricultural markets
Regional scope	The world. Complete modules for major OECD countries or regions, that is, 10 OECD countries/regions and three non-OECD countries/regions modelled explicitly, while the part of the world not taken into account is exogenous
Commodity/sectoral scope	Major OECD agricultural commodity markets, that is, in broad terms 19 commodities
Key applications	Yearly OECD medium term agricultural outlook and analysis of the impacts of specific alternative agricultural policy scenarios
Documentation and availability	The model is documented through a preliminary and incomplete document http://www.oecd.org//agr/Documents/aglink98.pdf However, the document is updated yearly, and some further and more complete information can be found on a OECD internet site, which is exclusively for member country use
Theoretical underpinnings	Partial equilibrium dynamic supply and demand model of the world agricultural commodity markets
Modeling of international trade	Homogeneous goods and pooled markets (net trade)
Representation of policies	Price linkages using OECD Producer Subsidy Equivalent (PSE) and Consumer Subsidy Equivalent (CSE) data and, explicit treatment of quantity restrictions
Theoretical consistency	Cross commodity linkages explicitly taken into account, but all other non-agricultural sectors are ignored
Model closures	World market equilibrium solving for world market prices
Regional aggregation	Complete modules for Argentina, Australia, Canada, China, EU-15, Hungary, Japan, Korea, Mexico, New Zealand, Poland, United States and the Rest of the World, while the Rest of OECD and the countries of the former USSR and Slovakia are considered exogenous to the model

Commodity aggregation	Main principal agricultural commodities: Wheat, rice, oilseeds, oilseed meal, oilseed oil, fresh dairy products, butter, cheese, skim milk powder, whole milk powder, caseine, whey powder, other dairy products, beef and veal, pigmeat, poultrymeat, sheepmeat, eggs, and wool
Base year/time series	1997. Mainly calendar year basis for all data. Data updated annually
No. of agricultural commodities	Same as commodity aggregation, see above
Variables generated and parameters needed	Variables: The quantities for the individual countries/regions of supply, demand and net-trade, as well as world market prices for the individual agricultural commodities Parameters: partial supply and demand elasticities
Sensitivity	Not reported
Parameter estimates	'Institutional calibration': From the Secretariat in co-operation with member states and consultants
Policy data	From OECD PSE and CSE data
Data sources	Information not available
Software	SIMPC
Data set publicly available	Information not available
Functional relationships	A dynamic model, which is mainly linear in the logarithms of the variables with lags in both exogenous and endogenous variables

A1.2 ESIM

	The European Simulation Model (ESIM)
Institutions and individuals	Institute of Agricultural Economics /University of Goettingen: Chair of Prof. Dr. S. Tangermann, Wolfgang Muench (wmuench@gwdg.de). The model was initially developed in a co-operation between the USDA/ERS and teams of Prof. T. Josling /Stanford and of Prof. S. Tangermann/Goettingen (1993-94). Goettingen focused on the modeling of the EU and the CEEC and pursued its research further on in this area. Linked to a set of single country CGE models (Martin Banse, mbanse@gwdg.de)
Goal of the model	Medium term projections and simulation of the effects of changing agricultural policies in Europe until 2005 incl. evaluation of accession of CEECs to the EU.
Regional scope	World, with special emphasis on European countries
Commodity / sectoral scope	Partial, agriculture, with rigorous macroeconomic links - 27 commodities representing the major part of agricultural production value
Key applications	Analysis of effects of CAP policies on agricultural markets and budgetary expenditure, particularly, WTO trade liberalisation, EU enlargement, CAP/Agenda 2000, development of competitiveness
Documentation and availability	Both the model and data set are the property of the University of Goettingen, model will be publicly available soon. Documentation: Münch,W. (1999). Market and Budgetary Implications of CEC Accession to the EU. A partial equilibrium approach. Phd. Dissertation. Göttingen. (forthcomming)
Theoretical underpinnings	Partial equilibrium model, with a special emphasis to Europe.
Dynamics	No (comparative static)
Modelling of international trade	Homogeneous goods and pooled markets (net trade)
Representation of policies	Export refunds: product of net trade and the difference between domestic market price and world price Compensation payments: the product of given payment rate per hectare and crop area Total budget expenditures: the sum of export refunds, compensation payments and other subsidies. Set-aside: there are special variables for defining area for set-aside. Quota restrictions incorporated
Theoretical consistency	The functional form is the isoelastic type for demand and supply It guarantees the theoretical conditions of homogeneity and symmetry as well as the strictly quasi convexity/concavity in the positive orthant.

Model closures	zero net exports on world markets
Regional aggregation	9 regions/countries: (EU-15, Bulgaria, Czech Republic, Estonia, Hungary, Poland, Slovakia and Slovenia, ROW)
Commodity aggregation	27 products: wheat (common, durum), coarse grains (barley, corn, other grains), rice, sugar, oilseeds (soybean, rape seed, sunflower seed), oilmeals (soymeal, rapemeal, sunflower meal), feed (corn gluten feed, other energy feed, other protein feed), dairy products (liquid milk, skimmed milk powder, butter, cheese), meat (beef, pork, poultry), eggs, oils (soybean oil, rape seed oil, sunflower oil)
Base year / time series	1994-1996, 13 periods
# of agric. Commodities	27 = 17agricultural + 10 food processing + 0 forestry and fishery products
Variables generated and parameters needed	Exogenous variables and parameters: technical progress, population growth, income growth, inflation, exchange rates, administered pricing regimes, quantitative controls on production, trade barriers Endogenous variables: domestic and world prices, production, consumption, international trade Necessary parameters: price elasticities of supply and demand, income elasticities, yield elasticities, feed cost elasticities, minimal import prices, intervention export prices, basic domestic and world market prices etc.
Sensitivity	Reported in Münch,W. (1999). Market and Budgetary Implications of CEC Accession to the EU. A partial equilibrium approach. Phd. Dissertation. Göttingen. (forthcoming)
Parameter estimates	Calibrated;
Policy data	CAP reform proposals, proposals of national policies.
Data sources	National statistical sources of the individual countries and generally available sources (OECD, EU)
Software	original version: Supercalc 5.5 in work: Excel version, Czech module: in GAMS
Dataset publicly available?	No

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A1.3 FAO world model

	World Food Model
General	
Institutions and individuals	Commodities and Trade Division, Food Agriculture Organization, Rome, Italy.
Goals of the model	- Medium- and/or long- term projection model of the most important agricultural and food products. - Simulating impacts of policy changes on prices, production, consumption and trade of the most important agricultural products.
Regional scope	Worldwide.
Commodity/sectoral scope	The World Food Model covers thirteen agricultural commodities including grain, livestock, and oilseed oils and fats.
Key applications	- To contribute to the outlook of FAO on agricultural commodity markets by providing medium and long term projections (base line) on prices, supply, demand and trade of most important agricultural and food products. - Impacts on, developed and developing countries' agriculture of the Uruguay Round.
Documentation and availability	- Documents publicly available and listed on the following web site: htpp/:www.fao.org/es/esc - Several in-depth papers can be obtained from Mr. De Nigris, senior econometrician, Commodities and Trade Division, FAO, Rome. - This model is not publicly available.
Theory	
General underpinnings	- Multi-product (sectoral), partial equilibrium, dynamic, world model - supply equations are typical partial adjustment (nerlovian) relationships with some modifications (see text). - demand equations are all static and specified acording to the final use of the product considered. Generally speaking, food demand equations depend direct and other relevant prices and GDP. Feed demand equations are typical compensated input demand relationships with arguments being the relevant prices of cereals and meals and livestock herds converted in cereals or protein meal equivalennts. Stock demand equations are specificed for crops and some livestock products (beef) in some regions (EU15).
Dynamics	- Adoption of the partial adjustment model specification for the supply equations. - Use of lagged prices to capture the dynamic decision process of crop and livestock production.

	- Use of time trend and constant growth rate specifications to capture the evolution of exogenous variables such as technical change, population and gross domestic product. - Price transmission equations between world and domestic prices are expressed in first order differences or in terms of relative rates of changes.
Modelling of international trade	Homogeneous goods and pooled markets (net trade)
Representation of policies	- tariff-equivalents and/or price wedges. - A typical price transmission equation linking domestic and world price is used for the majority of developing countries. All policy measures generating gaps between both prices are captured by a single parameter defined as the elasticity of transmission of domestic prices with respect to world prices. - For other countries (mostly developed or those for which PSE and CSE data are available), a linear price transmission equation between world and domestic price is used. The intercept term in this equation captures all the tariff equivalents of agricultural policy instruments which have an incentive on production but are not linked to world price levels while the slope reflects the 'ad-valorem' tariff equivalent of all policy policy instruments (which are directly linked to world price levels).
Model closures	This feature (specific to CGE models) corresponds to a partial equilibriulm model to the identity equating net imports and exports, leading to the dertemination of world equilibrium prices.
Functional forms	- All behavioural relationships (supply and demand) use constant elasticity functional forms which are linearized using the logarithmic transformation
Theoretical consistency	The World Food Model does not satisfy all the laws of demand or supply (homogeneiy, additivity, symetry and negativity). However, to avoid the ermergence of perverse effects during the simulation excercises, the linearized version of the model satisfies the existence condition of a unique price equilibrium solution. Basically, underlying to this existence condition is the necessity to have direct price elasticities (responses) bigger in absolute values thant their cross price counterparts.
Data	
Regional aggregation	Worldwide in scope, the World Food Model make projections for 147 invidual countries (115 developing and 32 developed countries). The European Community relates to the 12 member States including the new German Länder,

	the Republics of the Former USSR are treated a sone geographical entity.
Commodity aggregation	Thirteen agricultural commodities: - The grain group (5 individual commodities or groups of commodities) includes wheat, rice, maize, millet and sorghum, and other coarse grains. - Meat and meat product products group (4 individual meats and meat groups) is made up of bovine meat, sheepmeat and goatmeat, pigmeat and poultry meat. - Two dairy products are considered. On of these two dairy products is 'butter' which is viewed as a sub-commodity of fats and oils complex as well part of the dairy products group. - The fats and oils group is made up of two aggregate commmodities denoted 'fats oils' and 'oilmeals', respectively. The former commodity aggregate grouping includes 13 individual oils and fats converted in oil equivalents. The latter commodity aggregate includes 9 individual oilmeals.
Data set construction, endogenous variables	- Data pertaining to the quantity variables (supply, demand, stocks and trade) are directly obtained from the detailed commodity balance sheets of the FAO data AGROSTAT and/or provided by the FAO's Commodity and Trade Division. This data base provides 'supply utilization accounts' for 600 primary and processed crops, livestock and fish products. A 'standardization' procedure allows converting derived and processed products (such as wheat flour) into primary commodity equivalent through the use of appropriate conversion factors. - Data on domestic and world prices are also obtained from FAO databases.
Data set construction, exogenous variables	The only exogenous variables entering the World Food Model are population and gross domestic products.
Base year/time series	- The present version of the World Food Model uses the 1993-1995 period as the base period. - Concerning the agricultural policy instruments, PSE and CSE generated by the OECD and the USDA were used to generate the various tariff-equivalents. The base period chosen to measure these tariff-equivalents were the period 1986-1988.
Parameters needed	- Parameters include supply and demand price elasticities, income elasticities, price transmission, and partial adjustment coefficients and exogenous specified growth rates. - FAO publications stress that 'elasticities and parameters used in the equations are mainly from estimates made by FAO, supplemented by the elasticity databases of the

	USDA's SWOPSIM and the OECD's MTM models.
Model's sensivitiy	- Sensitivity analysis as it is conducted for CGE models by changing the values of key parameters is not conducted systematically in the World Food Model. - On the other hand, sensitivity analysis has been conducted for the Uruguay Round impacts by considering different policy scenarios based on different assumptions on the evolution of world economy and world agriculture
Dataset availability	- The dataset supporting the World Food Model is not publicly available.
Generating a baseline	- Since the World food Model is to provide projections on the supply, demand , trade and prices of th emajor agricultural commodities, it is necessary to make several assumptions on the exogenous variables. - Assumptions made on the rate of growth of each country's GDP are essentially based on long-term predictions made by the International Economics department of the World Bank. - Assumptions on the growth of each country's population are based on demographic projections prepared by the United Nations Population Division.
Algorithm and computer programmes	
Algorithm	- The World Food Model is mamouth model containing about 15 000 equations. Given this size, it has been divided into 18 blocks. - The World Food Model can be viewed as a hierarchical structure made up of many sub-models that can be resolved separately. Hence, it is possible to consider three submodel structures: i) Single-commodity, single-country model structures (consisting of four or five equations that are resolved sequentially. In this structure, the international prices and competing commodites' prices are set at exogenous levels) ii) Single-commodity global model model structure determines a unique world equilibrum price through the market clearing equation (sum of all net imports = sum of all net exports). Note that all other commodites prices are set at exogenous levels. iii) Multiple-commodity global model: all international commodity prices are endogenous and a set of mixed linear and nonlinear (however almost linear due to the use of the logarithmic functional forms for most of behavioural relationships) equations are resolved simulatenously. In this last structure, there are concerns about the existence of a

	single equilibrium solution and the overall dynamic stability of the model. This is the reason why the existence condition mentionned earlier must be satisfied. - Given the existence of dynamic specification of all supply equations with lagged prices, a large compoenent of the multiple-commodity global model can be viewed as a recursive structure whereby the supply (depending on lagged prices) is already determined during the current period. Then, equating exogenous supply with all the demand schedules allow to generate reduced form simultaneoous equations for all international prices which also are a function of all exogenous variables.
Computer programmes	- Home made softwares written in FORTRAN. - The Gauss-Seidel recursive method is used to resolve the World Fod Model through successive iterations.

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A1.4 FAPRI

Model	FAPRI Food and Agricultural Policy Research Institute
Institutions and individuals	Food and Agricultural Policy Research Institute at Iowa State University, USA Devados S., P. Westhoff, M. Helmar, E. Grundmeier, K. Skold, W. Meyers, S. R. Johnson
Goal of the model	Compound modeling system for: - Policy analysis; - Short, medium and long term projections (1-10 years), annual baseline
Regional scope	World, with special emphasive on USA
Commodity/sectoral Scope	partial agriculture: 24 agricultural products
Key applications	Quantitative evaluations of national and international agricultural policies that affect US and world agriculture Farm legislation reform (e.g Farm bill 1985, 1990) through Uruguay Round negotiations
Documentation and Availability	Some difficulties rise in relation to the base data availability of the models; FAPRI models cannot be used beyond a partnerships frame.
Theoretical underpinnings	Set of neoclassical, econometric partial and recursive dynamic models. Each component of FAPRI presents specific theory structure and can be solved individually. Components are: - Livestock models - Domestic crop models - World trade models - US government cost models - Net farm income model
Dynamics	Dynamics included both on the supply and demand sides
Modeling of International Trade	Homogeneous products and pooled markets (net trade)
Representation of Policies	Price wedges
Theoretical consistency	Imposition of theoretic restrictions (mainly homogeneity and symmetry) differs among models, but also depending on the short or long term specification
Model closures	No closures like those used for CGE models. Domestic Crop models and Trade models include Market Clearing Identity
Regional aggregation	29 countries and/or regions: USA and other countries. The number of countries and regions is variable depending on the models
Commodity aggregation	Major agricultural and processed commodities. The number is variable depending on the models type: Domestic livestock Models: beef, pork, chicken, turkey

	Domestic Crop Models: corn, wheat, soybeans, soymeal, soybean oil, sorghum, barley, oats, cotton, rice, sugar, corn gluten Trade models wheat: corn, sorghum, barley, oats, soybeans Government Cost Model: corn, wheat, soybeans, cotton, rice, sorghum, barley, oats, dairy Net Farm Income Model: domestic crops, livestock
Base year/ time series	Use of annual time series for estimation. The initial base year was 1988
Number of agricultural Commodities	Variable depending on the model versions and objectives
Variables generated And parameters needed	Supply and demand are endogenous except for countries where domestic production is not important. For that case, supply is exogenous.
Sensitivity	No information
Parameter estimates	Computation of elasticities at various year values (e.g for livestock models: 1984-86 mean values; for domestic crop models: 1988 values)
Policy data	Annual time series data, trade protection, output price support and farm produced input price policies
Data sources	Most data have been derived from publications in the USDA Agricultural Statistics Board Series, from circulars such as: World Grain Outlook and Situation Report, Oil Seed and Products Outlook, from the Food and Agricultural Organization reports
Software	SAS-AREMOS econometric package with LOTUS 123
Data set availability	Available for partnerships frame

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A1.5 GAPsi

Name of the model	GAPsi (**G**emeinsame **A**grar**P**olitik - **Si**mulation)
Institutions & individuals concerned with model development and application	Institute of Market Analysis and Agricultural Trade Policy (MA) of the Federal Agricultural Research Centre (FAL), Braunschweig, Germany Dirk Manegold together with Petra Salamon and Karl Frenz
Goal of the model	EU agricultural policy analysis
Regional scope	World: EU-15, applicant countries, main agricultural exporters, rest of world
Commodity / sectoral scope	Partial agriculture: 13 agricultural commodities
Key applications	CAP reform, Agenda 2000; planned: EU enlargement, WTO
Documentation & availability	Partly, see references below
Theoretical underpinnings	Partial multi-sector, multiregion equilibrium model
Dynamics	Recursive dynamics over a period of 10-15 years
Modelling of international trade	Homogeneous goods and pooled markets (net exports)
Representation of politics	Price wedges together with fixed prices and quota; EU set-aside programme discriminating between obligatory and voluntary set-aside (rate of obligatory set-aside applied to participating producers, voluntary set-aside according to RAUMIS results)
Theoretical consistency	Theoretical consistency is generally warranted, however, since cross-price elasticities are mostly zero, area use, meat demand, feed input and milk processing (dairy module) are of main concern
Model closures	Balancing world net trade
Regional aggregation	14 countries and 3 regions: Austria, Belgium/Luxembourg, Denmark, France, Finland, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom, plus 3 non-EU regions: EU applicant countries (combining Poland, Tschech Republic, Slovakia, Hungary), main agricultural exporters (combining Canada, USA, Mexico, Argentina, Brazil, Australia, New Zealand), rest of the world (combining all the remaining regions)
Commodity aggregation	Cereals, pulses, oilseeds, potatoes, sugar, dairy, beef, lamb, pork, poultry, eggs; compound feed (cereals, protein meals, milk, other non-grains)
Base year / time series	Base year: 1995 / time series: 1993-2005
Number of ag. commodities	13 agricultural commodities,
Variables generated & parameters needed	Variables generated: word equilibrium prices (derived: domestic market prices, producer prices, consumer prices)

	balancing changes in production and demand Exogenous variables: productivity shifters, estimates of population and economic growth, inflation and exchange rates
Sensitivity	Sensitivity is not regularly reported
Parameter estimates	Various sources: literature, SWOPSIM, model calibration
Policy data	Intervention prices, production quotas, direct payments (coupled to production), set-aside requirements, WTO export restrictions
Data sources	International agric. statistics (PS&D), UN population forecasts, agric. baseline projections (USDA, FAPRI, OECD), EU & national statistics (land use, prices, economic growth, inflation, exchange rates)
Software	GAMS (data management, model formulation), Excel (output)
Dataset publically available?	No.

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A1.6 MISS

Model	MISS (Modèle International Simplifié de Simulation)
Institutions and individuals	Institut National de la Recherche Agronomique (INRA), Station d'Economie et de Sociologie Rurale de Rennes, France Mahé L., Guyomrd H., Moreddu C., Tavera C. and C. Trochet
Goal of the model	Agricultural policy analysis by simulation, projections short and medium term (3-5 years)
Regional scope	Worldwide (4 regions/countries)
Commodity/sectoral Scope	Partial agriculture: output side: 10 agricultural commodities; input side: 6 agricultural inputs and 4 non-agricultural inputs
Key applications	Unilateral and bilateral trade liberalization between EU and USA Budget costs of CAP reform
Documentation and Availability	Model and documentation publically available Complete system of data and elasticities available upon request (Guyomard et al., 1991, p.124).
Theoretical underpinnings	Partial equilibrium model. Technical change introduced both on supply and demand sides (by ad hoc shifters) for more information about interactions of cross policy effects
Dynamics	No dynamics but trends of variables calculated for projection simulations over a 3-year time horizon
Modeling of International Trade	Homogeneous goods and pooled markets (net-trade)
Representation of Policies	Price wedges and explicit representation of policy instruments.
Theoretical consistency	Elasticities derived from review of studies and adjusted for more theoretical consistency including: - Theoretical properties of restricted profit function (homogeneity, symmetry and convexity in prices of the output supply and derived demand system) - other technical knowledge related to the complementarity and substitutability among commodities
Model closures	No closures like those used for CGE models but MISS starts with an initial equilibrium and presents a new (final) equilibrium.
Regional aggregation	4 areas: EU, USA, Rest of the World Market Economies, Centrally Planed Economies
Commodity aggregation	Agricultural sector disaggregated into outputs including grains (wheat and coarse grains), vegetable proteins, vegetable oils (escept for olive oil included in the rest of agriculture), cereal substitutes (corn gluten feed, manioc, citruspulp), beefmeat, pork, poultry and eggs, milk, sugar, rest of agriculture. 10 inputs are also included among them 6 are of agricultural origin for animal feed (grains, vegetable proteins, corn, manioc, other grain substitutes, milk) and 4 not produced by farming sector (other feed ingredients, fertilizers,

	other intermediate consumption, capital services)
Base year/ time series	Two main 'representative' years: 1986 and 1990
Number of agricultural Commodities	Variable depending on the model versions and objectives
Variables generated and parameters needed	Aggregate balance for each region and each product for specific users: human consumption, animal feed, other demand and net exports Prices, levels of taxation and protection rates. Elasticities of supply, derived demand and final demand all adjusted for theoretical consistency Domestic prices, taxes, protection rates and quotas can be either endogenous or exogenous.
Sensitivity	Some sensitivity analyses especially on the supply side
Parameter estimates	Calibrated elasticities
Policy data	The initial values of the protection rates are first estimated prior to calculate the range by which they must vary to move towards free trade. The protection coefficients are calculated from ratio of domestic to border price in the case of import quotas and from budget expenditures documents in the other cases with some corrections when necessary for special regimes
Data sources	Mostly Eurostat and EEC reports
Software	'Home made' software using a spreadsheet
Data set availability	Available on request. Some data and parameters are available in major papers related to MISS

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A1.7 SWOPSIM

	SWOPSIM (Static World Policy Simulation Model)
General	
Institutions and individuals	USDA ERS (Roningen, 1986)
Goal of the model	Simulation of effects of changes in agricultural support policies on production, consumption and trade
Regional scope	World: 36 regions
Commodity / sectoral scope	Partial agriculture: 22 US-traded agricultural commodities
Key applications	Multilateral trade liberalisation (GATT Uruguay round), Agricultural policy reforms in US and EU , effects on agriculture from EU enlargement
Documentation and availability	The model is publicly available and fully documented in Roningen, Sullivan & Dixit (1991); database in Sullivan, Wainio & Roningen (1989);
Theory	
Theoretical underpinnings	Partial equilibrium; constant-elasticity cross-price supply and demand equations (with Q effects also possible)
Dynamics	None (in basic model)
Modelling of international trade	Homogeneous goods and pooled markets (net trade in basic model); Armington in later version Dixit & Roningen (1986)
Representation of policies	Price wedges (PSEs, CSEs)
Theoretical consistency	Elasticities possibly inconsistent (see, Liapis 1990)
Model closures	Multi-market equilibrium
Data	
Regional aggregation	36 regions; including EC-10, Spain, Portugal, Other Western Europe, Eastern Europe, regions can be aggregated; 'small world' models possible
Commodity aggregation	22 commodities; 4 meats, eggs, 4 dairy, 4 grains, 6 beans/seeds/meals/oils, cotton, sugar, tobacco, can be aggregated
Base year / time series	1984 and 1986; most studies use 1986
No. of agricultural commodities	22
Variables generated, parameters needed	Variables generated: production, consumption, (net) trade; prices; producer/consumer/taxpayer welfare effects Parameters needed: supply & demand elasticities; feed share coefficients; policy price-wedge parameters
Sensitivity	Yes in some applications??
Parameter estimates	Taken from individual commodity/sector studies

Policy data	Price linkages (PSEs, CSEs)
Data sources	USDA FAS world supply and utilisation set
Software	Spreadsheet (Supercalc 3 or 5)
Dataset publicly available?	Yes (Sullivan, Wainio and Roningen (1989))

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A1.8 WATSIM

	WATSIM (World Agricultural Trade Simulation Model)
Institutions and individuals	Institute for Agricultural Policy, Market Research and Economic Sociology, Bonn University: Prof. Dr. W. Henrichsmeyer, M. v. Lampe and C. Moellmann
Goal of the model	Three target periods with different aims: Short-term shock analysis (in work, not yet available), Medium-term projections and policy analysis, Long-term projections and analysis of various shift factors
Regional scope	World, currently 15 regions incl. EU as one agregate (flexible, see database)
Commodity / sectoral scope	Partial agriculture, currently 29 agricultural commodities
Key applications	1) Baseline for years 2005, 2010, 2015 and 2020 2) Analysis of different shift factors including income in Asia, productivity in Transition Countries, irrigation in Asia, Africa and Latin America 3) Analysis of Agenda2000 and WTO trade liberalisation envisaged 4) Impact of a worldwide liberalisation of cereals, oilseeds and pulses markets
Documentation and availability	Database and model is property of the Federal Ministry for Food, Agriculture and Forestry, Bonn, and the Commission of the European Union Provisional documentation in Henrichsmeyer, W., von Lampe, M. and Möllmann, C. (1998). Weiterentwicklung und Andwendung 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 (german only) Detailed documentation in preparation
Theoretical underpinnings	Partial equilibrium model, global-multi-region multi-commodity
Dynamics	None
Modelling of international trade	Homogeneous goods with pooled world markets (net trade); reference (trade) prices depending on world market prices as well as on a region's net-trade quantity, In work: Differentiation of imports and exports
Representation of policies	Ad-valorem and specific tariffs, Floor-price fixation (non-differentiable price transmission), Other subsidies (direct payments, other payments etc.) from PSE/CSE estimations, Compensation payments per ha or head, Set-aside obligations, Production quotas, Export restrictions
Theoretical consis-	Curvature only approximated by sign of (compensated) own-price

tency	elasticities Joint calibration of elasticities for supply of agricultural products and feed use ensuring feed balance Separate calibration of elasticities for industrial processing of oil-seeds (to oils/cakes) and milk (to butter&cream, cheese and SMP) Seperate calibration of elasticities for consumption
Model closures	No closures like in CGE models.
Regional aggregation	15 regions: EU-15, Rest of Western Europe, Central and Eastern Europe, Commonwealth of Independent States, Sub-Saharan Africa (incl. South Africa), North Africa & West Asia, China (incl. Taiwan), India, ASEAN-Rim, Rest of Asia, Australia & New Zealand, USA, Canada, Latin America
Commodity aggregation	29 Products: 5 Cereals (Wheat, Barley, Maize, Rice, Other cereals), 4 Oilseeds (Soy, Sunflower, Rape, Other Oilseeds), 4 Veg. oils (corresponding), 4 Veg. Cakes (corresponding), 3 Other crops (Sugar, Starch products, Pulses), 4 Meat (Beef & Veal, Pigmeat, Poultry, Other meat), 2 Other livestock products (Eggs, Milk) 3 Milk products (Cheese, Butter & Cream, Skim milk products)
Base year/ time series	1994
Number of agricultural Commodities	18 primary products (12 crops, 6 livestock, s.o.), 11 processed commodities (s.o.)
Variables generated And parameters needed	Exogeneous data: Population, Urbanisation, real GDP, Wastes, Total land availability, irrigation, yields (given constant irrigation), Policy parameters Endogeneous data: Supply, demand (human consumption, feed, processing, seed use, other use), intervention stock change and net trade quantities; world, reference, market and incentive prices Necessary parameters: Supply, demand and feed price elasticities and income elasticities (literature), Feed requirement parameters (estimated from time series).
Sensitivity	Yes, Subject of the project for the Federal Ministry of Agriculture. Final Report: 31 May 1999 (german language) and subject of: von Lampe, M. (forthcoming): A modelling concept for the projection and simulation of long-term developments on the agricultural world markets - World Agricultural Trade Simulation Model WATSIM (dissertation).
Parameter estimates	Calibrated supply, demand, feed and income elasticities Estimated feed requirement parameters, based on time series (livestock production, feed energy use) and parameters from literature
Policy data	PSE and CSE OECD
Data sources	Which data sources are used and which processing is applied ? FAOSTAT (FAO), PS&D (USDA), World Data 1995 / World Development Indicators 1998 (World Bank), World Population Prospects 1996 (UN), PSE and CSE 1997 (OECD)
Software	Own software based on Fortran77, C, developed at the Institute

	PE Model written in GAMS Solved by Minos5 and Conopt2
Data set availability	No.

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Appendix 2 Economy-wide world models

A2.1 G-cubed

	G-cubed: Global computable general equilibrium growth model
General	
Institutions and individuals	Initiated by Dr. McKibbin W., J. and J. Wilcoxen, the model was constructed with funding from the Brookings Institution, the US National Science Foundation and US Environmental Protection Agency.
Goals of the model	Policy oriented model aimed at 'contributing to the on-going policy debate on environmental policy and international trade (with a focus on global warming policies)'.
Regional scope	World.
Commodity/sectoral scope	Economy-wide coverage, 12 sectors with focus on distinction between energy and non-energy sectors.
Key applications	Economy-wide impacts of warming policies (Kyoto protocol), Other applications: regional integration i Asia/ Pacific, impacts of global macroeconomic shocks (financial crisis in Asia), global predictions and outlook of the world economy.
Documentation and availability	Papers and/or reports which are publicly available and listed on the following special web site: http://www.msgpl.com.au/msgpl/msghome.htm
Theory	
General underpinnings	Intertemporal general equilibrium and macroeconomic model. The model combines a conventional CGE model representing the real sectors (models) and a model representation of financial and capital assets and flows. Short run behavior is a weighted average of neoclassical optimizing behavour and ad-hoc 'liquidity constrained' behaviour.
Dynamics	Intertemporal accounting of stocks and flows of real ressources and financial assets. Imposition of intertemporal budget constraints, rational expectations about key decision variables and other exogenous variables.
Modelling of international trade	Armington specification of bilateral trade flows for eight tradable commodities.
Representing policies	Quite full: taxes, interest rates, money supply, invest-

	ment tax credit, governement debt and government transfers, emission permits
Model closures	Full short run and long run macroeconomic closure with macro-dynamics at an annual frequency around a long run Solow/Swan neoclassical growth model.
Functional forms	A CES functional form is being used at most various tiers of the firms' production technology and consumers preferences. The Leontief functional forms are being used to represent the combination of emission permits and output in each sector. The present version of 'Gcu-bed' assumes that a Cobb-Douglas functional form represents the trade modeling structure and consumer preferences.
Theoretical consistency	As for any CGE models, 'Gcubed' is theoretically con-sistent.
Data	
Regional aggregation	8 regions including the United States, Japan, Australia, Other OECD (composite region), China, Less develop-ing countries (composite region), oil exporting developing countries (composite region), Eastern Europe and the Former Soviet Union (composite region).
Commodity aggregation	12 sectors. Energy sectors: electric utilities, gas utilities, petroleum refining, coal mining, and crude oil and gas extraction; non energy sectors: mining, agriculture, fishing and hunting, forestry and wood products, durable manufacturing, non-durable manufacturing, transporta-tion, and services.
Data set construction (variables generated)	- The principal source of information for these raw data was the benchmark input/output tables produced by the Bureau of Economic analysis at the U.S. De-partment of Commerce. The (commodity by industry) industry accounting matrix, the use matrix, the value added and the returns to primary factors and the components of final demand (private and government consumption, investment, exports and imports was developed for the United States. - Input/output tables are available for Japan, Australia, China and the Former Soviet Union and have been used to generate a consistent set of industry ac-counting matrices. For the remaining regions, the necessary data set has been developed using adjusted US-based information (shares) to account for actual final demand data from the national accounts of the corresponding region. - An eight by eight matrix of trade flows giving the

	import and export flows has been constructed for each of the twelve goods. The trade flow matrices seem to have been constructed using the 1987 United Nations trade database. - Consumer durables are not considered as consumer goods but as consumer investment. - Data on capital and labour are constructed using information obtained on the U.S. Economy. - Time series using ouput and employment data from a data set constructed by the Office of Employment Projections at the U.S. Bureau of Labor Statistics. - Macroeconomic data: no documettaiuon provided, but likely to be obtained from the database of the macroeconomic model 'MSG2'.
Policy instruments	Due to it's macroeconomic orientation, policy relevant variables are macroeconomic policy instruments such as tax rates, monetary policy. In addition corporate and labour income tax rates, investment tax credit, government debt, interest rates, exchange rates and government transfers; taxes on externalities (such as carbon dioxide emissions) and /or emissions permits by sector.
Base year/time series	The base period is 1987. - Time series were constructed for the US economy to estimate econometrically the consumption and production parameters (elasticity of substitution and distribution parameters of the US economy. For instance, consistent input/output tables were constructed for 1958, 1963, 1967, 1972, 1977 and 1982. These various input/output tables for the US economy are used to estimate the substitution and distribution parameters of the CES functional forms used to represent each sector technology.

Parameters needed	- Parameters related to final demand, each sector's production and the production function of new investment goods are 'econometrically' estimated for the U.S. economy. Then, the relevant parameters (e.g. elasticities of subsitution) are assumed to be equal across regions. Then once, the elasticities of substitution have been estimated, all other parameters in other regions are calibrated using the base period. - Concerning the U.S. economy, special care has been taken to estimate the production parameters of each sector: subsitution elasticities, share parameters and other parameters. All the substitution elasticities associated with the domestic production of each sector are econometrically estimated using U.S. data. It is assumed that all susbtitution elasticities are equal across regions and use of all the U.S. estimates everywhere. Substitution elasticities are estimated for each U.S. sector using 6 data points (1958, 1963, 1967, 1977 and 1982) and using an equation system's maximum likelihood estimation procedure. Share (distribution) and other parameters: are estimated 'residually' and econometrically once the substitution elasticities have been derived. - Trade (Armington) elasticities are imposed and assumed to be equal to one. - Other parameters are imposed and/or calibrated for the base period. - Parameters associated with macroeconomic relationships are needed, e.g. the interest elasticity of demand for money is set at –0.6.
Model's sensitivity	Systematic model sensitivity is not documented
Dataset availability	Not publicly available.

Generating a baseline	Due to its intemporal orientation, a 'business as usual' baseline scenario has to be generated, which serves a the benchmark for policy simulations. This baseline requires that assumptions on the long run evolution of exogenous variables be made (This concerns population, non-energy and energy productivity, energy efficieny and monetary policy). Tax rates and the shares of government spending devoted to each commodity remain unchanged. The baseline trajectory is constructed by solving the model for each period after 1990, given any shocks to variables, shocks to information sets or change sin inital conditions.
Computer software	Tailor made software developed by McKibbin for solving large models with rational expectations on a personal computer. The software is written in GAUSS programming language.

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A2.2 GTAP

	GTAP: Global Trade Analysis Project
Institutions and individuals	Purdue University USA (T. Hertel), GTAP consortium
Goal of the model	Global analysis of impacts of trade policy changes. Specifically agricultural trade.
Regional scope	World. (45 regions, including 4 EU member states, rest of EU, etc.)
Commodity / sectoral scope	Economy-wide. 50 sectors/commodities (Version 4), 12 primary agric., 8 food, 5 primary factors (land, 2 labour, capital, natural resources). Bias towards agriculture and food processing
Key applications	GATT/WTO Rounds, regional integration, technological changes, environmental policies; EU enlargement,
Documentation and availability	Book (Global Trade Analysis, ed. Hertel, 1997, Cambridge UP), website (www.agecon.purdue.edu/gtap/). Model is publicaly available.
2. Theory	
Theoretical underpinnings	Standard multi-region AGE model. Constant returns, perfect competition.
Dynamics	None in standard static model; recursive and fully dynamic model versions available
Modelling of international trade	Quite full, using Armington specification, CES demand
Representation of policies	Tax/subsidy instruments (price wedges) and income transfers. Qunatitative measures represented as tariff equivalents in standard version. Extensions using explict quota etc. available
Theoretical consistency	Theoretically consistent within standard general equilibrium framework
Model closures	Macro: Savings-driven investment levels (standard version). Other closures available, including partial equlibrium closures
3. Data	
Regional aggregation	Australia, New Zealand, Japan, Korea, Indonesia, Malaysia, Philippines, Singapore, Thailand, Viet Nam, China, Hong Kong, Taiwan, India, Sri Lanka, Rest of South Asia, Canada, United States of America, Mexico, Central America and Caribbean, Venezuela, Colombia, Rest of the Andean Pact, Argentina, Brazil, Chile, Uruguay, Rest of South America, United Kingdom, Germany, Denmark, Sweden, Finland, Rest of European Union, EFTA, Central European Associates, Former Soviet Union, Turkey, Rest of Middle East, Morocco, Rest of North Africa, South African Customs Union, Rest of southern Africa, Rest of sub-Saharan Africa, Rest of World
Commodity aggrega-	1 Paddy rice, 2 Wheat, 3 Cereal grains nec, 4 Vegetables, fruit,

tion	nuts, 5 Oil seeds, 6 Sugar cane, sugar beet, 7 Plant-based fibers, 8 Crops nec, 9 Bovine cattle, sheep and goats, horses, 10 Animal products nec, 11 Raw milk, 12 Wool, silk-worm, cocoons, 13 Forestry, 14 Fishing, 15 Coal, 16 Oil, 17 Gas, 18 Minerals nec, 19 Bovine cattle, sheep and goat, horse meat products, 20 Meat products nec, 21 Vegetable oils and fats, 22 Dairy products, 23 Processed rice, 24 Sugar, 25 Food products nec, 26 Beverages and tobacco products, 27 Textiles, 28 Wearing apparel, 29 Leather products, 30 Wood products,31 Paper products, publishing, 32 Petroleum, coal products,33 Chemical, rubber, plastic products, 34 Mineral products nec 35 Ferrous metals, 36 Metals nec, 37 Metal products, 38 Motor vehicles and parts, 39 Transport equipment nec, 40 Electronic equipment, 41 Machinery and equipment nec, 42 Manufactures nec, 43 Electricity, 44 Gas manufacture, distribution, 45 Water, 46 Construction, 47 Trade, transport,48 Financial, business, recreational services, 49 Public administration and defence, education, health services,50 Dwellings
Base year / time series	1995
# of agricultural commodities	12 primary, 8 food processing, 1 forestry, 1 fishing
Variables generated, parameters needed	Variables generated: market and income/welfare values Parameters needed: CES import demand substitution elasticities; compensated own-price and income elasticities of private household demand using CDE function; tax/subsidy rates
Sensitivity	Depends on modeller
Parameter estimates	Standard set available. Various sources.
Policy data	Standard set available
Data sources	Various, including national I-O tables, WTO, COMTRADE, USDA
Software	GEMPACK
Dataset publicly available?	Yes, at cost

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For an up-to-date list of applications see: http://www.agecon.purdue.edu/gtap/apps/

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A2.3 GREEN

	GREEN: GeneRal Equlibrium ENvironmental model
Institutions and individuals	OECD development centre. Burniaux, J.M., Martin, J.P. Nicoletti, G. and Oliveira-Martins, J.
Goal of the model	asses the economic impact of imposing limits on carbon emissions
Regional scope	World. 12 regions; 4 OECD countries, 2 East European countries, 5 Developing countries
Commodity / sectoral scope	Economy-wide. 20 sectors; focus on energy sectors.
Key applications	Environmental policies, Kyoto protocol
Documentation and availability	Documentation is available, the model is not
Theoretical underpinnings	Recursive dynamic multi-region AGE model
Dynamics	Recursive dynamic; period 1985 - 2050; equilibrium solution for every five year
Modelling of international trade	crude oil: homogenous product; other commodities: ARMINGTON assumption
Representation of policies	explicit implementation of policy instruments, emissions ceilings, trdable permits
Theoretical consistency	not documented; however, GREEN is theoretically consistent within the framework of a CGE model
Model closures	Neoclassical, savings-driven
Regional aggregation	12 Regions: United States, Japan, EEC, Other OECD, Former Soviet Union, Central and Eastern European Countries, China, India, Energy Exporting Countries, Dynamic Asian Countries, Brazil, and Rest of the World
Commodity aggregation	8 Sectors: agriculture, coal, oil, gas, refined petroleum products, electricity, gas and water, energy intensive industries, other industries and sectors
Base year / time series	1985; period 1985 - 2050
# of agric. commodities	1 primary agriculture
Variables generated and parameters needed	Prices and quantities on domestic and world markets as well as the related value flows; demand and supply elasticities
Sensitivity	Yes, in several applications
Parameter estimates	partly taken from the literature; remaining part is calibrated
policy data	FAO producer price data bank, for OECD countries this information is complemented and updated using the OECD Secretariat's PSEs/CSEs
Data sources	SAMs compiled by the OECD, SUA published from the FAO, FAO Production Year Book, CHELEM data base
Software	C

Dataset publically available?	No

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A2.4 INFORUM

	INFORUM: INterindustry Forecastin ate the University of Maryland
Institutions and individuals	INFORUM Center University of Maryland, Clopper Almon
Goal of the Model	Annual forecasts and public policy analysis
Regional scope	Not global. 13 linked country models
Commodity/sectoral scope	Economy-wide. Sectoral scope varies by country
Key applications	National US studies (KIFT), NAFTA, Austrian integration into EU
Documentation and availability	Documentation on country models available on request. General information on INFORUM: Almon, C. 'The INFORUM Approach to Interindustry Modeling.' *Economic Systems Research*. 3(1), 1991: 1-7. Website: http://www.inform.umd.edu/EdRes/Topic/Economics/EconData/Intpartn.html
Theoretical underpinnings	Linked system of dynamic national macroeconometric models with inter-industry Input-Output linkages. Three main components: 1) the real side, 2) the price-income side, and 3) the accountant. The real side estimates final demands and output by sector, as well as labor requirements. The price side estimates both the components of gross product originating by industry (value-added) and unit prices by product. The accountant closes the model with respect to income, determines the economic aggregates, and estimates transactions which have not been calculated elsewhere in the model. The components are run iteratively until the model converges on a solution.
Modelling of international trade	Price- and income sensitive econometrically estimated import and export equations
Representation of policies	Macroeconomic policy instruments, taxes and transfers.
Theoretical consistency	Forecast models of individual sectors are linked through input-output relationships, and the general shifts in prices and incomes that result are linked to demand patterns. Economy-wide constraints (i.e. capital and labor markets clearing) are not central to this class of models, and full adding-up conditions are not imposed.
Model closures	Single country models or linked system.
Regional aggregation	13 countries: United States, Canada, Mexico, Japan, Korea, Germany, France, United Kingdom, Italy, Spain, Austria, Belgium. China module under development.
Commodity aggregation	Varies by country: min. 33, max 100.
Base year/time series	Varies by country. Forecast horizon 2010
No. of agricultural com-	Varies by country

modities	
Variables generated and parameters needed	Variables: Production, bilateral trade, consumption, prices, EV, etc. Parameters: Elasticities of substitution in trade and factor use
Sensitivity	Not sytematically reportedAuthors explicit considered sensitivity.
Parameter estimates	Various methods. Econometric (time series) estimation.
Policy data	Various national sources
Data sources	Various national sources. Mainly I-O tables
Software	Basic INFORUM software package is called G, which is an econometric regression and model-building program for use on personal computers. It is designed for estimation of regression equations with annual, quarterly, or monthly data. PDG is the Public Domain version of G, with limited features. PDG is written in the C language.
Data set publicly available	Some datasets and software are freely available through INFORUM, but the public versions are limited, and critical features of the models and software are proprietary.

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A2.5 MEGABARE and GTEM

	MEGABARE and GTEM (Global Trade and Environment Model)
Institutions and individuals	Australian Bureau of Agriculture and Resource Economics (ABARE) Kevin Hanslow
Goal of the model	Policy scenario analysis primarily in climate change but also in global agricultural trade reform and trade in strategic commodities
Regional scope	World. See GTAP
Commodity / sectoral scope	See GTAP. Plus emphasis on energy sectors
Key applications	Climate change policy and the economic impact of the Kyoto Protocol, WTO and the agricultural trade liberalisation
Documentation and availability	Documentation of MEGABARE describing the main features available, the outcoming GTEM will be publicly available in the future, website: http://www.abare.gov.au/
Theoretical underpinnings	Recursive dynamic multi-region AGE, constant returns and perfect competition. Special feature: technoly bundles in energy sectors
Dynamics	Stock-flow dynamics with partial adjustment, growth in the labor force and population
Modelling of international trade	Bilateral trade flows, choosing between domestic and imported goods by Armington assumption
Representation of policies	All polices as tariff equivalent price wedges
Theoretical consistency	Theoretically consistent within general equilibrium framework
Model closures	Variable depending on the simulation
Regional aggregation	See GTAP
Commodity aggregation	See GTAP
Base year / time series	1992/1995
# of agric. Commodities	See GTAP
Variables generated and parameters needed	Price and quantity variables endogenously determined in the model, needs parameters on the substitution possibilities in the production structure and the consumption structure
Sensitivity	Not reported
Parameter estimates	Technology bundle parameters calibrated, savings behaviour calibrated, other demographic elasticities estimated
policy data	Protection and Support data GTAP
Data sources	GTAP, The technology bundles from various publications (IEA 1993a, b; International Iron and Steel Institute 1992), Birth rates

	and mortality based on econometric analysis (United Nations 1992, Encyclopaedia Britannica 1994)
Software	GEMPACK (Unix version)
Dataset publically available?	GTAP available, GTEM data in public release in the future

References

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A2.6 MICHIGAN BDS MODEL

	Michigan BDS Model (Brown-Deardorff-Stern Model)
Institutions and individuals	University of Michigan / Drusilla Brown, Alan Deardorff and Robert Stern
Goal of the model	To analyze microeconomic effects of trade liberalization policies
Regional scope	World. 34 regions.
Commodity / sectoral scope	Economy-wide. 29 commodities. Focus on manufacturing
Key applications	Regional trade agreements, Tokyo round, Uruguay round, CUSTA, NAFTA, EU enlargement
Documentation and availability	Model algebra and IO-tables of the regions in Internet http://www.spp.umich.edu/rsie/model
Theoretical underpinnings	AGE model with monopolistically competitive manufacturing industries
Dynamics	No dynamics. Comparative static
Modeling of international trade	Bilateral trade. Firm level product differentiation (Dixit-Stiglitz)
Representation of policies	Price wedges, endogenous tariff equivalents
Theoretical consistency	Satisfied within the AGE framework.
Model closures	Fied trade balance
Regional aggregation	34 individual countries + aggregate Rest of the world: Argentina, Australia, Austria, Belgium-Luxembourg, Brazil, Canada, Chile, Colombia, Denmark, Finland, France, Germany, Greece, Hong Kong, India, Ireland,Israel
Commodity aggregation	29 sectors: Agriculture&Forestry&Fisheries, Food&Beverages&Tobacco, Textiles, Paper&Paper Products, Printing&Publishing, Chemicals, Petroleum&Related Products, Rubber Products, Non-ferrous Mineral Products, Glass&Glass Products, Iron&Steel, Non-ferrous Metals, Metal Products, Non-electric Machinery, Electric Machinery, Transportation Equipment, Miscellaneous Manufactures, Mining&Quarrying, Electricity&Gas&Water, Construction, Wholesale& Retail Trade, Transportation, Storage and Communication, Finance&Insurance&Real Estate, Community- Social- and Personal Services
Base year / time series	Reference year 1990
# of agric. Commodities	1
Variables generated and parameters needed	Based on input-output, trade data and published studies on substitution elasticity parameters. Armington, capital-labor substitution elasticities and substitution elasticities between va-

	rieties needed.
Sensitivity	Not reported sensitivity analysis
Parameter estimates	Trade elasticities from Stern, Francis and Schumacher, capital-labor substitution elasticities from Zarembka and Chernicoff (1971). Substitution elasticity between varieties assumed to be 15 (Brown and Stern, 1989).
policy data	Tariffs and estimated tariff equivalents for quotas
Data sources	UNCTAD, United Nations trade statistics, national IO tables
Software	Gempack
Dataset publically available?	Database documentation, full statement and description of the equations and parameters of the model are available from authors on request. IO-tables and model equations are on internet.

References

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A2.7 RUNS

	Rural/Urban - North South (Runs) - Model
Institutions and individuals	OECD, Burniaux, J.M. (1987)
Goal of the model	Analysis of Agricultural policies
Regional scope	World. 22 regions; 6 OECD countries, 2 East European countries, 14 Developing countries
Commodity / sectoral scope	Economy-wide. 20 sectors; focus on agriculture
Key applications	Agricultural trade liberalization, GATT/Uruguay round
Documentation and availability	Documentation is available, the model is not
Theoretical underpinnings	Recursive dynamic multi-region AGE model
Dynamics	Recursive dynamic; period 1985 - 2002; equilibrium solution for every three year
Modelling of international trade	Agriculture: homogenous product; non-agriculture: Armington assumption
Representation of policies	Price wedges
Theoretical consistency	not documented; however, RUNS is theoretical consistent within the framework of a CGE model
Model closures	Neoclassical, savings-driven
Regional aggregation	22 Regions: United States, Canada, Australia/New Zealand, Japan, EEC; EFTA, Eastern European Economies, Soviet Union, Low Income Asia, China, India, Upper Income Asia, Indonesia, Africa, Nigeria, South Africa, Maghreb, Mediterranean, Gulf Region, Latin America, Brazil, Mexico
Commodity aggregation	20 Sectors / commodities (11 primary agriculture, 4 processed food): Wheat, rice, coarse grain, sugar (refined), beef, veal and sheep, other meats, coffee, cocoa, tea, oils and oil cakes, dairy and dairy products, other foods, wool, cotton, other non-food from the agricultural sector, other manufacturing, energy, services, equipment goods, fertilizer
Base year / time series	1985; period 1985 - 2002
# of agric. commodities	11 primary agriculture; 4 processed food
Variables generated and parameters needed	prices and quantities on domestic and world markets as well as the related value flows; demand and supply elasticities
Sensitivity	No
Parameter estimates	agricultural supply and demand elasticities: USDA's GOL model and MTM model developed by the OECD Secretariat
Policy data	FAO producer price data bank, for OECD countries this information is complemented and updated using the OECD Secretariat's PSEs/CSEs

Data sources	- SAMs compiled by the development centre, - Supply Utilisation Account of the FAO (SUA) - bilateral trade flows: CHELEM data base - primary factors in agriculture: FAO Production Year Book
Software	Fortran
Dataset publically available?	No

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A2.8 WTO housemodel

	World Trade Organization Model
Institutions and individuals	WTO and Joseph F. Francois, Bradley McDonald, and Håkan Nordström
Goal of the Model	To analyze global trade analysis issues such as the upcoming WTO Round
Regional scope	Global with 13 regions
Commodity/sectoral scope	Economy-wide based on 19 sectors
Key applications	Multi-region CGE analysis of the results of the Uruguay Round
Documentation and availability	Formal written documentation of the model is ad hoc. However, model code and data can be downloaded from http://www.intereconomics.com/handbook/disk.htm Moreover, a description of the model can be found in Joseph F. Francois et al., (1995)
Theoretical underpinnings	A global General Equilibrium Model, which exists in different versions, e.g.: Perfect competition, CRTS, static comparative, Armington representation Monopolistic competition and scale economics internal to each firm, and firms from different regions compete indirectly in an Armington-type framework Monopolistic competition and scale economics internal to each firm, and firms from different regions compete directly
Modelling of international trade	Armington or monopolistic competition where firms compete directly or indirectly
Representation of policies	Quotas (MFA and minimum market access) are modelled explicitly
Theoretical consistency	Consistent within general equilibrium framework
Model closures	Two types of closure rules to capture steady-state 'accumulation effects': Either fixed regional saving rates or endogenous regional saving rates
Regional aggregation	13 regions: Australia, Japan, Canada, United States, EU, EFTA, China, East Asia, South East Asia, Latin America, Africa, Eastern Europe, and Rest of the World
Commodity aggregation	19 broad sectors: Grains, other crops, livestock, forestry, fishery, mining, processed food, textiles, apparel, lumber, petroleum, chemicals, steel industry, non-ferrous metal industry, fabricated metal products, transport equipment, other machinery, other manufactures, and services
Base year/time series	1992 (GTAP version 3, updates to version 4 forthcoming)
No. of agricultural commodities	3 primary and 1 processing industries

Variables generated and parameters needed	Variables: Production, bilateral trade, consumption, prices, EV, etc. Parameters: Elasticities of substitution in trade and factor use
Sensitivity	Authors explicit considered sensitivity. Results depends critically on the chosen theoretical structure, and in addition they are sensitive to a number of parameters
Parameter estimates	Elasticity parameters are from the GTAP database of elasticities, while the rest of the parameters are calibrated from the model, the exogenously specified elasticities, and the information on initial prices and quantities contained in the benchmark data set
Policy data	MFN tariff rates are from GATT's Integrated Data Base, and the values of tariff equivalents for industrial non-tariff barriers are from estimates in the literature, while dumping duties are from national sources and actions reported to the GATT secretariat. Finally, agricultural protection data are from OECD and USDA
Data sources	Most social accounting data are from the GTAP database, supplemented with production and trade data for EFTA and ROW. With respect to policy data, see above.
Software	GAMS/MPSGE
Data set publicly available	Yes, model and data can be downloaded from http://www.intereconomics.com/handbook/disks.htm

References

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Appendix 3 EU agricultural-models

A3.1 SPEL

	SPEL/EU - Sectoral Production and Income Model for Agriculture
Institutions and individuals	Department for Economics, Agricultural Policy, and Agricultural Information Systems, University of Bonn European Center for Agricultural, Regional and Environmental Policy Research, EuroCARE, Luxembourg - Bonn, European Commission, GD 34, (SPEL group at Eurostat), Luxembourg
Goal of the model	Ex-post analyses of sectoral developments, Monitoring and diagnosis of the current situation in the agricultural sectors of the EU-Member States, Short and medium-term forecasts and policy simulations of the effects of agricultural policy decisions Checking the consistency of Eurostat's agricultural statistics
Regional scope	Regionalisation at EU-Member State level, 15 regional units and the entire European Union.
Commodity / sectoral scope	Agricultural partial equilibrium model: Production activities: 35 crop activities and 13 animal activities. Product groups: 51 crop products, 27 animal products. Intermediate input groups: 9 specific for crop production, 19 specific for animal production, 8 for crop and animal production.
Key applications	The Base System (BS) is continuously applied at Eurostat and EuroCARE (2 times a year) in order to up-date the reference period (1973 up to the current year). The Short-term Forecast and Simulation System (SFSS) is continuously applied in combination with the up-dating of the reference period at Eurostat (2 times a year) and further on request of the Commission for specific simulations. The SPEL/EU-Data (results of the BS and the SFSS) are published by Eurostat and available for everybody on technical media. The Medium-term Forecast and Simulation System (MFSS) is applied on request of the Commission at Eurostat in co-operation with EuroCARE The reference data set for these simulations are published by Eurostat (up to 7 projection years). Particularly, CAP/Agenda 2000 (Agenda 2000: Overview of the impact analysis of CAP reform proposals, Europe Agri No. 30, 1998) The SPEL/EU-Data and the SFSS are implemented and applied inside the political decision process of nine EU-Member States.

Documentation and availability	Dataset (SPEL/EU-Data) is publically available, while the model is not. Model is in details described in following publications: Wolf (1995), Zintl and Greuel (1995a en b), Henrichsmeyer (1995), Henrichsmeyer, Weber and Wolf.
Theoretical underpinnings	- The main part of SPELL is the SPEL/EU Base System (BS), which provides detailed ex-post descriptions of the structure, intensity and use of agricultural production and of income generation in the EU member states. - The Short-term Forecast and Simulation System (SFSS) is used to generate forecasts (1-2 years) by combining econometric, trend-based forecasts and the systematic incorporation of expert know-how. The Base System (BS) and the SFSS are continuously applied at Eurostat and EuroCARE (2 times a year) in order to update the reference period (1973 up to the current year). The SPEL/EU-Data (results of the BS and the SFSS) are published by Eurostat and available for everybody on technical media. - The Medium-term Forecast and Simulation System (MFSS) performs policy simulations relative to a reference data set (up to 7 projection years, which are based on econometric trends and expert assessments). The MFSS system contains a supply model which links price expectations of farmers (based on past experience), the reaction of production intensity (input use and yield per hectare) to expected input and output prices, and the central activity model which shows the level of production activities as a function of changes in value-added per unit of the production activities. Food demand is based on econometric analysis and a forecasting system. A partial equilibrium model is used for balancing supply with forecasted demand. The foreign trade component contains net-trade functions between the EU and the rest of the world.
Dynamics	Recursive dynamic for the simulation models.
Modelling of international trade	Homogeneous goods and pooled markets (net trade).
Representation of policies	Explicit incorporation of CAP policies, like Quota, Set-aside, Premiums, etc.
Theoretical consistency	No.
Model closures	No closures like those used in CGE models.
Regional aggregation	Individual EU member states
Commodity aggregation	5-6 digit NACE/CLIO breakdown
Base year / time series	1973 up to the current year
# of agric. Commodities	114 primary agricultural commodities
Variables generated	Indication of endogenous / exogenous split, depending on simu-

and parameters needed	lations scenario and depending on sub-model. For each model the whole national economy variables, like inflation rate, ex-change rates, etc. have to be specified exogenously.
Sensitivity	Not, reported.
Parameter estimates	Generation of parameters Literature, own specifications ex-post data based, parts are calibrated econometrically.
policy data	Production subsidies and taxes, direct payments as they are reported in EAA
Data sources	Mainly official statistics of Eurostat data 'NewCRONOS, domains: ZPA1, COSA, FEED, PRAG, SEC1 and FADN data of DG VI, Brussels and other official national statistics.
Software	Specific model software are tailor made, results are available by multi-purpose software.
Data set publicly available?	Yes, from Eurostat, see above.

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A3.2 ECAM

	ECAM (European Community Agricultural Model)
Institutions and individuals	Centre for World Food Studies, Central Planning Bureau and the Agricultural Economics Research Institute - C. Folmer, M.A. Keyzer, M.D. Merbis, H.J.J. Stolwijk and P.J.J. Veenendaal
Goal of the model	The assessment of the impacts of agricultural policies, rather than the forecasting and/or the projection of variables.
Regional scope	EU model: 9 EU countries
Commodity / sectoral scope	Economy-wide, with a focus on agriculture: 3 sectors (agriculture, tradeable and nontradeable non-agriculture)
Key applications	CAP reforms (price reductions, decoupling, quotas), MacSharry Reform, GATT Uruguay Round
Documentation and availability	Documented through research reports and academic publications. Model only available to the organizations sponsoring the model
Theoretical underpinnings	Applied general equilibrium model. The model has the structure of a nonlinear program, and consists of three main parts: a module for total demand, one for agricultural supply, and an exchange component, which balances demand and supply. As far as non-agriculture supply is concerned, the supply of the tradeable good is treated as a given endowment which grows according to an exogenous trend; the nontradeable sector (mainly building and construction services) operates under a constant returns to scale technology with fixed mark-up rate over variable costs, and the level of production driven by demand. Consumer demand follows expenditure minimization according to a two-level demand system: at the lower level s linear expenditure system (LES) with trends on commitments for food demand; at upper level an AIDS-system for food, beverages and tobacco and non-food.
Dynamics	Recursively dynamic
Modelling of international trade	No explicit modelling of the relations with non-member countries. Trade flows between each country and the EU-market level (intra-EU market clearing at given international prices).

Modelling of agricultural supply	ECAM mainly distinguishes itself from other models AGE models through its representation of agricultural supply, in particular its explicit treatment of pastures and other non-marketed green fodders, as well as the separate elaboration of yield and acreage relations (that is, crop yield per acre and acreage are both represented). Agricultural supply is modelled via a one-period, revenue maximizing nonlinear program with a land constraint, a livestock-feed energy constraint and a livestock operating-capacity constraint. The constraint set is completed with commodity balances including a green fodder balance. Yields of crops and animals follow exogenously specified trends which reflect technical progress. Non-linearity enters via production and transformation functions, which because of the decomposable structure of the program, can be dealt with via separate cost and revenue functions. The one-year production lag assumed in the crop and livestock allocation component explains why it is with given agricultural supply and given intermediate and investment demand for non agricultural commodities by the farmers that the market equilibrium is solved in every year of the simulation. The resulting incomes then affect migration and investments, while land outflow from agriculture is specified through a time trend.		
Representation of policies	Explicit modelling of the following instruments: production/input quotas, intervention price, production/consumption tax/subsidies, revenue tax and grants		
Theoretical consistency	Optimizing behaviour in a general equilibrium framework ensures theoretical consistency, but the recursive dynamics does not guarantee intertemporal optimization		
Model closures	(Semi-)Partial equilibrium, since the non-farm sector is (semi) exogenous		
Regional aggregation	Belgium-Luxembourg, Denmark, France, West Germany, Ireland, Italy, Netherlands, United Kingdom.		
Commodity aggregation	Different aggregations in different parts of the model (exchange, demand, agricultural supply)		
Exchange commodities	Supply activities	Consumer demand First level	 Second level
Wheat	Wheat	Food products	Bread and cereals
Coarse grains	Coarse grains		Beef and veal
Rice	Rice		Lamb
Sugar	Sugarbeet		Poultry meat
Fats and oils	Oilseeds		Pig meat

Protein feed	Consumable potatoes		Fish
Temperate fruit & vegetables	Vegetables		Milk and cheese
Subtropical fruit & nuts	Temperate fruit		Eggs
Wine	Non-temperate fruit		Fats and oils
Industrial crops	Olives		Fruits and vegetables
Carbohydrates	Grapes		Potatoes
Coffee, tea and cocoa	Industrial crops		Sugar
Butter	Non-consumable potatoes		Coffee, tea, cocoa
Dairy products	Other vegetable products		Other food products
Bovine and equine meat	Pasture grass	Beverages and tobacco	
Ovine meat	Fodder maize	Non-food products	
Pork	Other roughage		
Poultry and eggs	Dairy cows		
Fish	Laying hens		
Non-agricultural tradeable	Cattle and horses		
Non-agr. nontrad. Belgium/Lux.	Sheep and goats		
Non-agr. nontrad. Denmark	Pigs		
Non-agr. nontrad. France	Poultry		
Non-agr. nontrad. Germany	Fish		
Non-agr. nontrad. Ireland			
Non-agr. nontrad. Italy			
Non-agr. nontrad. Netherlands			

Non-agr. nontrad. UK			
Base year / time series	1982 / 1970-85 (mostly)		
# of agric. commodities	19 (exchange module) - 24 (agricultural supply module) - 15 food products (demand module)		
Variables generated and parameters needed	Variables generated depict the complete economy, at national level as at EU-level Parameters: substitution elasticities between output and inputs, yield trends, land outflow trend, impact of per capita income and lagged employment on occupational migration, substitution elasticities in feed and consumer demand		
Sensitivity	Robustness guaranteed by econometric results rather than sensitivity analysis. ECAM has been validated over the period 1982-1992. The model appears to replicate the past with reasonable accuracy, given the deterministic nature of the model and its focus on the main tendencies rather than on the details.		
Parameter estimates	Econometric estimation plus calibration for validation over the period 1982-1992. Although it is not possible to perform the full system econometric estimation (due to identification problems, restrictions on the distribution of disturbance terms, impossibility to drop variables rejected on statistical grounds, and lack of data), parameters of most of the behavioural equations have been obtained via time series estimation. Such a modular approach is more easily manageable, but it is insufficient to ensure a good fit for the model as a whole when it is validated over a historic period. This explains the need for a calibration phase (see 3e) in order to generate a good dynamic behaviour.		
Policy data	Prices, rates, quotas, indexed amounts		
Data sources	EAGGF, EU Commission, Eurostat, IMF, OECD, World Bank, FAO, FADN		
Software	Data Management Software - FORTRAN algorithm		
Dataset publically available?	No.		

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A3.3 CAPMAT

	CAPMAT (Common Agricultural policy Modelling and Accounting Tool)
Institutions and individuals	Centre for World Food Studies, Central Planning Bureau and the Agricultural Economics Research Institute - L. Bettendorf, M.A. Keyzer, M.D. Merbis, and J. Muskens
Goal of the model	Policy analysis. Since ECAM had been designed for the EU-9, a new tool was needed, covering all member states and starting from a more recent base year. It performs simulations to derive the implications of various policy scearios.
Regional scope	EU: 15 EU countries
Commodity / sectoral scope	Agricultural sector
Key applications	CAP reform (partial liberalization), agricultural proposals in 'Agenda 2000'
Documentation and availability	Scarce documentation Only available to the organizations sponsoring the model
Theoretical underpinnings	CAPMAT consists of three components: - a dedicated database, - an applied general equilibrium (AGE) model to simulate overall medium term effects, - a simulation and accounting tool (SAT) that applies selected growth factors from the AGE-model (or from explicit assumptions) to the information extracted from the database. CAP commodities follow the assumed intervention prices, while some sectors (pork, poultry, eggs and other animals) have a mark-up pricing (covering the unit cost with a given gross margin of the least-cost producer).
Dynamics	Same as the AGE-component
Modelling of international trade	No explicit modelling (gross imports and exports depend on a time trend)
Representation of policies	Explicit modelling of the following instruments: production/input quotas, intervention prices, production/consumption tax/subsidies, stock volumes, direct transfers
Theoretical consistency	Optimizing behaviour in a general equilibrium framework ensures theoretical consistency of the AGE component. It is questionable whether this is maintained in the SAT's simulations.
Model closures	Same as the AGE-component
Regional aggregation	13 countries and 1 region: Austria, Belgium-Luxembourg, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom.

Commodity aggregation	30 products: wheat, coarse grains, milled rice, pulses, consumable potatoes, refined sugar, fats and oils, protein feeds, tobacco, other industrial crops, carbohydrates, vegetables, fruits, wine, other final crops, fresh fodder, dry fodder, fat from milk, skimmed milk, beef and veal, pork, meat from sheep and goats, egg, poultry meat, other animal products, fish, manure, fertilisers, plant protection, pharmaceutical inputs.
Base year / time series	1995
# of agric. commodities	27 products
Variables generated and parameters needed	Supply and utilization accounts by commodity and country Costs and revenue for every activity by country Farm revenue by country EU budget
Sensitivity	No
Parameter estimates	No documentation
Policy data	EAGGF expenditures, prices and quotas
Data sources	EU-budget, Eurostat, EU Court of Auditors, OECD, World Bank, FAO, FADN, FAPRI, SPEL, EXMIS
Software	Database aggregation procedure and SAT (GAMS programs)
Dataset publically available?	No