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Simulating Free Agricultural Trade among the OECD Countries Using the IIASA World Food and Agriculture Model System*

by
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The Organization for Economic Cooperation and Development*** (OECD) is presently engaged in estimating the effects of a "balanced and gradual" reduction in the barriers to agricultural trade by the OECD countries. Their work uses a partial equilibrium framework and is not available to the general public now and may never be fully available. However, the IIASA/FAP System**** is a global general equilibrium model that can deal with trade liberalizations large enough to affect world prices significantly. Two projections using the IIASA World Agriculture System are presented here. The first is a reference projection that assumes no change in policies. In the second the border measures of the OECD countries that restrict agricultural trade are eliminated over the 1986-1990 period. Commodity policies in the United States are eliminated over the same period. The purpose of this paper is to present and compare two projections and to describe the version of the global system used for this analysis.

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***The OECD countries include Australia, Austria, Canada, EEC-10, Japan, New Zealand, Turkey, and the United States. Finland, Iceland, Norway, Portugal, and Spain are also members of OECD, but could only be included in the simulations described below in the rest-of-the-world.

****The model system used for these projections was developed by the Food and Agricultural Program (FAP) of the International Institute for Applied Systems Analysis (IIASA) in cooperation with many other institutions and individuals. The Centre for World Food Studies (Free University of Amsterdam) made notable contributions. The United States model was developed and maintained by the United States Department of Agriculture and Michigan State University.

Overview of the IIASA System

The version of the IIASA/FAP World Agricultural Modeling System used here consists of a series of 2Ø Basic models of countries or country groups with a fixed international commodity list of 9 agricultural commodities and 1 non-agricultural commodity traded among up to 2Ø countries and trading blocks and a regional rest-of-the-world model based on trends and elasticities. This whole system is referred to as the Basic Linked System (BLS).

Each Basic national model estimates production, inputs, stocks, and consumption consistent with that country's policy variables, especially tariffs, quotas, and price controls. These internal commodities are then aggregated into the ten Basic internationally traded commodities. For example, production of corn, sorghum, barley, and oats in the US model are added together to comprise coarse grains, an internationally traded Basic commodity. The ten Basic commodities are wheat, rice, coarse grains (other cereals), beef and sheep, dairy products, other animal products, protein feeds, other foods, non-food agriculture, and non-agricultural. See Appendix A.

The Basic country models available in the present system are Argentina, Australia, Austria, Brazil, Canada, China, CMEA (Soviet Union and Eastern Europe), Egypt, European Economic Community (1Ø), India, Indonesia, Japan, Kenya, Mexico, New Zealand, Nigeria, Pakistan, Thailand, Turkey, and the United States. See Appendix B. The included countries have approximately 8Ø percent of world production, consumption, population, arable land, and trade. See Appendix C. Very simple regional models are used for the other country groups not explicitly included above.

Structure of the Basic Linked System The IIASA/FAP Basic Linked System consists of a world market mechanism and the country (or country group) models. First I will describe the function of the important parts and then deal with their interrelationships in more detail. Each country model has (at least) two parts, supply and exchange. The supply submodel calculates variables (such as input usage and production by commodity) for the following year on the basis of current and historical information, especially the current year's prices. The exchange submodel of each country calculates consumption, stocks, and net trade for each of the ten Basic commodities on the basis of the current world trade prices. The government policies of a country may be allocated between the supply and exchange submodels or placed in a third submodel.

The system starts with some initialization routines which specify first year values of such variables as production. The exchange submodels of all countries are then solved simultaneously by iteration (using a technique that allows quotas). The iteration proceeds from an estimate of world prices, solves the exchange submodel of all of the included countries and refines the price estimate until the world exports are sufficiently close to world imports for each commodity. The system then solves the supply submodel of each country independently for the following year. The system proceeds recursively year by year.

Types of Models in the Basic Linked System The models of countries or country groups in the BLS consist of two types: the Basic models and the simple Rest-of-World (ROW) models. The Basic models differ in their degree of detail and sophistication, but they all project population, labor force, production, human consumption, feed use, net imports or exports, and they all have some government policy mechanism that helps to determine the reaction of the country model to world prices. All of the Basic models have a more disaggregated internal list of commodities than the Basic list which is traded internationally. Except for the China and CMEA models, all Basic models have distinct sets of producer and consumer prices which are affected by variables such as world prices, processing margins, transportation costs, market clearing conditions within the country (or country group) and government policies including tariffs and quotas. In contrast to the Basic models, the ROW models project only production, consumption, and net trade for the ten internationally traded commodities. These models use only simple growth rates and elasticities and have no governmental policy components.

The Basic models have six different model structures. Most of the models, including the EEC, have the new Standard model structure but Kenya, New Zealand, and Thailand still have the old Standard model structure. The US, India, China, and the CMEA (Soviet Union and Eastern Europe) each have Basic models with unique structures. Each of the six structures will be discussed, with emphasis on the new Standard model structure and the US model structure.

The supply side of the New Standard Models starts with the world price, supply, and demand results of one year and calculates the supply variable for the following year. The factors of production that are modeled explicitly are land under cultivation, labor, capital, fertilizer, and feed use. Labor input is determined by last year's agricultural labor force and the income disparity between agriculture and non-agriculture. Capital in each sector is treated as homogeneous and is determined by gross investment, previous capital stock and depreciation rates. The total gross investment for the country is a function of total gross domestic product, the trade deficit and the previous two year's change in the gross domestic product. The proportion of total gross investment that goes into agriculture depends on variables such as the ratio of agricultural and non-agricultural price indexes and the ratio of the output of the two sectors. The fertilizer calculations assume that nitrogen, potassium and phosphorus are applied in fixed proportions. Fertilizer input is a function of the price of a unit of the fixed mixture of fertilizer and last year's crop production. The amount of feed per animal unit is derived from a feed cost minimization model which depends on output per animal, time, and expected feed prices. The inputs (except feed) are allocated to the different commodities using a non-linear programming model, criterion function and inequality constraints. Both technical and economic relationships are included. The farmers are assumed to maximize net revenue. The non-agricultural sector is aggregated to one commodity and uses a Cobb-Douglas production function.

The exchange side of the model calculates demand for the

following year using the prices of that year and a Linear Expenditure System (LES). A processing margin is used for each commodity to derive the retail level price from the producer price. Each year the marginal budget shares and the committed demand quantities are calculated taking into account expected income, total calorie intake, and the technical conditions of an LES.

The old Standard Basic models were an earlier generation with a structure similar to the new Standard models, but with the notable difference that they did not include land as an input.

The supply side of the present US model starts with the realized prices, stocks, harvested acres, herd sizes, and so on and uses these to calculate the factor inputs and production for the following year. The factors of agricultural production that are modeled explicitly are land under cultivation and feed use. Unlike the Standard IIASA models, most of the price responsiveness of the US model comes from variability in the amount of land under cultivation. A resource development component handles the longer run aspects of crop land expansion. The crop land area used for crops in a given year is aggregated from the individual acreage equations. Acreage equations include variables such as expected prices, prices of competing crops, fertilizer prices, lagged acreage, and variables to summarize policy variables such as loan rates, target prices, set-asides, and diversion payments. Yields are also endogenous for many crops with expected price as one of the independent variables. Non-agricultural production depends on labor and capital and is treated as one commodity produced with a Cobb-Douglas production function. Capital is treated as homogeneous and is determined by gross investment, previous capital stock and depreciation rates. The total gross investment for the country is a function of total gross domestic product.

The exchange side of the U.S. model calculates not only demand by commodity, but also wheat and coarse grain stocks using contemporaneous prices. Stock behavior is affected realistically by loan rates. The demand uses a year-specific Linear Expenditure System. As in the Standard models, a processing margin is used for each commodity to derive the retail level price from the producer price.

The Basic India model has much more detail on income distribution and individual commodities. The production side uses price-responsive acreage and yield equations.

Both the CMEA and China Basic models have little responsiveness to international prices. The CMEA model is more sophisticated with some adjustments in stocks, feed use, and human consumption possible in response to international price changes. The China model is even more rigid than the ROW models with international trade responsiveness limited to the non-agricultural sector.

Governmental Policies Affecting Trade in the Basic Linked System Since we are concentrating on the use of the BLS for examining trade liberalization in the OECD, the description of the model mechanisms to simulate governmental policies affecting trade will be limited to the Standard models and the US. Both old and new Standard models use a similar mechanism and they include all of the modeled OECD countries except for the US.

The border measures represented in the United States Basic model take full advantage of the ability of the system to deal correctly with quotas. Quotas on both beef/mutton imports and dairy products are modeled as such and not as tariff equivalents. Thus when the import quotas are binding, the internal price of the constrained commodity will rise above the value that it would have in the absence of the quota. The sugar import policies are impossible to model accurately with the Basic list of commodities because it is combined with fruits and vegetables and fats and oils in other food in the international trade part of the model. The government programs for wheat, feed grains, and soybeans are modeled by policy variables that affect the acreage equations and the stock equations. Rice programs are not included in the present Basic model. Milk programs are crudely represented, with most of the effect on price coming from import quotas.

In the Standard models, governmental policies are represented by tariff equivalents in a price transmission mechanism. It is necessary to give a little background of the different types of prices to understand the effect of government policies at the border. From the world price of commodity X, the border world market price is calculated by adding the transportation and appropriate processing margins. This is the price as commodity X reaches the customs station. For example, the border world market price for the EEC might be c.i.f. Rotterdam. The raw material price is the price just past the customs station and is calculated by a price transmission mechanism which includes the effects of border protection, self-sufficiency policies of the country, and inertia in price transmission. Thus the governmental border policies enter here. From this raw material price and processing and distribution margins, the producer and retail prices are calculated. The price transmission equation is (in FORTRAN notation where x*y means x times y and x**y means x to the power of y):

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praw(t) = A * pw(t)**b * pw(t-1)**c * praw(t-1)**d * ssr(t-1.5)**e

where  ssr(t-1.5) = (ssr(t-1) + ssr(t-2)) / 2.Ø
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and praw is the raw material price, t is time, pw is the border world market price, and ssr is the self-sufficiency ratio.

Clearly, if b=c=Ø, then the raw material price, praw, is independent of border world market prices, pw. If the EEC border world market price, pw, for wheat and coarse grains is less than the EEC raw material price, praw, the variable levy would assure that b=c=Ø. The self-sufficiency ratio, ssr, is still important since a ssr less than one raises revenue for the European Community budget while an ssr more than one requires an accumulation of stocks or disposal abroad.

In the old Standard countries models, praw is a multiplicative function of pw with the tariff equivalent represented by a coefficient.

The Projections

Assumptions The IIASA/FAP World Agriculture Modeling System was run to the year 2000, with all agricultural protection measures, including US commodity programs, removed for the OECD countries over the period 1986-1990. For the purposes of this discussion, the OECD is composed of Austria, Turkey, the EEC-10, Canada, the US, New Zealand, Australia, and Japan. Some other European members of the OECD are not modeled explicitly in the IIASA system and hence did not participate in the liberalization, although they were a part of the rest of the world.

For the United States both the border measures and the federal government commodity policies were phased out over the transition period. The most important border measures were the import quotas on beef and mutton and dairy products. Sugar quotas could not be changed since sugar is combined in other foods. There are no dairy programs in the present US model: the import quota is the only measure protecting domestic prices from the world market.

The comparative projections that accompany this report assume that for the New Standard OECD countries (Austria, Australia, Canada, EEC, Japan, and Turkey) the parameter b moves from its original value towards 1.0 over the years 1986-1990. The parameters c, d and e move towards zero in the same period.

New Zealand is an old standard model with a single coefficient representing the tariff equivalent. This coefficient moves towards 1 over the 1986-1990 period.

Overview of Results. This summary discusses the "long-run" results in the 1991-2000 period, after the system has settled down. The results of the liberalization runs are compared with a reference run in which no policy changes are made. The long-run result of full trade liberalization in the OECD countries was to raise world prices for all agricultural commodities, but especially for grains and protein feeds. Beef/sheep and dairy product prices rose mode that prices for other animals, other foods, and non-food agriculture.

Table 1. Change in World Results due to OECD Liberalization

	Price Change (relative to non-agriculture)	Production Change	
	Percent	Percent	1000 metric tons
Wheat			
1991-1995	12.70	-0.06	-397
1996-2000	14.25	-0.65	-3971
Rice (milled)			
1991-1995	21.70	0.88	2897
1996-2000	18.72	1.11	4027
Coarse grains			
1991-1995	7.93	0.78	7750
1996-2000	9.83	0.83	9138
Beef/sheep (carcass weight)			
1991-1995	7.26	-0.41	-332
1996-2000	7.07	-0.38	-327
Dairy products (fresh milk equivalent)			
1991-1995	13.12	0.33	1956
1996-2000	6.91	0.18	1151
Other animal prod. (protein equivalent)			
1991-1995	2.40	0.52	126
1996-2000	2.01	0.55	146
Protein feeds (protein equivalent)			
1991-1995	17.10	0.88	497
1996-2000	15.83	1.35	833
Other Food			
1991-1995	3.11	-0.14	
1996-2000	3.51	-0.12	
Non-Food Agriculture			
1991-1995	2.85	-0.46	
1996-2000	2.20	-0.66	
Non-agriculture			
1991-1995	0.00	0.07	
1996-2000	0.00	0.09	

Source: Runs with IIASA system (June 1986 ERS version)

All the agricultural price changes were increases, and some of them were quite large. Agriculture prices overall increased 6.57 percent relative to non-agriculture in the 1991-95 period. On the other hand, production had only slight changes with decreases in wheat, other foods, and non-food agriculture. The changes for the second five year period after liberalization (1996-2000) were fairly close to the changes for the first five year period (1991-1995). For the rest of this section only the results for 1991-95 will be discussed unless explicitly noted to the contrary.

In the case of wheat, the modest Ø.4 million metric ton reduction in world production was obviously due primarily to the reduction in EEC wheat production, which decreased 13.1 million metric tons. In the EEC, the liberalization not only caused a reduction in total grain production, but also a shift from wheat towards coarse grains. Wheat acreage in the EEC decreased 12.7 percent while coarse grain acreage increased 9.8 percent. Since coarse grain yield only dropped 7.1 percent, the result was an increase in coarse grain production. This shift from wheat to coarse grains resulted in a world wheat price rise that was 4.8 percentage points more than the world coarse grain price rise.

In the case of other foods, the drop in world production of 461 million units (quantity measured in 197Ø dollars) for the 1991-95 period was less than the drop in EEC production of 894 million units. It was not possible to ascertain how much of this was due to a drop in EEC sugar production, but this is obviously one category of EEC agriculture that would shrink dramatically in a free trade environment.

In the case of non-food agriculture, the 1991-95 drop in world production of 168 million units (quantity measured in 197Ø dollars) was less than the drop in EEC and US production (85 million units for the EEC and 91 for the US.) The reduction in the US occurred due to a drop in acreage devoted to cotton.

In all cases, the global production drop was due to the change in the EEC and/or the United States, with the rest of the world partly offsetting the production decrease.

Income and Distributional Effects The Gross World Product per capita increased by Ø.Ø7 percent in 1991-95 and Ø.Ø9 percent in 1996-2ØØØ due to OECD-wide trade liberalization, with world agricultural product (measured in 197Ø dollars) increasing by about Ø.15 percent in both periods. Among the OECD countries, all gained in total GDP, but there were sharply mixed results on agricultural GDP. The inelastic centrally planned countries showed practically no change. All of the developing countries showed an increase in agricultural GDP. Except for Indonesia and India, all developing countries experienced an increase in agricultural GDP of more than Ø.5Ø percent over the 1991-95 period. On the other hand, OECD agricultural trade liberalization had sharply mixed effects on the total GDP of the various developing countries.

The Australian model appears to exhibit anomalous behavior. The price linkage parameters that IIASA/FAP has estimated show strong positive protection of grains, other animals, and protein feeds. The dairy and beef/sheep sectors on the other hand show negative protection. Thus the result of a liberalization is to shift production from grains and other animals to the dairy, beef, and sheep areas.

In the US, increased imports of dairy products contrast with gains in grain exports. In Canada on the other hand, grain exports are down, but the dairy sector shows a somewhat surprising increase in exports of 6.7 million metric tons of fresh milk equivalent. This is largely offset by a 5.7 million ton increase in imports by the United States. The cause in the Canadian model is the elimination of a restriction on dairy production and a

shift of resources from grain to dairy production. The complete relaxation of the dairy import quota in the US model results in large dairy imports due to both reduced production and increased demand. Since Canada borders on the US, fresh milk trade as well as trade in other dairy products would be feasible in a free trade environment. Taking Canada and the US together, the net result is that the US and Canada together increase grain exports in response to the increased international prices.

Table 2. Percent Change due to OECD Liberalization Relative to Reference Run (1991-1995 Average)

	GDP	GDP, Agriculture		GDP	GDP, Agriculture
World	Ø.Ø71	Ø.15			
Argentina	Ø.Ø37	2.42	Indonesia	-Ø.Ø32	Ø.11
Australia	Ø.137	-1.Ø1	Japan	Ø.132	-4.54
Austria	Ø.167	-1.78	Kenya	Ø.339	Ø.97
Brazil	-Ø.16Ø	Ø.56	Mexico	-Ø.62Ø	1.3Ø
Canada	Ø.164	7.49	New Zealand	Ø.314	2.ØØ
China	Ø.Ø	Ø.Ø	Nigeria	Ø.264	Ø.9Ø
CMEA	-Ø.Ø37	-Ø.Ø2	Pakistan	Ø.215	1.55
EEC-1Ø	Ø.193	-4.63	Thailand	Ø.Ø92	1.12
Egypt	-Ø.Ø87	Ø.9Ø	Turkey	Ø.29Ø	-3.12
India	-Ø.ØØ2	Ø.Ø3	United States	Ø.Ø96	1.21

Source: Runs of the IIASA/FAP system (June 1986 ERS version).

Price Relationships Price relationships among the grains were influenced by two causes: The protection for wheat was higher than the coarse grains in the EEC model. This caused a shift in EEC acreage to coarse grains as protection was eliminated, so that the EEC produced somewhat more coarse grains and much less wheat. As a result, the world price of wheat rose more than the world price of coarse grains. The world price of rice rose due to an unrealistically high increase in the use of rice for feed in Japan as the domestic price dropped sharply. This appeared to be due to the failure of the model to distinguish between good quality rice and those rice by-products or inferior rice that are only suitable for feed. The estimation procedure may have also treated some governmentally induced use of rice for feed as a market response.

Conclusions

The price linkages in the models of the system need more work, but it is already possible to see broad overall results. The change to free trade in the developed market economies would definitely help their overall economies as the OECD countries shifted production towards their comparative advantage, both among the agricultural commodities and between agriculture and non-agriculture. The effects on the various agricultural sectors in the different OECD countries, however, would vary sharply. In the

LDCs, however, the overall effect would depend mainly on whether the country in question was a food exporter or importer. In almost all cases, however, the production in the agricultural sector would increase due to higher world prices for most agricultural commodities.

APPENDIX A

COMMODITIES

Internationally traded commodities:

1	Wheat	1ØØØ metric tons
2	Rice	1ØØØ metric tons
3	Other Cereals	1ØØØ metric tons
4	Bovine and Ovine Meats	1ØØØ metric tons, carcass weight
5	Dairy Products	1ØØØ metric tons, fresh milk equiv.
6	Other Animal Products	1ØØØ metric tons, protein equiv.
7	Protein Feeds	1ØØØ metric tons, protein equiv.
8	Other Food	millions of 197Ø US dollars
9	Non-food Agriculture	millions of 197Ø US dollars
1Ø	Non-agricultural Production	millions of 197Ø US dollars

APPENDIX B

BASIC COUNTRY MODELS

The Basic country models available in the present system:

Country:	Type of Model
Argentina	Standard
Australia	Standard
Austria	Standard
Brazil	Standard
Canada	Standard
China	Special
CMEA (Soviet Union and Eastern Europe)	Special
Egypt	Standard
European Economic Community	Standard
India	Special, detailed
Indonesia	Standard
Japan	Standard
Kenya	Old standard
Mexico	Standard
New Zealand	Old standard
Nigeria	Standard
Pakistan	Standard
Thailand	Old standard
Turkey	Standard
United States Intermediate	A special country model

Rest-of-the-World (This model solves in a simple fashion for the production, consumption, and exports of all countries not included in the run explicitly--includes regional models for most of the developing world not included above. Supply largely determined by scenario.)

Note: All countries marked Standard are the new Standard country models with production depending on land, labor, capital, and fertilizer. The old Standard models did not have land as an input.

APPENDIX C

STATISTICS ON INCLUDED COUNTRIES

Percentages of world population, production of agricultural commodities, land base, and agricultural trade in 1976

Country	Population	Production	Land base	Imports	Exports
Australia	.3Ø	1.6Ø	1.3Ø	.25	5.ØØ
Austria	.2Ø	.4Ø	.1Ø	.62	.31
Canada	.6Ø	1.2Ø	2.ØØ	1.99	3.25
EEC *	6.4Ø	11.9Ø	3.3Ø	38.83	26.Ø5
Japan	2.8Ø	1.8Ø	.4Ø	8.36	.Ø5
New Zealand	.1Ø	.5Ø	.1Ø	.14	2.Ø9
US	5.3Ø	12.3Ø	9.8Ø	8.Ø7	18.85
Subtotal Market Developed	15.7Ø	29.7Ø	17.ØØ	58.26	55.6Ø
CMEA **	9.ØØ	16.7Ø	17.5Ø	12.72	5.74
China	21.4Ø	13.2Ø	17.3Ø	1.64	1.81
Subtotal Centrally Planned	3Ø.4Ø	29.9Ø	34.8Ø	14.36	7.55
Argentina	.6Ø	2.ØØ	1.7Ø	.14	2.86
Brazil	2.8Ø	4.7Ø	4.ØØ	.75	5.55
Egypt	1.ØØ	.7Ø	.3Ø	.94	.56
India	15.5Ø	6.7Ø	14.6Ø	1.Ø6	1.3Ø
Indonesia	3.4Ø	1.6Ø	1.5Ø	.64	1.Ø2
Kenya	.3Ø	.2Ø	.2Ø	.Ø6	.33
Mexico	1.5Ø	1.5Ø	1.3Ø	.35	.82
Nigeria	1.6Ø	.5Ø	1.6Ø	.5Ø	.4Ø
Pakistan	1.8Ø	.9Ø	1.4Ø	.34	.34
Thailand	1.ØØ	1.1Ø	1.1Ø	.18	1.23
Turkey	1.ØØ	1.6Ø	1.6Ø	.14	.96
Subtotal Developing Countries	3Ø.5Ø	21.5Ø	29.3Ø	5.1Ø	15.37
Subtotal Basic Models	76.6Ø	81.1Ø	81.1Ø	77.72	78.52
Simple Elasticity and Growth Rate ROW Model	23.4Ø	18.9Ø	18.9Ø	22.28	21.48
Total Basic and ROW Models	1ØØ.ØØ	1ØØ.ØØ	1ØØ.ØØ	1ØØ.ØØ	1ØØ.ØØ

* The current European Economic Community (EEC) model includes: Belgium , Denmark, France, Ireland, Italy, the Netherlands, the United Kingdom, and West Germany.
** The current CMEA model includes: Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Rumania, and the Soviet Union